Energy and Ecosystems: Prairie, Water and Woods

Authors:
Patricia Franzen, Germantown Hills, IL
Nicole Kitzmiller, Rotolo Middle School, Batavia, IL
Sue Sheehan, Fermilab Education Office

Consultants:
Ryan Campbell, Fermilab Ecologist
Susan Dahl, Fermilab Education Office

Fermilab Docents:
Jane Gravelle (graphics)
Mary Jo Murphy

Editor:
LaMargo Gill
Fermilab Education Office

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Power of the Prairie

GRASS

Pile the bodies high at Austerlitz and
Waterloo.
Shovel them under and let me work—
I am the grass; I cover all.

And pile them high at Gettysburg
And pile them high at Ypres and Verdun.
Shovel them under and let me work.
Two years, ten years, and passengers ask
the conductor:
What place is this?
Where are we now?

I am the grass.
Let me work.

Carl Sandburg
Illinois Poet

Interactions and Relationships:
The Secret Worlds within Ecosystems: Prairie, Ponds and Woodlands

Unit Focus Question:
How do abiotic and biotic factors work together to restore diversity, promote productive interactions/relationships and provide ecosystem services?

Unit Driving Phenomena:
Share the unit question with students and ask them to identify anything they read in the first part of the wolf letter or see in the video that they think may be important in formulating an answer to the unit question. Encourage students to record any questions they have.

Wolf Letter
The wolf letter includes an introduction and a page to precede each lesson set.

Yellowstone Wolves Video (Found in *Resources* section)

Overarching ideas to be used throughout the entire unit:

- **Student Research Journal**
- **Student Research Journal Assessment**
- **Investigation Rubric** – Measuring day-to-day activity, responses, online journal, etc.
- **Participation Rubric** – Considering scientific attitudes or habit of the mind, as well as cooperative team behaviors
- **Performance Rubric** – Appropriate for classroom events such as town meetings, forums, debates, open-ended class discussions, student sharing of a project, etc.
- **Science and Engineering Practices Rubrics**
- **Ecosystem Services**
- **Fermilab Habitats**

Learning Set 1 Preview

QUESTION: *How do abiotic factors affect biotic factors in an ecosystem?*

Storyline
Students participate in learning activities to build and understanding on content in the following areas:

- Parts of an ecosystem
- Interactions within ecosystems
- Gathering and interpreting data on abiotic factors
- Gathering and interpreting data on biotic factors

Students show mastery of this content knowledge in the lesson set assessment.

Brief Lesson/Lesson Set Description:
The differences between abiotic and biotic factors in an environment and their relationship to each other is the focus of this series of investigations. Students will gather data about organisms either through an actual data collection during a field experience or through data given to them in the classroom; other data sets could additionally be analyzed. Students then gather data on abiotic factors of the environment, analyzing that data to develop an explanation for the relationships between the organisms that were found. Limiting factors and how those factors affect the populations of organisms are investigated as well as how potential changes in abiotic factors may affect those populations.

Performance Expectations:

LS1-5. Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.

LS2-1. Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.

LS2-2. Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.

LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

Science and Engineering Practices:
Students will be skilled at:

- Using data as evidence to back up a claim.
- Making a scientific explanation that is supported by evidence.
- Constructing an argument supported by evidence to support an explanation or explain phenomena.

Disciplinary Core Ideas:
Students will understand:

- Organisms, and populations of organisms, are dependent on environmental interactions with living and nonliving factors.
- Organisms compete for limited resources.
- Growth of organisms and population increases are limited by access to resources.
- Genetic factors as well as local conditions affect the growth of the adult plant.
- Disruptions to physical or biological components of an ecosystem can lead to shifts in populations.

Crosscutting Concepts:
Students will be able to use:

- Cause and effect in relationships to predict phenomena and support explanations.

- Small changes in one part of a system can cause large changes in another part.

Common Core ELA Standards: (Similar for grades 6-8; grade 7 link is given.)
CCSS.ELA-LITERACY.RI.6-8.1
Cite several pieces of textual evidence to support analysis of what the text says explicitly as well as inferences drawn from the text.

CCSS.ELA-LITERACY.RI.6-8.4
Determine the meaning of words and phrases as they are used in a text, including figurative, connotative, and technical meanings; analyze the impact of a specific word choice on meaning and tone.

CCSS.ELA-LITERACY.W.6-8.1
Write arguments to support claims with clear reasons and relevant evidence.

CCSS.ELA-LITERACY.W.6-8.2
Write informative/explanatory texts to examine a topic and convey ideas concepts, and information through the selection, organization, and analysis of relevant content.

CCSS.ELA-LITERACY.W.6-8.7
Conduct short research projects to answer a question, drawing on several sources and refocusing the inquiry when appropriate.

CCSS.ELA-LITERACY.W.6-8.9
Draw evidence from literary and informational texts to support analysis, reflection, and research.

CCSS.ELA-LITERACY.W.6-8.10
Write routinely over extended time frames (time for research, reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

Common Core Math Standards:
CCSS.MATH.CONTENT.6.SP.A.1
Recognize a statistical question as one that anticipates variability in the data related to the question and accounts for it in the answers.

CCSS.MATH.CONTENT.7.SP.A.1
Understand that statistics can be used to gain information about a population by examining a sample of the population; generalizations about a population from a sample are valid only if the sample is representative of that population. Understand that random sampling tends to produce representative samples and support valid inferences.

CCSS.MATH.CONTENT.6.SP.A.2
Understand that a set of data collected to answer a statistical question has distribution, which can be described by its center, spread, and overall shape.

CCSS.MATH.CONTENT.7.SP.A.2
Use data from a random sample to draw inferences about a population with an unknown characteristic of interest. Generate multiple samples (or simulated samples) of the same size to gauge the variation in estimates or predictions.

Science/Technical Subjects:

Reading:

CCSS.ELA-LITERACY.RST.6-8.3
Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

CCSS.ELA-LITERACY.RST.6-8.4
Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to *grades 6-8 texts and topics*.

CCSS.ELA-LITERACY.RST.6-8.7
Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

Writing:

CCSS.ELA-LITERACY.WHST.6-8.1.A
Introduce claim(s) about a topic or issue, acknowledge and distinguish the claim(s) from alternate or opposing claims, and organize the reasons and evidence logically.

CCSS.ELA-LITERACY.WHST.6-8.1.B
Support claim(s) with logical reasoning and relevant, accurate data and evidence that demonstrate an understanding of the topic or text, using credible sources.

CCSS.ELA-LITERACY.WHST.6-8.1.C
Use words, phrases, and clauses to create cohesion and clarify the relationships among claim(s), counterclaims, reasons, and evidence.

CCSS.ELA-LITERACY.WHST.6-8.4
Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

CCSS.ELA-LITERACY.WHST.6-8.5
With some guidance and support from peers and adults, develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on how well purpose and audience have been addressed.

CCSS.ELA-LITERACY.WHST.6-8.10
Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

Prior Student Knowledge Expectations:

Students will need a basic background in types of relationships between biotic factors in an environment (symbiotic, mutualism, parasitic, etc.), although will not need to be able to identify and label these relationships within the environment studied. Students will also need to be able to identify necessary resources for survival for a variety of organisms in an ecosystem.

Activities:

- What is an Ecosystem?
- Thinking Environmentally
- Measure Up!
- Abiotic Study
- What's the Weather?
- Estimating Percentages
- Candle Eating
- Quadrat Study: School Lawn
- Quadrat Species Sampling – Plants and Invertebrates
- Aquatic Diversity and Water Quality

Learning Set 1 Student Assessment

Learning Set 2 Preview

QUESTION: *How can biotic factors increase the likelihood of survival?*

Storyline
Students participate in learning activities to build and understanding on content in the following areas:

- Physical characteristics of organisms
- Classification of organisms using physical characteristics
- Adaptations of organisms

Students show mastery of this content knowledge in the lesson set assessment.

Brief Lesson/Lesson Set Description:
Students choose an organism from the studied ecosystem to investigate. Students identify adaptations that influence behaviors which aid in population increases. The relationships between organisms are explored, for example, any way an insect may assist in seed dispersal. Biotic and abiotic factors threat to the organism population is studied.

Performance Expectations:

LS1-4. Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of plants and animals respectively.

LS2-2. Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.

Science and Engineering Practices:
Students will be skilled at:

- Constructing an argument using evidence to support an explanation or explain a phenomenon.
- Constructing scientific explanations that include qualitative or quantitative relationships between variables that predict phenomena.

Disciplinary Core Ideas:
Students will understand:

- Animals engage in characteristic behaviors that increase the odds of reproduction.
- Plants reproduce in a variety of ways, sometimes depending on animal behavior and specialized features for reproduction.
- Predatory interactions may reduce the number of organisms or eliminate whole populations.
- Mutually beneficial relationships may develop into relationships necessary for survival.
- Relationships between organisms may cross ecosystems and may involve both living and nonliving things.

Crosscutting Concepts:
Students will be able to use:

- Cause and effect in relationships to predict phenomena and support explanations.
- Patterns to identify cause and effect relationships.

Common Core ELA Standards: (Similar for grades 6-8; grade 7 link is given.)
CCSS.ELA-LITERACY.RI.6-8.1
Cite several pieces of textual evidence to support analysis of what the text says explicitly as well as inferences drawn from the text.

CCSS.ELA-LITERACY.RI.6-8.4
Determine the meaning of words and phrases as they are used in a text, including figurative, connotative, and technical meanings; analyze the impact of a specific word choice on meaning and tone.

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Write arguments to support claims with clear reasons and relevant evidence.

CCSS.ELA-LITERACY.W.6-8.2
Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content.

CCSS.ELA-LITERACY.W.6-8.7
Conduct short research projects to answer a question, drawing on several sources and generating additional related, focused questions for further research and investigation.

CCSS.ELA-LITERACY.W.6-8.9
Draw evidence from literary or informational texts to support analysis, reflection, and research.

CCSS.ELA-LITERACY.W.6-8.10
Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

Common Core Math Standards:
CCSS.MATH.CONTENT.6.SP.A.1

Recognize a statistical question as one that anticipates variability in the data related to the question and accounts for it in the answers.

CCSS.MATH.CONTENT.7.SP.A.1

Understand that statistics can be used to gain information about a population by examining a sample of the population; generalizations about a population from a sample are valid only if the sample is representative of that population. Understand that random sampling tends to produce representative samples and support valid inferences.

CCSS.MATH.CONTENT.6.SP.A.2
Understand that a set of data collected to answer a statistical question has distribution, which can be described by its center, spread, and overall shape.

CCSS.MATH.CONTENT.7.SP.2
Use data from a random sample to draw inferences about a population with an unknown characteristic of interest. Generate multiple samples (or simulated samples) of the same size to gauge the variation in estimates or predictions.

Science/Technical Subjects

Reading:
CCSS.ELA-LITERACY.RST.6-8.3
Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

CCSS.ELA-LITERACY.RST.6-8.4
Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to *grades 6-8 texts and topics*.

CCSS.ELA-LITERACY.RST.6-8.7
Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

Writing:
CCSS.ELA-LITERACY.WHST.6-8.1.A
Introduce claim(s) about a topic or issue, acknowledge and distinguish the claim(s) from alternate or opposing claims, and organize the reasons and evidence logically.

CCSS.ELA-LITERACY.WHST.6-8.1.B
Support claim(s) with logical reasoning and relevant, accurate data and evidence that demonstrate an understanding of the topic or text, using credible sources.

CCSS.ELA-LITERACY.WHST.6-8.1.C
Use words, phrases, and clauses to create cohesion and clarify the relationships among claim(s), counterclaims, reasons, and evidence.

CCSS.ELA-LITERACY.WHST.6-8.4
Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

CCSS.ELA-LITERACY.WHST.6-8.5
With some guidance and support from peers and adults, develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on how well purpose and audience have been addressed.

CCSS.ELA-LITERACY.WHST.6-8.10
Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

Prior Student Knowledge Expectations:
Students will most likely have some background knowledge of animal relationships and that those relationships are not always positive. Students probably do not include plants in those relationships. Many students also may not recognize that abiotic factors influence survival and that changes in abiotic factors change survival rates in biotic populations.

Activities:
- Sightless Drawing
- Calico Beans
- The Key to the Keys
- Pinecone Search
- Critical Attributes – Plants and Invertebrates
- Adaptations
- Seed Adaptations for Survival and Dispersal
- Seeds of Flight
- Sustained Writing
- Baked Potato Invertebrate Trap
- Airborne and Crawling Invertebrate Survey

Learning Set 2 Student Assessment

Learning Set 3 Preview

QUESTION: *How do abiotic and biotic factors work together to cycle energy and resources through an ecosystem?*

Storyline
Students participate in learning activities to build and understanding on content in the following areas:

- How biodiversity contributes to a healthy ecosystem
- Modeling energy transfer
- The role of photosynthesis in energy transfer
- Fire's role in ecosystem restoration

Students show mastery of this content knowledge in the lesson set assessment.

Brief Lesson/Lesson Set Description:
Students explore photosynthesis and the role of the chemical reaction in an ecosystem food web. Students identify components of a food web and the relationships between organisms in a food web. Students also begin to explain how abiotic factors affect a food web.

Performance Expectations:
LS1-6. Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms.

LS2-2. Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.

LS2-3. Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.

Science and Engineering Practices:
Students will be skilled at:
- Constructing an explanation based on evidence from experiments and scientific principles and theories that describes how the natural world functions and will function in the future.
- Models that are developed and used to describe, test, and predict phenomena.

Disciplinary Core Ideas:
Students will understand:
- Plants use energy from light to make food (photosynthesis), which releases oxygen. The sugar produced can be used immediately or saved for later.
- Plants producing sugar require an energy input (sunlight). In this reaction, carbon dioxide and water combine to form carbon-based organic molecules and release oxygen.
- Food webs model how energy is transferred and how producers, consumers and decomposers interact with each other.
- Atoms that make up organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem.

Crosscutting Concepts:
Students will be able to use:
- Within a system, energy transfers drive the motion and cycling of matter.
- The transfer of energy can be tracked as it flows through a natural system.

Common Core ELA Standards: (Similar for grades 6-8; grade 7 link is given.)
CCSS.ELA-LITERACY.RI.6-8.1
Cite several pieces of textual evidence to support analysis of what the text says explicitly as well as inferences drawn from the text.

CCSS.ELA-LITERACY.RI.6-8.4
Determine the meaning of words and phrases as they are used in a text, including figurative, connotative, and technical meanings; analyze the impact of a specific word choice on meaning and tone.

CCSS.ELA-LITERACY.W.6-8.1
Write arguments to support claims with clear reasons and relevant evidence.

CCSS.ELA-LITERACY.W.6-8.2
Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content.

CCSS.ELA-LITERACY.W.6-8.7
Conduct short research projects to answer a question, drawing on several sources and generating additional related, focused questions for further research and investigation.

CCSS.ELA-LITERACY.W.6-8.9
Draw evidence from literary or informational texts to support analysis, reflection, and research.

CCSS.ELA-LITERACY.W.6-8.10
Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

Common Core Math Standards:
CCSS.MATH.CONTENT.6.SP.A.1
Recognize a statistical question as one that anticipates variability in the data related to the question and accounts for it in the answers.

CCSS.MATH.CONTENT.7.SP.A.1
Understand that statistics can be used to gain information about a population by examining a sample of the population; generalizations about a population from a sample are valid only if the sample is representative of that population. Understand that random sampling tends to produce representative samples and support valid inferences.

CCSS.MATH.CONTENT.6.SP.A.2
Understand that a set of data collected to answer a statistical question has distribution, which can be described by its center, spread, and overall shape.

CCSS.MATH.CONTENT.7.SP.2
Use data from a random sample to draw inferences about a population with an unknown characteristic of interest. Generate multiple samples (or simulated samples) of the same size to gauge the variation in estimates or predictions.

Science/Technical Subjects

Reading:
CCSS.ELA-LITERACY.RST.6-8.3
Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

CCSS.ELA-LITERACY.RST.6-8.4
Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6-8 texts and topics.

CCSS.ELA-LITERACY.RST.6-8.7
Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

Writing:
CCSS.ELA-LITERACY.WHST.6-8.1.A
Introduce claim(s) about a topic or issue, acknowledge and distinguish the claim(s) from alternate or opposing claims, and organize the reasons and evidence logically.

CCSS.ELA-LITERACY.WHST.6-8.1.B
Support claim(s) with logical reasoning and relevant, accurate data and evidence that demonstrate an understanding of the topic or text, using credible sources.

CCSS.ELA-LITERACY.WHST.6-8.1.C
Use words, phrases, and clauses to create cohesion and clarify the relationships among claim(s), counterclaims, reasons, and evidence.

CCSS.ELA-LITERACY.WHST.6-8.4
Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

CCSS.ELA-LITERACY.WHST.6-8.5
With some guidance and support from peers and adults, develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on how well purpose and audience have been addressed.

CCSS.ELA-LITERACY.WHST.6-8.10
Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

Prior Student Knowledge Expectations:
Students should have an elementary understanding of what photosynthesis is. Students should also understand that different living things acquire energy in different ways (producers, consumers and decomposers).

Activities:
- Everyone's Important

- Pollinators and Consumers – CSI Ecosystem
- Trophic Interactions and Food Webs
- Photosynthesis
- Life in a Log – Soil Structure
- Fire Ecology
- Home on the Range

Learning Set 3 Student Assessment

Engineering Assessment

- Peanut Butter and Jelly Sandwich
- Problem-Based Research Component – Engineering Design

Student Research Component

At the conclusion of the unit, students can be provided with the opportunity to select an ecosystem services topic and conduct a self study. Students should select a topic based on interest and complete the self-study with a focus on either the pond, forest or prairie ecosystems. Students should focus their final product on the performance expectations found in each component. Growth in the practices can be monitored using the linked rubrics. Teachers are encouraged to prelude the research component modules with the Bumble Bee Study to give students a feel of how to conduct research.

Science/Technical Subjects

Reading:

CCSS.ELA-LITERACY.RST.6-8.8

Distinguish among facts, reasoned judgment based on research findings, and speculation in a text.

CCSS.ELA-LITERACY.RST.6-8.9

Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.

Writing:

CCSS.ELA-LITERACY.WHST.6-8.7

Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.

Ecosystem Services Research Components

- Ecosystem Services Research Component
- Ecosystem Services Research Component – Pollination
- Ecosystem Services Research Component – Erosion Control
- Ecosystem Services Research Component – Weather Disturbance Regulation
- Ecosystem Services Research Component – Nutrient Cycling
- Ecosystem Services Research Component – Climate Regulation

Field Research Components

- Field Research
- Abiotic Study
- Quadrat Species Sampling – Plants and Invertebrates
- Airborne and Crawling Invertebrate Survey
- Pollinators and Consumers – CSI Ecosystem
- Aquatic Diversity and Water Quality
- Fermilab Past, Present and Future
- Fermilab Land Management Map
- Fermilab Land Management
- Bumblebee Watch

Resources:

- Planning Your Fermilab Field Trip
- Special Education Considerations
- Prairie Plant Key
- Herbarium Specimen Collection
- Things to Consider when Planning a School Prairie
- Illinois Prairie Loss Maps
- FQI Skill Builder
- FQI – Fermilab Sites
- Common Woodland Plants in Fermilab Student Plot
- Common Wetland Plants at Lederman Science Center Pond
- Causes and Effects of Water Chemistry
- Lake/Pond Stratification and Turnover
- Fermilab Surface Water Flow/Control Map
- Sampling Terrestrial Invertebrates
- WANTED Posters
- What is Symbiosis?
- Ecosystem Services – Student Research
- Bison is U.S. National Mammal!
- Ecology Resources
- Glossary

Table of Contents

Introduction
Wolf Letter I-1
Student Research Journal I-7
Student Research Journal Assessment I-15
Investigation Rubric I-17
Participation Rubric I-19
Performance Rubric I-21
Science and Engineering Practices Rubric I-23
Ecology and the 5E Instructional Model I-31
Ecosystem Services I-33
Habitat Communities of the Fermilab Site I-35

Set One – How do abiotic factors affect biotic factors in an ecosystem?
What is an Ecosystem? 1-1
Thinking Environmentally 1-11
Measure Up! 1-19
Abiotic Study 1-29
What's the Weather? 1-45
Estimating Percentages 1-53
Candle Eating 1-61
Quadrat Study: School Lawn 1-69
Quadrat Species Sampling – Plants and Invertebrates 1-77
Aquatic Diversity and Water Quality 1-95
Learning Set 1 Assessment 1-107

Set Two – How do biotic factors increase the likelihood of survival in an ecosystem?
Sightless Drawing 2-1
Calico Beans 2-11
The Key to the Keys 2-17
Pinecone Search 2-27
Critical Attributes – Prairie Plants and Invertebrates 2-33
Adaptations 2-45
Seed Adaptations for Survival and Dispersal 2-55
Seeds of Flight 2-67
Sustained Writing 2-71
Baked Potato Invertebrate Trap 2-79
Airborne and Crawling Invertebrate Survey 2-87
Learning Set 2 Assessment 2-97

Set Three – How do abiotic and biotic factors work together to cycle energy and resources through an ecosystem?
Everyone's Important 3-1
Pollinators and Consumers – CSI Ecosystem 3-13

Trophic Interactions and Food Webs 3-31
Photosynthesis 3-51
Life in a Log – Soil Structure 3-65
Fire Ecology 3-77
Home on the Range 3-87
Learning Set 3 Assessment 3-101

Engineering Assessment

Peanut Butter and Jelly Sandwich.....4-1
Problem-Based Research Component – Engineering Design 4-5

Engineering Components

Ecosystem Services Research Components 5-1
Ecosystem Services Research Component – Pollination 5-3
Ecosystem Services Research Component – Erosion Control 5-5
Ecosystem Services Research Component – Weather/Disturbance Regulation 5-7
Ecosystem Services Research Component – Nutrient Cycling.....5-9
Ecosystem Services Research Component – Climate Regulation.....5-11

Field Research Components

Field Research 6-1
Abiotic Study 6-7
Quadrat Species Sampling – Plants and Invertebrates.....6-23
Airborne and Crawling Invertebrate Survey 6-41
Pollinators and Consumers – CSI Edosystem 6-51
Aquatic Diversity and Water Quality.....6-69
Fermilab: Past, Present and Future 6-81
Fermilab Land Management Map 6-101
Fermilab Land Management 6-103
Bumblebee Watch 6-107

Resources

Planning Your Fermilab Field Trip.....7-1
Special Education Considerations.....7-3
Prairie Plant Key.....7-7
Herbarium Specimen Collection.....7-17
Things to Consider when Planning a School Prairie 7-19
Illinois Prairie Loss Maps.....7-25
FQI Skill Builder.....7-27
FQI – Fermilab Sites 7-31
Common Woodland Plants in Fermilab Student Plot 7-33
Common Wetland Plants at Lederman Science Center Pond 7-35
Causes and Effects of Water Chemistry 7-37
Lake/Pond Stratification and Turnover.....7-39
Fermilab Surface Water Flow/Control Map 7-41
Sampling Terrestrial Invertebrates 7-43

WANTED Posters.....7-53
What is Symbiosis? 7-75
Ecosystem Services – Student Resource 7-77
Bison is U.S. National Mammal!.....7-79
Ecology Resources 7-83
Glossary 7-91

Dear Human,

It's late at night and I can see you sitting by your campfire. The fire caught my attention and the smells of something new made me too curious to stay away. I can hear you telling stories and laughing like you're truly enjoying your time camping in the woods. But every now and again I can see you turn to look around your shoulder. You tell yourself that I'm not here; I haven't been seen around these campgrounds in decades. There's nothing to be scared of.

But today, as you hiked along the river you saw a strange footprint. I heard you say, "It must be a coyote; they can get pretty large." You're having a hard time getting the image of that footprint out of your head. It was so big! Something keeps telling you it's not a coyote. We've been here for just a short time and we haven't let many humans see us yet. They're not used to seeing us and so they forget that we've come back home.

As it gets dark, you hear me howl and I know you're scared. My brothers return the call and the echoed howl splits the chilly air. You try to hide it but I can smell your fear. I can see you shake in the night, but I don't understand why. If you knew me, you would know that I'm not the monster humans think I am. I actually help this place survive.

The fact that I'm here brings a lot of attention to this place. People from all over come to visit just to get a glimpse of me, and that means that they are enjoying other wildlife, too. Some people may never have come to this place if I wasn't here. They wouldn't have had the chance to fall in love with the scenery and take home with them the desire to bring attention to conservation efforts that will save my home from becoming the next neighborhood.

I can't believe you doubted I would be here. Everyone is talking about how my family has finally arrived and we are thriving. The spotlight is on us—and this magnificent place. Because we are surviving, there may be others who get the chance. We are proving that we can make a comeback. There will be efforts in other ecosystems, and the fact that we are here will drive scientists and conservationists to continue their efforts.

We have also balanced out an ecosystem that was missing a vital piece of the food web. We are restoring that balance and, therefore, populations are starting to level off to sustainable numbers. We are thinning herds that have grown too big and, because of us, many populations are healthier and more stable. When populations grow too big, it's not always good; animals spread disease easier, they have to compete more for space, and they consume more food than can be replenished.

If our family can multiply, we may be able to keep our species from the brink of extinction. The more members of our family we have and the more families that are surviving, the more opportunities we have for strong, healthy cubs. Having a variety of parents strengthens our gene pool and secures our place back in this ecosystem.

So we are here. Maybe you'll see us if you keep your eyes open. If you do spot us, don't be scared. Remember, we are not here to hurt you. In fact, we know that you are doing your best to help us. In return, we'll do our part to restore our home to what it once was so that future generations can enjoy a natural wonder. Our journey is not over yet; we have a long way to go before we have secured our spot. We won't give up, though, so don't give up on us.

–*Wolf*

Set 1: How do abiotic factors affect biotic factors in an ecosystem?

Dear Human,

Things are different here now. The forest is not exactly how I remember it. There are more trees than there was before; I can hide better. The animals I prey on can't always see me coming when I hunt. Sometimes the trees block my line of sight and they make maneuvering hard. A few times I've gone to hunt further away from my den in the open fields. It's easier to hunt there, but it's a longer trek back home with what I've caught.

Hunting is not the only thing the trees make difficult. Many are pine trees with sticky needles that get caught on my paws and in my fur. I'm lucky I have a pack to help me groom and hunt when my paws are too sore to walk on.

I don't remember the needles like this before; the pines used to be farther out from where my pack had its dens. I also don't remember the rain being so bad either. It has rained a lot lately and the wind has been strong. The winds have been blowing straight at us. Luckily we have our thick coats, so the wind is more of a nuisance than dangerous. It takes a lot more than a little rain and wind to cut through my thick coat and to keep me from hunting.

Even though the trees have caused my pack a few problems, they have brought a lot of shade when we need it. When it's not raining and the sun is out, it can get really hot when you've got a fur coat on. I appreciate the shade on hot days. I have to keep up my energy if I am to hunt at night. Lying in the sun just takes too much out of me.

The trees also attract small animals and birds. When hunting out in the open fields, there is not always anything to catch. It's not a safe place to be during the day; it's too open and vulnerable. The small animals do come to forage in the safety of the trees, though; they know where it's less likely that they can be spotted by a hawk flying above them or a stalking fox who can see their movement in the grasses.

–*Wolf*

Set 2: How can biotic factors increase the likelihood of survival?

Dear Human,

Food has been abundant in the last year and our pack has almost doubled in size. Because the pine trees have brought so many smaller mammals to our area, there is almost no need to travel far to hunt. The fruits of the small plants growing under the pines are just too enticing for the rabbits and woodchucks. Even though they know we are here, they keep coming anyway just to get those fruits and nuts. The flowery smells even smell good to me and I'm not much of a plant eater.

For the first time, I wake up to birds singing. It's not raining today, which is a change. The sun is warm and it makes me want to sleep a while longer. Every time I think I can't take another day of rain, I remember what all those plants have brought the pack. We've never had so much rain and so many plants. They are growing so fast, and there are so many. Those little mammals have more than enough to eat and now so do we.

The winds shift suddenly and I can smell that it's about to rain again; maybe not until later this afternoon, but it's coming. The rain certainly makes it hard to enjoy the season. My coat always seems soaked and it's difficult to find a place to keep the pups dry. Our dens are well made, but when we are always coming in soaking wet, it is not easy to keep a sleeping space dry. But my belly is full and so no complaints.

In the distance, I hear a coyote howl. You might think it was one in my pack, but I can tell our calls apart. The coyotes have also been enjoying more food than they have ever had before. Their pack has grown much larger than ours. They have become greedy and expanded their hunting ground. They don't take just what they need; they take whatever they can. This benefits us. There is plenty to go around and as the small mammals try to escape the coyotes, they make their way over to this area. The coyotes don't dare to follow them this far out. They can't take the competition.

–*Wolf*

Set 3: How do abiotic and biotic factors work together to cycle energy and resources through an ecosystem?

Dear Human,

I haven't had the energy to communicate in a while. The abundance of food we were enjoying earlier in the year is gone and we are in dire need of something to eat now. *Anything*! The rains that brought those plants that lured all those animals never stopped. It rained so much that the soil from underneath us just washed away and took the plants with it. It happened slowly and we didn't realize it in time to move the pack. The ground got more and more saturated until the plants were drowned out. When the heavier rains came, they washed away the soil and everything that grew in it.

When the plants died out, the small mammals moved out, too, on to other places. The coyotes became desperate and started to come closer and closer to our pack, picking off the animals that did stay. We fought them off at times, but sometimes they just outhunted us and we went home with hungry bellies. I can still hear their howls at night, although now they sound as weak as we do.

The days are shorter and the nights are colder now. Some of the smaller animals have begun to hide away for winter. The sun doesn't shine brightly enough for plants to regrow. We'll have to wait the winter out and forage for what we can. Hopefully we have built up enough fat reserve to last for a while. We can survive hungry for a while, although I don't know how long.

We have held out here as long as we can; it's time to move on. If we can't find an area where we can hunt, we won't last more than a month. Our pack has come too far to give up now. We will move on and find another place to live. There are better conditions out there and there will be food. We will find it; we have to. We have worked so hard to make a comeback and to reclaim our place in this ecosystem. We won't let one bad season destroy all that we have worked to regain.

–*Wolf*

Student Research Journal

Topic: The science journal enhances scientific literacy, offers students an opportunity to compile new knowledge and data, and provides evidence of growth in thought and skill throughout this unit of study.

Brief Lesson/Lesson Set Description:
In an effort to place students in the role of scientific researcher and emulate the methods used in the field to record and maintain data, students will learn how to utilize a research journal.

Science and Engineering Practice: Obtaining, Evaluating and Communicating Information

Crosscutting Concept: Depending on the view of the journalist, all crosscutting concepts may be seen throughout this activity.

INVESTIGATION

Objectives: Students will:

- Demonstrate the ability to document and organize data as they assume the role of student researcher.
- Maintain their research journal throughout the unit and be able to access information to support a claim, a prediction or an unexpected finding.
- Utilize their journal as a communication tool between peers, teacher, and parents.
- Synthesize ideas and data collected for analysis and reflection.

Narrative/Background Information:
The ability to access information in a few seconds has made communication of that information an essential skill to develop in the science classroom. The direct communication links provided by science journaling is a key component in accessing, interpreting, conveying and assessing scientific knowledge in the classroom as well as in the scientific laboratory.

Scientists have maintained journals in various forms since the beginning of written history. From the earliest works of the Greeks and Romans to Newton and Fleming to the present, scientists have relied on notes, ledgers, and journals to effectively have the opportunity to allow them to emulate professional scientists with the journaling strategy.

Science journals can enhance personal skills and provide communication links between peers, teachers, and parents in the following ways:

- Model an essential skill of professional scientists.
- Maintain class notes and related work in a chronological, organized format.

- Develop and record qualitative and quantitative data from lab and field experiences.
- Experience a variety of science writing techniques and strategies that are meaningful and essential to learning.
- Promote a positive learning environment by allowing free verbal reactions to classroom-presented topics in a medium that is less threatening to some students.
- Communicate with families about curricular science topics, learning and growth.
- Review and reinforce learning through metacognitive reflection.
- Facilitate the construction of new knowledge in a manner that favors the continual process of conceptual change.
- Assist in identifying scientific misconceptions through the diagnostic reading and analysis of journal content by parent, peer, or teacher.
- Add the component of humanism within the scientific community by eliciting inquiry of ethical and/or emotional issues.
- Provide an outlet for student inquiries, thoughts, ideas and wonderments.
- Provide a tool to display growth in the area of science, in both content and skill.

Prior Student Knowledge Expectations:

- Use journaling on an ongoing basis.
- Journal will always be available to them.
- Teachers will look to journals as a way to understand student thinking on an individual level.
- Teachers will look to journals as a way to provide differentiation within the context of a single assignment.

Possible Preconceptions/Misconceptions:
Students may struggle to see the journal as a tool applicable to science.

Vocabulary: Varies depending on entries. Encourage students to use proper vocabulary in their observations.

Materials:

- Spiral notebook, binder with paper, or computer
- Writing instruments

ENGAGE:
Students may benefit from seeing an example of a science journal or participating in a class discussion about what information would be valuable to include in a science journal. Students may think that only quantitative data should be used when qualitative data could be just as important during observations.

EXPLORE:
Process:

1. Explain the importance of science journaling in the lives of career scientists. (Provide an example of an authentic scientist's journal, if possible.)

2. Assign the acquisition of the appropriate materials.
3. Outline expectations of the journal assignment. Examples include:
    a. Class notes, daily homework.
    b. Questions, predictions, student wonderments.
    c. Lab data, both quantitative and qualitative.
    d. Data analysis; tables, graphs, graphic organizers.
    e. Vocabulary or essential formulas.
    f. Scientific principles.
4. Provide examples and practice with graphic organizers.
5. Indicate how journals will be assessed (self, peer, parent, teacher, etc.).
6. Encourage students to use their journals and to share their journals with each other.
7. Ask students, who are creative in how they use their journals, to share their ideas with their team or the class.
8. Develop a system to keep track of the information used as evidence to support a claim so students can visually see how often they use information from their journals to explain their thinking.

EXPLAIN:
Engage students in a discussion using their observations. Encourage students to give rationale for what types of information they include in their journals and to identify one type of data collection that a peer has used and that they would want to explore.

ELABORATE:
Ask students to explore using a few of the provided graphic organizers to record their observations. Students that find success in this can work to develop their own organizers and share successful designs with their peers.

EVALUATE:
Formative Monitoring: Periodically monitor the quality of observations and data collected, giving feedback on successes and improvements that students could make to add detail to their notes.

Summative Assessment: N/A

Elaborate Further/Reflect/Enrichment: Ask students to keep a record of additional questions that come from their journal entries. Students may wish to use these questions to find patterns in their thinking and further research topics of interest.

Graphic Organizer Examples

1. Time/Order Sequence

Cenozoic Era Periods	Mesozoic Era Periods
1. Quaternary	1. Cretaceous
2. Tertiary	2. Jurassic
	3. Triassic

2. Cause → Effect

Drought → Non-native plants suffer
Drought → Animals move toward water
Drought → Prairie plants' roots grow deeper

3. Problem → Solution

Loss of native grasslands → Prairie restoration and redemption

4. Problem → Solution → Result

Loss of native grasslands → Prairie restoration and redemption → natural remedies, beauty, prairie research sites, and MORE

5. Mind Map/Concept Map

A.

FAULT
↓
Movement
↓
EARTHQUAKE
↓
Seismic waves
↓
P WAVES ← S WAVES → L WAVES

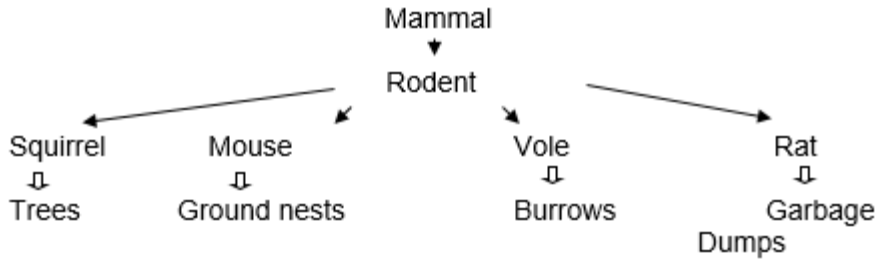
B.

Pangea → split by → Plate Tectonics

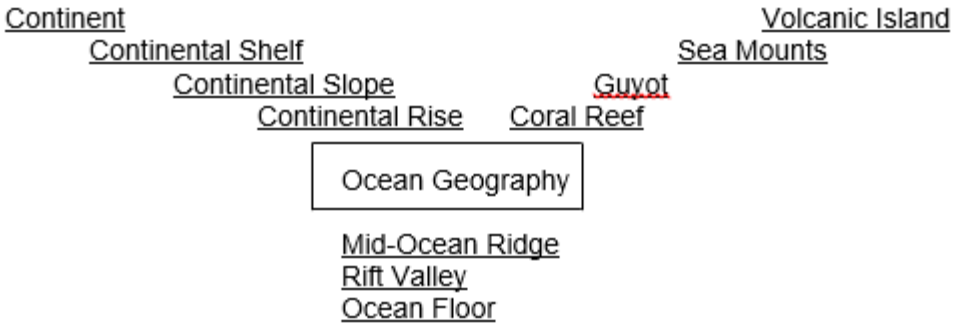
Plate Tectonics → Via → Continental Drift → forming → Lithosphere

Plate Tectonics → Via → Mid-Ocean Spread → forming → Lithosphere

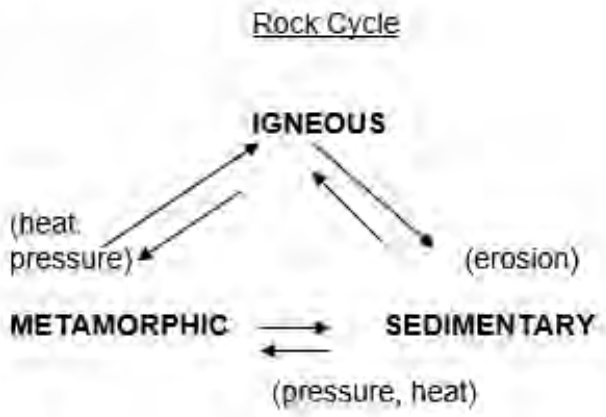
6. Word Map



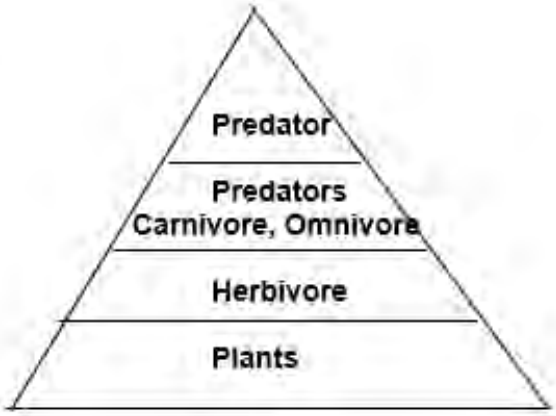
7. Spider Web



8. Cycle



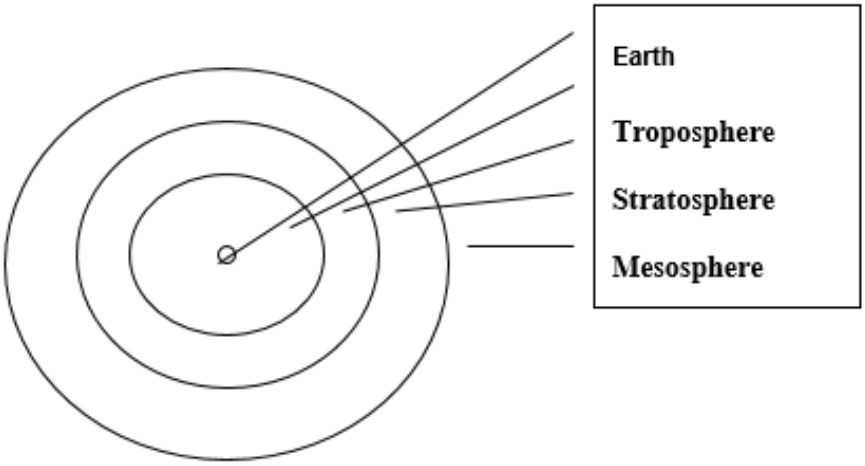
9. Pyramid



10. Matrix

Animal	Antennae	Mouth Parts	Legs
Spider	None	Sucking	8
Butterfly	Long, smooth	Sucking proboscis	6
Grasshopper	Smooth	Chewing	6

11. Concentric



Student Research Journal Assessment

Reminders:

- ALWAYS distribute the assessment rubric prior to activity or administration of the task.
- The journal assessment allows students to understand individual accountability and track progress in every aspect of the science experience.
- The student research journal is designed as a tool for the student. Just as a career scientist uses a journal for reference and research, the student will maintain critical information, ideas, and reflections in the journal.
- The student research journal assessment may also function as a peer/self-assessment if desired.
- The teacher may wish to send the journal home periodically for parent/guardian review.
- Encourage students to place completed assessments in portfolios where they have free access to evidence of their progress throughout the learning experience.
- Take time to discuss the results with each student, acknowledging growth relative to the individual learner.

The teacher is encouraged to modify the following assessment to meet the unique needs of the individual classrooms and students.

Rubrics:
Appropriate assessment of student progress is key to student achievement. Journals are a tool to be used in authentic assessment.

Teachers are encouraged to manipulate the criteria to best fit their unique classroom situation.

Consider the following tips to best ensure success:

- Discuss expectations of the task and elements of the rubric prior to the activity.
- Assess students individually.
- Cooperation and team effort is factored into the assessment rubric.
- Feel free to weight categories, change criteria to fit your classroom, and/or eliminate a rubric option.
- In addition to the detailed rubric provided for teacher consideration, encourage student peer- and self-assessment.
- Stress the importance of documentation and quality of content material.
- Advise students that assessment must be taken seriously and, if student implementation, completed in an ethical manner.
- Encourage students to use their journals often as a tool to pull information.
- Take time to discuss the results with each student, acknowledging growth relative to the individual learner.

Student Research Journal Assessment Rubric

Criteria Points Earned	Exceeds Expectations 3 points	Meets Expectations 2 points	Needs Encouragement 1-0 points
Frequency	Consistent daily, dated entries	Nearly consistent daily, dated entries	Few entries, and/or undated entries
Information	Ample qualitative and quantitative information	Adequate qualitative and quantitative information	Minimal qualitative and/or quantitative information
Procedural Evidence	Evidence of “blind alleys” and steps taken to remedy	Some evidence of “blind alleys” and steps taken to remedy	Little to no evidence of “blind alleys” and steps taken to remedy
Reflections	Frequent reflections and questions to pursue	Some reflections and questions to pursue	Few reflections and questions to pursue
Format	Organized; components can easily be found.	Organized, but components can not always be found	Not organized; information is difficult to find.
Functional	Clearly, concisely written or depicted; information can be used and understood easily by others.	Adequately written or depicted; information can be used and understood with only a few questions.	Poorly written or depicted; information cannot be used and understood by others.
Total			

Total Points Earned: _____

Comments:

Investigation Rubric

Criteria Points Earned	Exceeds Expectations 3 points	Meets Expectations 2 points	Needs Encouragement 1 point	No Effort or Uncooperative 0 points
Self-Directed Study	Self-starter; needs little facilitation	Needs some assistance	Lacks initiative	No initiative
Level of Engagement in the Tasks	Actively engaged, inspires others with enthusiasm	Does what is asked	Indifferent; unengaged	Works to undermine progress
Investment in Questions Analysis	Offers many insights and suggestions for the team	Follows the group; offers assistance	Lacks interest; may contribute some but must be coaxed	Generally uninterested; contributes little
Journal Entries	Takes useful notes; extends research beyond expectation	Writes what is necessary	Infrequent; sketchy log	No log
Team Debriefing Tasks	Well-designed debriefing ideas; takes initiative for team activities	Uses ideas of others more than generating own ideas	Makes little effort to complete the team tasks	No effort
Research Beyond the Questions	Actively gathers information from a variety of sources; generates new questions	Researches some but relies on others; generates new questions	Makes little effort to contribute; generates few new questions	No evidence of research; does not generate new questions
Total				

Total Points Earned: _____

Comments:

Participation Rubric

Criteria Points Earned	Exceeds Expectations 3 points	Meets Expectations 2 points	Needs Encouragement 1 point	No Effort or Uncooperative 0 points
Team Task Completion	All tasks are completed as a team and represent everyone's best work.	All tasks are completed as a team.	Some tasks are not completed as a team.	Little or no evidence of teamwork
Cooperative Group Behavior	Initiated positive group dialogue; encouraged team members; proactive	Productive member of group; followed team plans; good cooperation	Did only what was assigned; took little initiative to promote teamwork	Uncooperative; did not contribute well in a teamed effort; divisive
Approach to Technology Resources	Functions as a technology leader; willing to attempt new computer skills; helps others	Willing to learn new technology skills; makes significant progress; shares equipment	Hesitates to develop new skills and/or has difficulty sharing equipment	Does not participate with team strategy; "hogs" equipment or refuses to try new technology
Demonstration of the Traits of a Scientist	Consistently models skills reflected in each of the SEP practices	Consistently models skills reflected in most of the SEP practices	Consistently models skills reflected in some of the SEP practices	Does not model skills reflected in the SEP practices
Total				

Total Points Earned: _____

Comments:

Performance Rubric

Criteria Points Earned	Exceeds Expectations 3 points	Meets Expectations 2 points	Needs Encouragement 1 point	No Effort or Uncooperative 0 points
Preparation	Ample examples of factual information for presentation; well organized and documented; provided positive leadership; an exemplar for all research teams	Adequate examples of factual information for presentation; organized and generally well documented; well received by teams	Barely enough factual information to participate in presentation; poorly organized; little documentation; difficulty relating to other team members	Incomplete factual information; little evidence of organization or prior planning; unable to participate in presentation
Content	Complete, clear, factual inclusion of content including information about most facets of the student's focus	Clear, factual inclusion of content including information about several facets of the student's focus	Attempted to provide some content; incomplete or incorrect inclusion of some of the content	Inadequate information included; contains significant errors and/or omissions
Presentation	Clear evidence of participation in some form in every team focus; all parts well planned; strong portrayal of the unique special interest of team	Evidence of participation in the majority of team focus; good planning and execution; special interest of team is evident in the effort.	Participation by only one or two aspects of team focus; little evidence of planning; special interest of team not clearly presented	Presentation contribution not completed; unable to participate in presentation
Forum	Final tangible product is technology-based;	Final tangible product is technology-	Final tangible product is not technology-	Final tangible product is not adequately

	excellent use of data; clearly well designed to provide solution to dilemma or question	based; good use of data; solution to a dilemma or question is apparent.	based; poor use of data; some effort to offer a solution to a dilemma or question	formed; little to no effort to offer a solution to a dilemma or question is evident.
Total				

Total Points Earned: _____

Comments:

Science and Engineering Practices Rubric

Asking Questions and Defining Problems	1	2	3	4	5
Asking questions based on observations	Questions reflect thinking about a change in variables.	Questions are asked to seek additional information about/clarify phenomena, models or results of an investigation or design solution.	In addition, questions are also asked to clarify evidence used in an argument.	In addition, questions are asked to determine relationships between independent and dependent variables or relationships in models.	Questions link to unexpected results and seek to clarify information, understand relationships and refine models, explanations or problems.
Asking questions that can be answered by an investigation	Questions can be identified as scientific and nonscientific. Questions can be investigated and used to predict outcomes.	Questions require evidence to answer.	In addition, questions are investigated and a hypothesis can be written.	In addition, questions can be investigated and a hypothesis can be written based on observation and scientific principles.	Questions focus on whether an investigation is relevant, doable and result in a hypothesis that is based on a model or theory.
Challenging through questions	Questions are asked about phenomena.	Questions are formed as a response to arguments.	In addition, questions challenge arguments.	In addition, questions challenge data sets used to support arguments.	Questions challenge arguments, data sets or designs.
Defining a problem	Prior knowledge is used to describe a simple problem that can be solved through the development of an object, tool, process or system. The problem includes criteria for success and constraints on solutions.	A design problem can be defined and solved through the development of an object, tool, process or system that includes criteria and constraints.	A design problem can be defined and solved through the development of an object, tool, process or system that includes criteria and constraints backed by scientific knowledge.	A design problem can be defined and solved through the development of an object, tool, process or system that includes criteria and constraints backed by scientific knowledge and limitations.	The problem involves the development of a process or system with interacting components and includes criteria and constraints that include social, technical and environmental considerations.

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Developing and Using Models	1	2	3	4	5
Developing model(s) to describe phenomena	Model describes mechanisms and/or phenomena using little to no key content vocabulary. The model is limited due to lack of evidence.	Model is used to describe some mechanisms and/or phenomena using some key content vocabulary. Model is limited, yet has several pieces of evidence.	Model is used to describe mechanisms and/or phenomena using some key content vocabulary and observable and unobservable evidence.	Model is used to describe unobservable mechanisms and/or phenomena using key content vocabula*ry* and observable and unobservable evidence.	Model is used to describe unobservable mechanisms and/or phenomena using key content vocabulary and observable and unobservable evidence. Model explains relationship within the system.
Analysis of model(s)	Model is not explained; it is only developed.	Model attempts to explain the benefits and limitations but lacks sufficient ideas or evidence.	Model explains the benefits and limitations of the system.	Model evaluates the limitations of the system. Model provides the benefits and limitations of one model.	Model evaluates the limitations of the system. Model provides the benefits and limitations of two different models.
Using models to predict phenomena	The model does not predict phenomena	The model inaccurately predicts phenomena.	The model attempts to predict phenomena.	Model predicts phenomena but doesn't define specific areas that lend themselves to predictions.	Model clearly defines the areas of the system that lends itself to predict phenomena
Using models to communicate ideas	Student communicates what they modeled lacking the reasoning and process.	Student shares in small group the reasoning and process behind their model.	Student shares with the whole class the process and reasoning behind the model only.	Students are able to answer questions about the model when asked to present to the whole class.	Student shares advantages and disadvantages of the model with the whole class and is able to answer questions about the model.
Modeling for data	Model lacks sufficient data.	Model uses data but is inaccurate.	Model demonstrates use of data during the investigation.	Model clearly demonstrates data used during the investigation.	Model clearly demonstrates data used during the investigation and suggests data missing or other pieces of data to make the model more comprehensive.

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Planning and Carrying Out Investigations	1	2	3	4	5
Hypothesis	Hypothesis is made based on limited knowledge of the purpose of the investigation.	Hypothesis is logical and made based on knowledge of the purpose of the investigation.	Hypothesis also includes reasoning for claims made.	Hypothesis also includes predictions for changes in variables.	Hypothesis also includes models and explanations of scientific principles and theories.
Procedure	Follow a step-by-step procedure. Evaluate tools needed and number of trials needed.	Create, with assistance, and follow a step-by-step procedure, including tools needed and number of trials needed.	Create and follow a step-by-step procedure, including tools needed, number of trials needed and measurements of materials.	Create and follow a step-by-step procedure, evaluate tools needed, number of trials needed and measurements of materials.	Create and follow a step-by-step procedure, including tools, number of trials and measurements needed. Consider environmental and social impacts.
Variables	Controls and constants are identified as well as the number of trials needed to conduct a fair investigation.	Independent and dependent variables are identified as well as controls and constants; identifications are accurate less than 50% of the time.	Independent and dependent variables are identified as well as controls and constants; identifications are accurate 70% of the time.	Independent and dependent variables are identified as well as controls and constants; a variable is added when needed.	Independent and dependent variables are identified as well as controls and constants; variables are manipulated when appropriate.
Data	Data is collected when following a procedure.	Data is collected when a procedure is developed but is not always accurate or logical.	Data is collected when a procedure is developed and is accurate or logical; data cannot be used as evidence to support a claim.	Data can be used as evidence to support a claim.	Data can be used as evidence to support a claim; limitations on data collection are considered.
Results	The investigation results can be used to explain a model, tool or processes.	The investigation results can be used to determine improvements to any part of the investigation.	The investigation results can be used to determine improvements to any part of the investigation under a range of conditions; results are used to back up a claim.	The investigation results in a claim that includes data evidence and proven scientific theories and principles.	The investigation results in a claim that includes data evidence and proven scientific theories and principles; the investigation results can be used to make predictions and explain other phenomena.

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Analyzing and Interpreting Data	1	2	3	4	5
Using graphs	Graph data to show patterns and relationships.	Interpret data and graph to show linear and nonlinear relationships.	Graph data to show linear and nonlinear/ temporal and spatial relationships. Identify causal and correlational relationships.	Use data as evidence in explaining phenomena.	Use tools, technologies and models to analyze data and make scientific claims or choose a design solution.
Using math to interpret data	Use data to make sense of phenomena.	Use statistics to interpret data.	Use statistics and probability to interpret data.	Use statistics and probability to interpret data; use digital tools.	Use statistics and probability to answer questions and solve problems; use digital tools.
Limitations of data analysis	Identify what a source of error is and the effects it may have on data.	Identify a source of error within an investigation.	Identify a source of error within an investigation and identify improvements in tools or methods of gathering data.	Identify sources of error and identify improvements in tools and methods of gathering data.	Identify multiple sources of error and explain how this may affect data results.
Comparing data	Compare and contrast data from different groups to find similarities and differences in the results.	Analyze data from an investigation to determine similarities or differences in the results.	Analyze data from an investigation to determine similarities and differences in the results.	Analyze data from several investigations to determine similarities and differences in the results.	Compare and contrast several types of data sets to determine consistency of measurement and observation.
Results	Analyze data to determine if a design solution is effective.	Identify the data needed to determine if the design (object, tool or process) meets the set criteria for success.	Analyze data to determine if the design (object, tool or process) meets the set criteria for success.	Analyze data to determine if the design (object, tool or process) meets the criteria for success; identify the criteria needed for success.	Evaluate the impact of new data on a working explanation or process; analyze data to identify design features that could be improved.

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Using Mathematics and Computational Thinking	1	2	3	4	5
Quantitative and qualitative data	Identify the difference between qualitative and quantitative data.	Decide when to use qualitative and quantitative data.	Collect qualitative and/or quantitative data.	Identify reasons why data collected is not valid.	Decide when to use qualitative and quantitative data when deciding the best solution.
Patterns	Organize data sets to show a pattern.	Group data sets appropriately to see a few similar patterns.	Group data sets appropriately to see a variety of different patterns.	Use digital tools to show patterns in large data sets.	Use patterns to create a model or simulation that can predict a phenomena, design, process or system.
Using graphs	Graph quantities such as area, volume, weight and time to answer questions or solve problems.	Identify correct mathematical representations needed to support a claim or design a solution.	Correctly display mathematical representations needed to support a claim or design a solution.	Use mathematical representations to support scientific conclusions and design solutions.	Use mathematical, computational and/or algorithmic representations to design solutions, support claims and support evidence.
Using quantitative and qualitative data	Use data displayed in graphs and charts to compare two design solutions.	Use math concepts create a solution to engineering problems.	Use digital tools to test and compare solutions to design problems.	Create algorithms to solve a problem.	Use algebra to solve engineering problems; identify whether or not a model makes sense by using math; use math to solve measurement problems with compound units.

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Constructing Explanations and Designing Solutions	1	2	3	4	5
Constructing Explanations	The explanation includes a model but lacks sufficient data.	The explanation includes a model that uses quantitative and/or qualitative data. The explanation does not include a relationship between variables and/or does not predict phenomena in the explanation.	The explanation includes a model that uses quantitative and/or qualitative data. The explanation includes some relationships between variables but does not predict phenomena in the explanation.	The explanation includes a model where quantitative and/or qualitative data is defined. The explanation includes the relationships between variables but does not predict phenomena.	The explanation includes a model where quantitative and/or qualitative relationships between any variable are defined and explained and predicts and/or describes the phenomena.
Constructing Scientific Explanations	The scientific explanation includes explanation of phenomena but includes no evidence.	The scientific explanation does not have sufficient evidence.	The scientific explanation includes evidence, but the evidence lacks validity and logic.	The scientific explanation includes valid and reliable evidence from sources, including the students' own investigations or models.	The scientific explanation has been revised; the explanation includes valid and reliable evidence from sources including the students' own investigations or models.
Applying Scientific Ideas or Principles	Student attempts to apply scientific ideas or principles to a new situation or process.	Student applies scientific ideas to test a design of a tool or process only.	Student applies scientific ideas to show why the data and evidence is adequate, but does not use the scientific ideas appropriately.	Student applies scientific ideas or principles to construct and/or use the explanation for real-world examples. Student applies scientific ideas or principles to construct a design.	Student applies scientific ideas or principles to revise and/or use the explanation for real-world phenomena. Student applies scientific ideas or principles to improve a design.
Designing a Project	Student generated multiple solutions to a problem but did not plan or carry out the design process.	Student planned but did not construct a design to a proposed solution.	Student created a project to implement a solution given by the teacher and teacher set the criteria for the design.	Student created a project to implement a student-developed solution that meets specific criteria set by the teacher.	Student designed a solution to a complex problem using scientific knowledge, evidence and prioritized criteria set by the student.

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Engaging in Argument from Evidence	1	2	3	4	5
Comparing and Contrasting Arguments	Identifiy the similarities and differences of the viewpoints only.	Compare and contrast two arguments based on facts only.	Compare and contrast two arguments based on evidence and facts presented.	Compare and critique two arguments of the same topic and analyze whether the two arguments have similar or different evidence or interpretations of facts.	Compare and critique two arguments with new evidence and analyze whether the two arguments have similar or different evidence or interpretations of facts.
Counterclaim	Student respectfully poses a question based on evidence or their personal knowledge.	Student respectfully provides critiques on the procedure of the investigation by citing evidence. The evidence may or may not allow for elaboration.	Student respectfully provides critiques on models only by citing relevant evidence and poses questions that allow for elaboration and detail.	Student respectfully provides critiques on models and explanations by citing relevant evidence and poses questions that allow for elaboration and detail.	Student respectfully provides critiques on scientific arguments by challenging ideas and conclusions. Additional information is given/identified to resolve a contradiction to the argument.
Oral or Written Arguments	The oral or written argument only offers a cause and effect relationship between observed phenomena and the proposed explanation.	The oral or written argument is supported by either prior knowledge or data.	The oral or written argument is based on empirical data only to support and refute an explanation or model.	The oral or written argument is based on empirical data as well as scientific principles to support and refute an explanation or model.	The oral or written argument is created to support or refute a model or phenomena based on evidence and data. A counter argument based on evidence and data is created.
Evaluating Competing Design	Student is able to make a claim about the effectiveness an object, tool or solution using evidence.	Student is able to make a claim about the value or importance of a solution to a problem by citing relevant evidence.	Additionally, the student is able to explain how the solution fits and meets the criteria as well as the limitations of the solution.	Student creates an independent claim that supports or refutes a solution, tool or process by citing evidence; the claim meets the criteria and the limitations of the solution.	In addition, the student is able to use evidence from other relevant factors: economic, societal, and ethical considerations.

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Obtaining, Evaluating, and Communicating Information	1	2	3	4	5
Obtaining information	Student is able to summarize a complex text to describe how the text is supported by evidence.	Student is able to combine information from complex texts such as tables, diagrams and/or charts to explain phenomena.	Student is able to summarize complex texts and other reliable media to explain how the technical ideas are supported through evidence presented in the texts.	Student is able to combine information from multiple sources to explain the purpose of the reading and explain how the texts use valid and accurate evidence.	Student can critically read scientific texts and is able to paraphrase the texts accurately; they can determine if the technical information presented describes patterns; student is able to provide evidence of the patterns.
Evaluation of information	Student is able to describe how specific images or diagrams support a scientific idea or engineering idea.	Student is able to compare and contrast two complex texts to support a scientific idea or engineering idea.	Student is able to compare and contrast complex texts and other media to support a scientific idea or engineering idea.	Student is able to read and synthesize information from multiple sources. In addition, the student can assess the credibility and bias of each publication to describe how they are supported or not supported by evidence	Student is able to evaluate data, hypotheses and conclusions in scientific and technical texts. Also, the student is able to identify other sources that could refute the given information.
Communicating information	Student communicates to their peers about the development and design of an object, tool or scientific process in a written format only. The student uses multiple formats (media and text) to effectively communicate.	Student communicates to their small group about the development and design of an object, tool or scientific process in a written format only. The student uses multiple formats (media and text) to effectively communicate.	Student communicates to the whole class information about the development and design of an object, tool or scientific process in a written format only. The student uses multiple formats (media and text) to effectively communicate.	Student communicates to the whole class information about the development and design of an object, tool or process in a written report) and through an oral presentation. The student uses multiple formats to effectively communicate.	Student analyzes and communicates to the whole class information about the development and design of an object, tool or process other than his/her own in a written report and through an oral presentation. The student uses multiple formats to effectively communicate.

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Ecology and the 5E Instructional Model

The ecology curriculum at Fermilab, *Energy and Ecosystems: Prairie, Water and Woods*, subscribes to the constructivist approach to science education through its commitment to set up real-world, researchable problems and/or scenarios for students to explore. Students are encouraged to formulate research questions by first becoming familiar with environmental topics and applying this knowledge base to contemporary questions. The role of the instructor is to support student exploration by presenting real-world issues, encouraging inquiry, monitoring progress, and promoting new ways of thinking.

Activities within this curriculum are hierarchical in nature, offering skill building and the opportunity to use prior knowledge as a foundation for new learning. The exploration topics investigate abiotic and biotic forces in the natural world with the ultimate goal of better understanding the interactions and relationships of the organisms at Fermilab and throughout Northern Illinois.

Fermilab provides rich databases to enhance the student inquiry process. These resources provide opportunities to compare and contrast contemporary and archived field data, some of which spans over 20 years. These raw data banks are primary sources, reflecting longitudinal data stores that are fully accessible for student use. Students, in the role of citizen scientists, also have the opportunity to add to the databases. Their efforts will enrich and strengthen the body of knowledge needed by onsite field ecologists. As of 2016, the most prolific database is prairie related. Student researchers have contributed to the prairie data since 1993. While prairie data will still be collected, Fermilab ecologists now also need species data from the wetland and woodland areas. As restoration in these areas continues, surveys showing evidence of progress are critical. The opportunity for research questions that originate as the result of these new data collections is limitless.

To best prepare the student for the research experience, investigations throughout the curriculum are designed around the 5E Instructional Model and facilitate opportunities to build on prior knowledge, construct new understandings and monitor their own understanding of the concepts. Its five components each signify a stage in the learning process. These stages include:

Engage: Pulls students into the topic/experience by making real-world connections with the targeted concept. Whether a compelling question, interactive exercise, short video clip or relevant current event, students have the opportunity to activate prior knowledge, react to situations or conditions, generate questions and provide a context for learning.

Explore: Strengthens the student research teams by providing a common experience that will benefit further investigation. Depending on the activity, students may actively clarify concepts, learn skills, work with new materials or use familiar materials in a new way.

Explain: To ensure understanding, students have the opportunity to explain the exploration's concepts by interactive activities, journaling, discussion/debate and data collection, interpretation, analysis and conclusions. Teachers may augment by providing resources for terminology, skills, and scientific dispositions as well as identify misconceptions and clarify concepts.

Elaborate: Practical applications and extensions of the target concepts further strengthen conceptualization by putting skills into practice. Students are actively involved in tasks, some of their own design, that deepen and broaden their understanding/s. These tasks include skill building, field study (research, questioning, data collection and analysis, conclusions), ecosystem services research components, scientific writing, web links, and discussion/debate.

Evaluate: Throughout the investigations, students self-evaluate as they reflect on and respond to formative assessments. Teachers continually monitor student progress. Summative assessments appear in the form of student pages, projects and/or research-based investigations. Capstone assessments focused on student inquiry are topically based.

NGSS and Common Core Links
http://ngss.nsta.org/making-connections-common-core.aspx

What Makes an Essential Question?
http://www.ascd.org/publications/books/109004/chapters/What-Makes-a-Question-Essential%A2.aspx

Public TV station WGBH in Boston explains the constructivist approach to teaching science using the 5-E format.
http://enhancinged.wgbh.org/research/eeeee.html

NASA – 5Es Overview
http://www.nasa.gov/audience/foreducators/nasaeclips/5eteachingmodels/

Ecosystem Services

Throughout civilization, there are certain aspects of the natural world toward which humans gravitated to settle. These traditionally are areas with access to water, shelter and food sources. Not much has changed over the thousands of years that humans have walked the earth. Water, shelter and food remain survival staples. Consider the location of many of the world's greatest cities in proximity to oceans, large lakes and rivers.

Particularly in the last 150–200 years, considerable human innovation has altered the natural plan in developed countries. Due to these innovations, including modern transportation modes and what we now consider to be business and household necessities, many humans are more and more separated from the natural places. This separation can serve to insulate humankind from the power and especially the value of the natural world. Without proper functioning of ecosystems within our natural world, life as we know it could perish in a frightfully short time. We are directly reliant on ecosystem services.

Ecosystem services are defined as the important benefits for human beings that arise from healthy functioning ecosystems (Costanza, 1997). Broad benefits of ecosystem services include:

- Gas regulation (production of oxygen and carbon dioxide needed for photosynthesis and respiration)
- Climate regulation (Transpiration by plants helps regulate temperature and relative humidity.)
- Disturbance regulation (storm protection/flood control/erosion buffer)
- Water regulation (natural filtration and flood control; water cycle)
- Erosion control/sediment retention (Root systems hold soil in place; plants block wind.)
- Soil formation (Decomposition/Detritus processing add nutrients to form rich, organic soil.)
- Nutrient cycling** (storage of food nutrients and minerals, nutrient cycling, biochemical breakdown)
- Waste treatment** (recovery of mobile nutrients and removal of xenic/toxic substances; natural areas offer filtration mechanisms to keep the environment clean.)
- Pollination (fertilization of plants essential to life on Earth)
- Biological control (trophic dynamic relationships/keystone species; food chains/food webs)
- Refugia (habitat for migration/visiting species)
- Food production (Native plants and animals are food/medicine sources; commercial farming)
- Raw materials (biofuels; hemp fiber; multitudes of uses for native plants and animals including medicinal value)

- Genetic resources** (medicine; restoration/gene pools; improved crops)
- Recreation* (What's not to love about playing/hiking/camping/fishing . . .?)
- Culture* (revival of Native American uses of natural area flora and fauna for crafts, medicine, dyes, fine art, musical instruments, etc.)

*N/A within NGSS context
**Concepts beyond middle level

NOTE: Examples are **not** inclusive. Many other advantages may be considered within this context.

Costanza, R. et al. "The value of the world's ecosystem services and natural capital." *Nature.* Vol. 387. 15 May 1997, pp. 252-260.

Habitat Communities of the Fermilab Site
Ryan Campbell

Known for its international role in particle physics research and accelerator science, Fermilab has a more local side to it; the land. Surrounding us, former farmland has filled in with suburbs and shopping centers, busy roads and growing cities. Fermilab has remained a tranquil oasis, a quiet refuge known by many local citizens as a haven with trails, quiet streets, coyotes and wildflowers everywhere you look. Indeed the rich mosaic of remnant habitats, coupled with the aggressive prairie restoration program, has created a very nice place to work and visit. These habitats continue to be restored for biodiversity and ecosystem function.

The classifications scientists use to describe natural communities give a short, simple name to a very complicated thing. When we talk of "oak savannas" or "tallgrass prairies," we are referring to communities that may include hundreds of species of plants, and—when you add up all the beetles, spiders, snails, and centipedes—thousands of species of animals. When we study a natural area and decide what communities are present, we look at the entire biota, historic evidence and abiotic factors.

The land within the boundaries of Fermilab has everything from agriculture to lakes, prairies, swamps, oak savannas and sedge meadows. It is a microcosm of many ecosystems found in the Midwest. We categorize these areas by community type to determine how to best restore and maintain them. At Fermilab, habitat community types follow classifications found in the Chicago Wilderness Terrestrial Community Classification System (CWBRP, 1999) and Plant Communities of the Midwest: Illinois subset document (Faber-Langendoen, 2001).

To preserve or restore these habitats at Fermilab, they need to be managed. The following sections describe the various habit community types and refer to some of the land management units that represent that community type. Overarching habitat community goals at Fermilab include:

- Establish 50 as the minimum floristic quality index target for all land management units (LMU).
- Control rampant invasive species to less than 5% total cover per LMU; eradicate small populations and new invaders.
- Use appropriate fire return interval as dictated by time since restoration (restorative fire vs. maintenance fire).

Tallgrass Prairie

Tallgrass prairie communities are dominated by grasses intermixed with abundant forbs on mineral soil. Trees and shrubs may be present, but less than 10% of the area has a tree or shrub canopy. Soils are deep and fine-textured—usually silt loam or clay loam derived from loess or glacial till. This includes the typical, “black-soil” prairies.

Topography varies from level to moderately sloping and soil moisture ranges from dry to wet. The tallgrass prairie ecosystem has suffered extreme losses throughout its range since European settlement, with 99.9% being lost in the prairie state—Illinois (Sampson and Knopf, 1994). Wet and mesic tallgrass prairies are critically imperiled globally.

Fermilab has two remnant tallgrass prairie areas, each less than 3 acres. Nearly 1,000 acres of tallgrass prairie ranging from mesic to wet is being restored. Floristic quality index in tallgrass prairie ranges from 29 to 72. Invasive plant species affecting tallgrass prairies at Fermilab include white sweet clover, reed canary grass, crown vetch, bird's foot trefoil and teasel. Prescribed fire should be carried out every 1–3 years to maintain tallgrass prairie communities (Betz, 1986; Betz, 1999; Bowles and Jones, 2013).

Old-Field Grassland

Non-prairie grassland communities are generally described as old fields and have become established on fallow agricultural fields or where pasture grasses were planted. These grasslands are composed of non-native, cool-season grasses, such as orchard grass, tall fescue and Hungarian brome, with occasional forbs and annual weeds. These communities can also include invasive species such as crown vetch, field thistle, and tall goldenrod. Soils are typically disturbed clay-loam with medium soil moisture. Because of the short stature of the vegetation, some native grassland birds nest in old-field grasslands. A varied approach to managing old-field grasslands in order to optimize habitat structure would include grazing, mowing, haying and occasional prescribed burning. Native prairie plant species can be introduced to increase pollinator resources.

The Eola Road grasslands, totaling 500 acres, are the primary old-field grassland habitat at Fermilab. These grasslands are mowed yearly to maintain this habitat.

Shrubland

Shrublands are an important intermediary successional community. Shrubs, as the name suggests, dominate the canopy while small trees, snags, grasses and herbaceous vegetation also contribute to the dynamic structural composition. Historically, shrublands were transitional habitats, succeeding to woodlands or, with drought-induced frequent fire, becoming shrubby prairies. Shrubland communities are a shifting mosaic across the landscape and their structural uniqueness is important for many types of wildlife, especially birds.

Many small parcels of shrubland exist at Fermilab, mostly adjacent to woodlands and savannas, but also in wetlands. Soil moisture determines the dominant shrubs present. Dry-mesic shrublands can be composed of grey dogwood, hazelnut and American plum, while blue-fruited dogwood, meadowsweet, and sandbar willow might dominate in wet-mesic shrublands. The Sparrow Hedge area is mostly classified as unassociated woody growth. These areas support a variety of weedy native and non-native trees and shrubs, such as box elder, grey dogwood, common buckthorn, autumn olive, and American plum. While plant composition is not highly desirable, the structural

heterogeneity is excellent for nesting and migrating shrubland birds. Prescribed fire should be carried out every 3–5 years to maintain this successional community.

Oak Savanna
Large-diameter trees, primarily bur and white oak, dominate the oak savanna community type. These trees are widely spaced and create only 10–50% canopy cover. This mosaic of sun and shade generates an environment where prairie and forest plants can grow together amongst a suite of unique species designated as savanna plants (Packard, 1988). A savanna may have shrubby areas and has soils that are transitional between forest and prairie. Less than 2% of savanna communities remain intact in the Midwest (Nuzzo, 1986), though efforts to restore this distinct ecosystem have been expanding (Packard and Mutel, 2005). Oak savannas are critically imperiled systems globally (Faber-Langendoen, 2001).

Fermilab has three distinct oak savannas on site, yet there is evidence that many of the current woodland parcels were open-grown savannas prior to European settlement (observation, 1939 aerial photographs and original land surveyors' notes). This is most apparent in several wet woodlands harboring relict swamp white and bur oak canopy trees. Floristic quality index in oak savannas at Fermilab ranges from 34 to 57. Invasive plant species affecting oak savannas include: buckthorn, honeysuckle, oriental bittersweet, reed canary grass, crown vetch, and smooth brome. Prescribed fire should be carried out every 2–3 years to maintain oak savanna communities (Packard and Mutel, 2005; Campbell, 2010; IFNA, 2016).

Woodland
Woodlands are less dense than forests but have greater stems per acre than the oak savanna community type. A conservative woodland shrub and herbaceous layer may be present in the best quality remnants, with a diversity of spring ephemerals. Soils can be deep and loamy and hydrology ranges from dry-mesic to wet-mesic. Vernal pools may also be present in woodlands. In the absence of fire, many woodland areas became forest communities after European settlement. Such sites can be most easily recognized by failure of the canopy tree species (e.g., oaks and hickories) to reproduce, with few, if any represented, in the seedling or sapling layer. This is because they are not shade-tolerant (light-limited). High-quality woodlands are imperiled systems globally (Faber-Langendoen, 2001).

Fermilab has several woodland communities on site in all moisture gradients (Big Woods South, Big Woods North, Owl's Nest Woods and Kingnut), with the potential for more by thinning a number of current forests. The mesophytication of woodlands throughout the Midwest has created an abundance of dense, shaded forests. At Fermilab, this is most apparent in the Big Woods, which was a mosaic of open woodland and savanna, but is now a closed-canopy forest. Management of woodland communities is aimed at maintaining diversity and structure while restoring natural light levels to the understory. Many times canopy thinning or invasive species removal has resulted in spontaneous growth of conservative woodland plants. Floristic quality index in woodlands at Fermilab ranges from 29 to 66. Invasive plant species affecting

woodlands include buckthorn, honeysuckle, Japanese barberry, oriental bittersweet, multiflora rose, garlic mustard and reed canary grass. Low-intensity fires should be carried out every 2–3 years to maintain woodland communities (Faber-Langendoen, 2001).

Forest

The forest community class is dominated by trees, with an average canopy cover of greater than 80%. Forest communities have a multi-layered structure composed of the canopy, sub-canopy, shrub, and herbaceous layers (CWBRP, 1999). Soils can be deep, loamy and dry (upland forest) to saturated and anoxic (floodplain forest or flatwoods). Forests are typically developed in the "fire-shadow" of large rivers, lakes or wetlands or in the floodplain of rivers and streams. Fire intensity was typically low and frequency was less than woodlands or savannas. Canopy tree species are well represented in varying age classes from seedling to canopy-sized individuals. High-quality forest communities are imperiled systems globally (Faber-Langendoen, 2001).

Fermilab has many forest parcels in all three subcategories. Sugar maple, white and red oak, basswood and cherry trees dominate upland forests. Examples include Ed Center Woods and Morgan's. Floodplain forests are found adjacent to streams at Fermilab and are dominated by silver maple, swamp white oak, cottonwood and green ash. Examples include Indian Creek Woods and Giese Woods. Flatwoods occur on level soil and have a perched water table. This community type seems to merge with wet-mesic forests. Floristic quality index in forest communities ranges from 17 to 71. Buckthorn and honeysuckle are the two primary invasive plant species severely affecting biodiversity in forests while others include: reed canary grass, autumn olive, Japanese barberry and garlic mustard. Prescribed fire should be carried out every 3–5 years to maintain forest communities; however, annual burning should occur for several years after restoration to discourage invasive species and promote native community recovery.

Sedge Meadow

Sedge meadows are sedge-dominated wetland communities with wet prairie grass co-dominants on saturated soils. Sedge meadows are characterized by their dense groups of tussock-forming sedges, which often grade into shallowly, flooded marsh edges. Typical species include a diversity of sedges (*Carex* spp.), blue-joint grass, spike rushes, great angelica, sneezeweed, and boneset. Rare wetland birds and invertebrates (e.g., butterflies and odonates) can be found in remnant sedge meadows. *Phragmites*, reed canary grass and purple loosestrife are typical invasive species in sedge meadows. Frequent fire is recommended to retain the open structure of a sedge meadow (CWBRP, 1999). Fermilab has a restored sedge meadow, which is part of the wetland mitigation.

Basin Marsh

Marshes are seasonally flooded or inundated wetlands with a mix of grasses, sedges, reeds and aquatic plants. Depth of basin, fire frequency, and herbivore activity determine vegetation structure and water levels. Variations in groundwater levels, surface runoff volumes and annual precipitation cause wetlands to experience complete

drawdown periods, sometime lasting years, to periods of partial or total annual inundation. Marshes mostly develop in glacial kettle basins, potholes or swales typically within a larger prairie complex. Typical plants include: soft-stemmed bulrush, river bulrush, dark green bulrush, bur reed, cattail, sweet flag, swamp milkweed, arrowhead and smartweeds. Invasive species that should be controlled are the same as in sedge meadow communities. Marsh habitats can be burned every few years to retain herbaceous vegetation and limit shrub growth.

Nepese Marsh and several of the lakes such as A.E. Sea, Dusaf Pond and the Sea of Evanescence on the east side of Fermilab are examples of marsh habitat at Fermilab.

Open Water

Lakes and ponds represent open water habitat communities at Fermilab. Open water communities have submerged, emergent and shoreline vegetation that can provide important microhabitat structure for aquatic wildlife such as fishes, mussels, snails and other invertebrates. Most open water at Fermilab is also vital to Laboratory operations as part of the Industrial Cooling Water system. Invasive species occurring in open waters are zebra mussels, *Phragmites*, reed canary grass, and purple loosestrife.

Lake Law, Swan Lake and Main Ring Lake are some examples of open water habitat at Fermilab.

Moving Water

Moving waters of the Chicago region are divided into several size categories, two of which are found at Fermilab. The smallest of these is the headwater stream, a tiny creek that may flow only intermittently. Indian Creek and Ferry Creek are examples of headwater streams at Fermilab. Low-order streams, such as Kress Creek, are small- to medium-sized creeks whose bottoms have been shaped by the water to produce riffles and pools, alternating sections of fast shallow water and slow deep water. Riparian buffers and adjacent wetlands can be important to maintaining biodiversity in moving water communities by reducing nutrient and sediment loads and providing structure for aquatic wildlife. Invasive species occurring in open waters are zebra mussels, *Phragmites*, reed canary grass and purple loosestrife.

What is an Ecosystem?

How do abiotic factors affect biotic factors in an ecosystem?

Topic: To discover prior knowledge of ecosystems and ask questions for further research

Brief Lesson/Lesson Set Description:
Students identify what they know and what they would like to know more about as they begin to look at ecosystems. Utilizing a grouping strategy, students brainstorm prior understandings about ecosystems. This is a whole class activity designed to create a common base upon which to build accurate knowledge. Through the process, topical categories will emerge, providing insight into misconceptions and/or inaccurate information about ecosystems.

Science and Engineering Practice: Asking Questions and Defining Problems

Crosscutting Concept: Patterns

INVESTIGATION

Objectives: Students will:

- Assume ownership of the unit by establishing learning priorities.
- Rank priorities allowing this list to become a base for cooperative learning group investigations.
- Select organisms to be studied within the *Particles and Prairies* research component (optional).

Narrative/Background Information:
This activity is meant to uncover the background information that students have. It is a valuable schema-building activity that will fulfill its objective in any discipline. You may wish to invite another academic teacher to use this activity as a cross-curricular experience. Students are asked to generate words/phrases that relate to ecosystems in general. Terms like plants and animals or weather and climate are typical. As the list grows, terms like encroachment or pollution may appear. Encourage participation by all class members. If a student is not an active participant in the list-building classroom exercise, encourage him/her to take a lead role in the group segment. Once a broad classroom list is produced and displayed, students in groups place the terms in exactly five named categories—no more, no less. A comparison will reveal similarities and differences and the class will agree upon five final topics.

Items/questions generated may be further scrutinized utilizing a KWHL strategy. (**KWHL:** What do you **K**now? What do you **W**ant to know? **H**ow will you research? What did you **L**earn?) Prior to facilitating this activity, the teacher should be familiar with ecosystem vocabulary.

Prior Student Knowledge Expectations:

- Basic vocabulary to describe ecosystems
- General differences between local ecosystems
- Willingness to contribute to class discussion and defend opinions regarding items and their placement.
- General understanding and acceptance of collaborative behaviors

Possible Preconceptions/Misconceptions:

- Define what it means to brainstorm so that all students share their answers and thoughts. Since this is a preliminary activity, preconceptions and misconceptions will be evident as the students discuss.
- A common misconception is that each ecosystem needs radically different resources, while other students believe that differing ecosystems need exactly the same resources. Neither is wholly true. As students learn to compare the attributes/requirements of specific organisms to varying ecosystem attributes/requirements, the concepts of adaptations, diversification and niche will clarify.

Vocabulary: biologist, biome, biosphere, biotic community, brainstorm, community, diversity, ecology, ecologist, ecosystem, environment, extinction, forest, habitat, organism, pond, prairie

Materials:

- Smart board or other mechanism for presenting class-generated lists
- Student recording sheet
- Scratch paper
- Pen or pencil

ENGAGE:

Brainstorm with your class by asking, “When you think of an ecosystem, what comes to mind?” Students will have seen the wolf video. Have posters of different habitats. Ask students what they notice in the pictures? Or since they will have seen the video, what stood out in the video?

EXPLORE:

Process:

1. This activity involves asking about the three focus ecosystems: the prairie, woodland and pond. Group students so that they focus on one only.
2. Accept all responses as valid and record responses for the class.
3. Continue until you have at least 40 responses, but let everyone have a chance to respond.
4. Instruct students to copy words onto scratch paper and individually separate their responses into no more than five labeled categories. Label the circles on their student worksheet. Remind students that their categories can be different from others. Do not allow a category to be named other or miscellaneous.

5. Separate the class into small groups. Each student will share their category lists and titles with the group. The group agrees upon five categories—no more. Ask groups to designate a recorder to fill out a student sheet for the team. Observing the group dynamic will give insight to possible research groups.
6. Reconvene class and ask all groups to share categories. List all topic titles for the class, eliminating duplicates. Allow no more than five categories. Instruct a recorder to fill out a final student sheet for the class.
7. Instruct each student to complete the Student Reflection sheet. Revisit this at the end of the unit so that students can see how their ideas of an ecosystem have changed.

EXPLAIN:
Engage students in a discussion using responses from questions 1–4 on the Student Reflection sheet.

ELABORATE:
When students complete the grouping, post the topical lists. Remarkably, these lists often relate directly with the studies to come. Refer to the lists when a direct hit occurs. This strategy validates the students' collective work and helps to make the pursuit a relevant and exciting challenge.

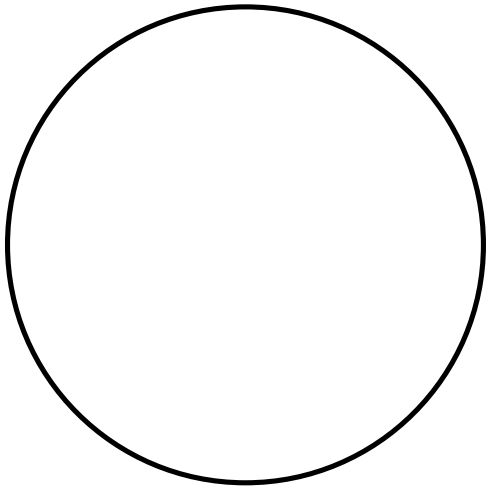
EVALUATE:
Formative Monitoring: Use Student Reflection questions for discussion throughout the investigation.

Summative Assessment: N/A

Elaborate Further/Reflect/Enrichment: Students may begin to formulate questions that can be answered throughout the unit. Teacher could group these questions according to the lesson set questions and refer back to them as they are answered throughout the unit.

Name: _____

What is an Ecosystem?



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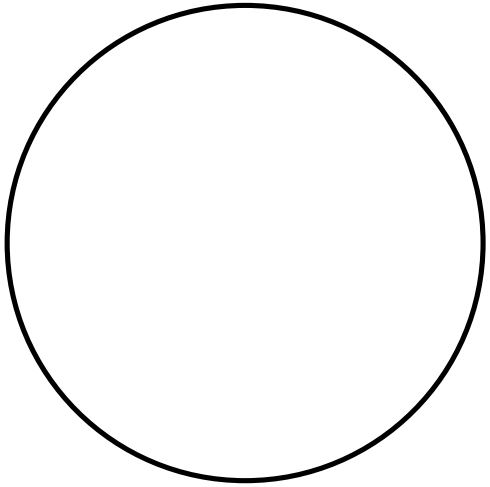

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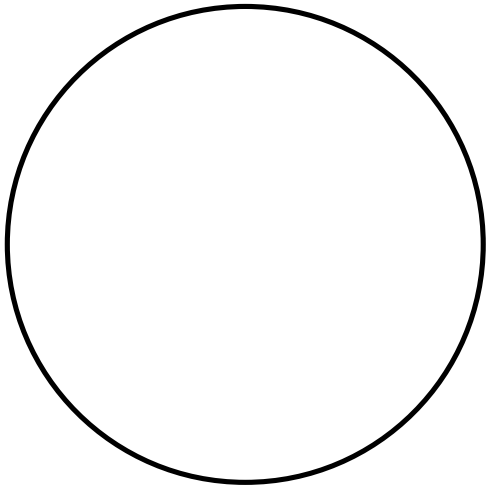

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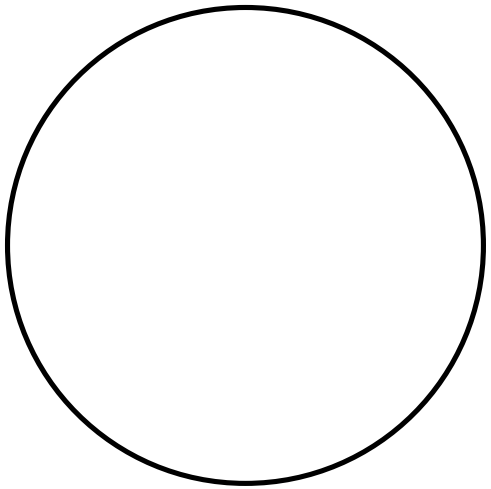

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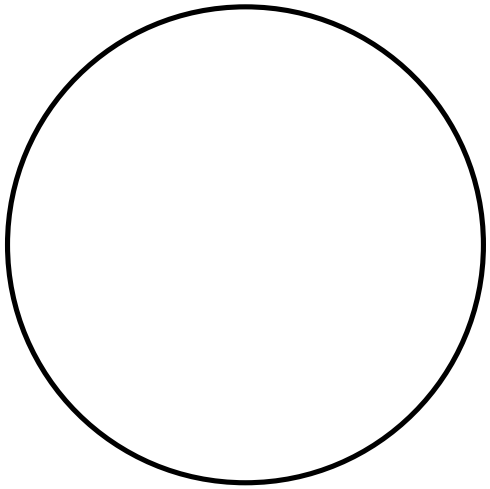

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Name: _____

Student Reflection: What is an Ecosystem?

1. During this activity, you gathered information and ideas about ecosystem from your classmates. How did you categorize the information?

2. What patterns do you notice as you classified the information from the class brainstorm?

3. How do classifying parts of an ecosystem help scientists conduct research?

4. How do classifying parts of an ecosystem help you conduct scientific research?

Write a short essay, compose a poem, or draw a picture depicting your vision of a prairie, forest or pond ecosystem.

Teacher Page

Student Reflection Suggested Responses: What is an Ecosystem?

1. During this activity, you gathered information and ideas about ecosystem from your classmates. How did you categorize the information?

   Students may recognize that ideas offered during the brainstorming session may not be correct. These ideas offer the collective knowledge of the class at the start of the unit. This offers an opportunity to see growth at the end of the unit as students compare their ideas after this activity and their ideas at the end of the unit; these ideas offer excellent opportunities for further study and research. Accept logical categorizations.

2. What patterns do you notice as you classified the information from the class brainstorm?

   Answers will vary. Emphasize the skill of noticing patterns.

3. How do classifying parts of an ecosystem help scientists conduct research?

   Answers will vary. Accept logical ideas.

4. How do classifying parts of an ecosystem help you conduct scientific research?

   Answers will vary. Accept logical ideas.

Write a short essay, compose a poem, or draw a picture depicting your vision of a prairie, forest or pond ecosystem.

Talk with students about how this artifact will represent their ideas before the learning in the unit. By comparing their ideas of what an ecosystem is at the end of the unit, students will see growth in content understanding and increase in their ability to participate in the practices of science.

Thinking Environmentally

How do abiotic factors affect biotic factors in an ecosystem?

Topic: To discover prior knowledge of ecosystems and ask questions for further research

Brief Lesson/Lesson Set Description:
Students will gain exposure to the interconnectedness within ecosystems.

Science and Engineering Practice: Obtaining, Evaluating, and Communicating Information

Crosscutting Concept: Systems and System Models

INVESTIGATION

Objectives: Students will:

- Know and apply concepts that describe how living things interact with each other and with their environment.
- Know and apply concepts that describe the interactions between the environment and society.
- Recognize and appreciate ecosystem services as they apply to humanity.

Narrative/Background Information:
"Humans are part of an incredibly complex and interdependent web of life, and we're just beginning to understand our place in it. We're beginning to realize how dependent we are on biodiversity for most, if not all, our needs. We're also beginning to realize that a significant loss of biodiversity could seriously undermine our long-term economic, intellectual, physical and emotional well- being. Why haven't we been more aware of biodiversity and its importance before now? The answer may be partly due to our loss of intimacy with other living things.

In many cases we've lost contact with the natural foundations on which our lives are built. Our ignorance of nature and the way it works may be catching up with us. The challenge now is to learn as much as we can to gain a new perspective on our place in the natural world, so that not only will we be better able to protect living things, but we'll also create a more sustainable and responsible society.

The diversity of life on earth shapes and nourishes every facet of our existence. But the connections between species are seldom obvious. Due to a variety of factors, biodiversity is rapidly declining. To ensure the long-term health of the planet, an informed and motivated citizenry needs to be developed that understands what biodiversity is and why it's important. Citizens are needed who have the skills and confidence to rise to the challenge of protecting biodiversity and who feel empowered to do so. Education is one of the best tools for achieving this goal.

In education, biodiversity is an important topic that encompasses many disciplines and provides real-world contexts and issues that promote critical- and creative-thinking skills, citizenship skills and informed decision-making. Biodiversity also illustrates the complexity of environmental issues and the many perspectives and much uncertainty connected with them." (*Illinois Biodiversity Basics,* Illinois Department of Natural Resources, 1999.)

These words were written many years ago and hold true today. Attitudes toward the environment and the appropriate uses of our natural resources have changes and will continue to change over time. In 1999, recycling was in its infancy.

Today, sophisticated systems are in play in many communities to more efficiently reclaim much of the waste we once took to the dump. Waste in some circumstances has become treasure. We know that within our ecosystems may be the answer to disease cures and longevity.

We also recognize the value of ecosystem services, which closely align with NGSS:

- Gas regulation (production of oxygen) – **MS-LS1-6; MS-LS2-3; MS-ESS2-4**
- Climate regulation – **MS-LS1-5; MS-PS3-4**
- Disturbance regulation (storm protection/flood control) – **MS-LS2-4; MS-ESS3-3**
- Water regulation – **MS-ESS2-4**
- Erosion control/sediment retention – **MS-LS2-4; MS-ESS3-3**
- Soil formation – **MS-LS2-3; MS-ESS2-4**
- Nutrient cycling** (storage, nutrient cycling, biochemical breakdown)
- Waste treatment** (recovery of mobile nutrients and removal of xenic/toxic substances)
- Pollination – **MS-LS2-4; MS-LS1-8**
- Biological control (trophic dynamic relationships/keystone species) – **MS-ESS3-3**
- Refugia (habitat for migration/visiting species) – **MS-LS2-1; MS-LS2-2**
- Food production – **MS-LS2-1**
- Raw materials (biofuels) – **MS-LS1-6; MS-LS2-3; MS-ESS2-4**
- Genetic resources**
- Recreation*
- Culture*

*NA within NGSS context
**Concepts beyond middle level

Therefore, we must keep this overarching question in mind: *How do abiotic and biotic factors work together to restore diversity, promote productive interactions/relationships and provide ecosystem services? Thinking Environmentally* will accentuate the interrelationships from organism to organism and abiotic factors.

Prior Student Knowledge Expectations:

- Basic vocabulary related to various ecosystems

- Familiarity with the most common plants, animals and abiotic factors within the ecosystem
- Basic understanding of needs of living organisms and the services they provide
- General understanding of collaborative behaviors

Possible Preconceptions/Misconceptions:

- We really do not need all those organisms.
- Underestimation of the diversity of a flourishing ecosystem and the role each organism plays
- Variety of interconnections between organisms
- Dependence on abiotic factors for basic needs/effects of changes

Vocabulary: animal community, biodiversity, conservation, interaction, interdependence

Materials (per student group):

- 30 – 3" x 5" notecards or cut paper per group of 3–4 students
- Larger cards/papers stating Prairie, Woodland, or Pond so that each group has an appropriate card
- Large newsprint pages or butcher paper to mount the cards
- Tape

ENGAGE:

Imagine that an event took place and you are the only organism alive. How long will you live? What do YOU need to survive? What do other organisms need to survive?

EXPLORE:

Process:

1. In a group of 3–4 students, brainstorm at least 30 biotic/abiotic factors present in a prairie, woodland or pond ecosystem. (If there are 27 students in a class, there will be three groups of three for each ecosystem.)
2. Each group will write an organism or factor on the cards until all 30 are represented: one organism or factor per card.
3. Distribute ecosystem cards and newsprint. Ask students to place the ecosystem title in the center and surround it with the smaller factor cards.
4. Instruct students to establish and indicate with arrows the relationships.
5. After groups are satisfied with their placements, have them tape the cards to the newsprint.
6. Bring same ecosystem groups together and ask them to compare their webs. Are they the same? Describe similarities and differences.
7. Share webs with the entire class. How do all of the ecosystem webs compare?

EXPLAIN:

Everything in nature is interrelated within an ecosystem and from ecosystem to ecosystem.

ELABORATE:
Ecosystem services for this exercise do not directly apply, but students will appreciate the interconnections that are evident. This exercise offers a strong correlation to adaptations and organism survival in changing conditions such as climate change, water availability, disturbance and biological control.

EVALUATE:
Formative Monitoring: Use Student Reflection questions for discussion throughout the investigation.

Summative Assessment: Students design an ecosystem.

Elaborate Further/Reflect/Enrichment: What further questions do students generate?

Name: _____

Student Reflection: Thinking Environmentally

1. The natural world is filled with relationships and interactions. How might the interconnectedness be altered? Which has the most potential impact on your web? (Nature on humankind?) Why do you believe this to be true?

2. Select an organism from your web. Which attribute(s) do you feel best distinguishes the organism? Why is this so?

3. Which organisms do you believe are closely genetically interrelated? Support your belief with observable evidence using a research tool such as http://a-z-animals.com/animals/.

4. Look for a similar factor across the ecosystem. Remove that factor from the webs. What do you believe will occur? Remove another. Now what?

5. Do the lists include people? Pollution? Fire? If not, speculate what effect they might have.

6. Why do we care? What ecosystem services does the ecosystem provide? Why are these services important?

Consider an environmental impact, such as a building project in the area, a long-term warming trend or change in annual precipitation. Suggest at least three ways that organism relationships will be stressed. What do you predict the outcome to be?

Teacher Page

Student Reflection: Thinking Environmentally

1. The natural world is filled with relationships and interactions. How might the interconnectedness be altered? Which has the most potential impact on your web? (Nature on humankind?) Why do you believe this to be true?

   Responses will vary. Thoughtful consideration of cause/effect is expected; abiotic conditions factor into relationships and interactions. Students may tap news stories and/or personal experience to respond, but responses should be based on confirmed evidence of environmental interactions.

2. Select an organism from your web. Which attribute/s do you feel best distinguishes the organism? Why is this so?

   Responses will vary. Expect students to key into adaptations that fulfill that organism's niche, such as feeding structures or means of attracting other organisms beneficial to them.

3. Which organisms do you believe are most closely genetically interrelated? Support your belief with observable evidence using a research tool such as http://a-z-animals.com/animals/.

   Responses will vary. The key thought is "most closely related." For example, mammals are more closely related to other mammals than to birds, but dogs are more closely related to wolves than to cats. Butterflies are more closely related to grasshoppers than to spiders. Organisms in the same class are acceptable as genetically more closely related than organisms related at the phylum level but not beyond.

   NOTE: The activity "The Key to the Keys" focuses on taxonomy.

4. Look for a similar factor across the ecosystem. Remove that factor from the webs. What do you believe will occur? Remove another. Now what?

   Responses will vary. For example, we know that removing the producers is devastating. What happens if a large population of first-level consumers goes?

5. Do the lists include people? Pollution? Fire? If not, speculate what effect they might have.

   Responses will vary depending on factor. Some biotic and abiotic factors are beneficial—other detrimental—but often it depends on the frequency, intensity or abundance of the factor.

6. Why do we care? What ecosystem services does the ecosystem provide? Why are these services important?

   Responses will vary. Refer to the list provided for ecosystem services. Challenge students to take one service to explore.

Consider an environmental impact, such as a building project in the area, a long- term warming trend or change in annual precipitation. Suggest at least three ways that organism relationships will be stressed. What do you predict the outcome to be?

Responses will vary with the origin of the impact. Natural trends and fluctuations impact an area very differently than humans. The question implies speculation. Care should be taken to use evidence to support the predictions.

Measure Up!

How do abiotic factors affect biotic factors in an ecosystem?

Topic: Practicing working with abiotic tools to take measurements

Brief Lesson/Lesson Set Description:
Measure Up! is a skill builder familiarizing students with equipment to measure abiotic conditions in the field. Abiotic data collection is important in field study, especially with consideration of the invertebrate life. Students will practice using wind meter, soil and air thermometer, sling psychrometer, soil moisture meter and light meter.

Science and Engineering Practice: Planning and Conducting an Investigation

Crosscutting Concept: Stability and Change

INVESTIGATION

Objectives: Students will:
- Safely use a wind meter, soil and air thermometer, sling psychrometer, soil moisture meter and light meter.
- Accurately read instruments and record the data.
- Design a data chart to collect abiotic data over time and in different places.
- Appreciate the significance of weather and weather conditions as an abiotic factor in nature.

Narrative/Background Information:
The term *abiotic* refers to any non-living factor in an environment. Examples of abiotic factors include wind, temperature, humidity, soil moisture, and light. Most heat-recording instruments used for this purpose are calibrated with the Celsius scale. All the thermometers used at Fermilab are Celsius, a practice consistent with the scientific community.

When using the Celsius scale, this jingle will help your students relate temperatures to the more common Fahrenheit scale.

30s are HOT.
20s are nice.
Teens are “cool.”
And zero is ice.

Relative humidity may be a familiar term to the students and a new calculation concept. A psychrometer is used to determine the relative humidity of an area. The difference between the wet and dry bulbs is important. The relative humidity of an area has much to do with the ecosystems of an area. In the Midwest, relative humidity varies from day-to-day and trends change from season-to-season. Rainforests have a much higher

consistent average relative humidity while deserts tend to be much lower on the average.

An example of this concept is illustrated by how the human body reacts to relative humidity. The evaporation of water (perspiration) from your body pulls heat away from your body. This is one of your body's defenses against overheating. The principle is the same with the psychrometer; water evaporating from the wet bulb effectively cools the instrument, creating a wider margin between the two temperatures. The wider the margin, the lower the relative humidity. If the humidity is too high (nearing or at 100%), evaporation will not occur and the heat in the wet bulb thermometer will remain. This is why it is so hard to stay cool on a hot and HUMID day.

Prior Student Knowledge Expectations:

- General understanding of the role of abiotic factors in the natural world
- Familiarity with the Celsius scale for temperature
- Ability to use the measuring instruments safely and accurately
- Willingness to stand in the natural area in spite of possible inclement weather and/or insects
- General understanding and acceptance of collaborative behaviors

Possible Preconceptions/Misconceptions:
Novices to field study often think that "if you've seen one forest, you've seen them all." In truth, natural places are never exactly the same from day-to-day or even minute-to-minute. Teacher attitude regarding field study is critical. Approach the tasks with energy and enthusiasm! This activity should be framed as an adventure for the class.

NOTE: Students will quickly realize that field study can be challenging and sometimes uncomfortable, but nonetheless fascinating. Students will also discover that the closer they look, the more they see. Even though the task is to collect abiotic data, it's prudent to note other interesting observations.

Vocabulary: abiotic, data, control group, eutrophication, experimental group, nonrenewable resource, percolation, renewable resource

Materials:

- Celsius thermometers
- Cups
- Water
- Psychrometer
- Wind meters
- Moisture and light meters (generally on the same instrument)
- Electric fan

ENGAGE:
Ask students to visualize themselves standing outside waiting for the bus in the morning, and then again in the afternoon. How would they describe the conditions and

how would they compare these conditions at two different times of day. Conduct a short discussion to brainstorm what abiotic factors are and how they might be tested during a study of an ecosystem. Ask students to think through how to collect data on these abiotic factors.

EXPLORE:
Process:

1. Discuss and demonstrate how to use each instrument. Use student volunteers.
2. Set up stations around the room and have groups of students practice using the instruments. Remind them to read temperatures in Celsius.
    a. Station 1: Place thermometers in cups of hot (A) and cold water (B). Have the students read and record data. Replenish water as temperature equalizes.
    b. Station 2: Place thermometers in cups of soil that have been heated (A) or chilled (B). Replenish soil as temperature equalizes.
    c. Station 3: Practice using the psychrometer. What is the relative humidity in your classroom? If practical, allow students to test outdoors, too.
    d. Station 4: Provide the students with cups of soil. Cup A is dry, cup B is damp, and cup C is wet. Use the soil moisture meter to determine the amount of moisture in cups A, B and C.
    e. Station 5: The moisture meter has, as a secondary function, a light meter. What is the light level next to the window? Now move to the door. What is the light level here?
    f. Station 6: Turn on fan and test for wind speed at different height levels and speeds of the fan using the wind meter.

EXPLAIN:
Using vocabulary in context, ask students to describe their results based on their original expectations and their results. Were there any *AHA* moments? Take time to reflect and share. Challenge students to create a data chart to relate their data.

ELABORATE:
The nature of this activity is skill building. Accurate measurements in science are critical. Accurate measurement in *environmental* science can be illusive and often is determined by not only proper methodology, precision of the instruments and accessibility of the location, but also on the researchers' instincts. Attention to observations other than simply the tools can be important to the research effort.

EVALUATE:
Formative Monitoring: Use Student Reflection questions for discussion throughout the investigation.

Summative Assessment: N/A

Elaborate Further/Reflect/Enrichment: Predict differences in abiotic data from two different ecosystems. Reflect back on these predictions after completing field studies.

Name: _____

Measure Up! Data Sheet

Prior to every task, read the directions and predict what you believe will occur.

Station 1: Prediction _____

Use the thermometer and record the temperature in each cup.

Temperature of water in cup A: _____°

Temperature of water in cup B: _____°

Remove the thermometer from the cup and leave on the table.

Station 2: Prediction _____

Use the thermometer and record the temperature in each cup.

Temperature of soil in cup A: _____°

Temperature of soil in cup B: _____°

Remove the thermometer from the cup and leave on the table.

Station 3: Prediction _____

Wet the wick over one thermometer bulb. Then spin the psychrometer for a minute.

Dry bulb reading is_____º.

Wet bulb reading is_____º.

The difference between these two temperatures (in degrees): _____º

Use the psychrometer differential table and determine the relative humidity. _____%

Station 4: Prediction _____

Use the moisture meter to measure the moisture in each of these cups.

The moisture level in cup A: _____

The moisture level in cup B: _____

The moisture level in cup C: _____

Station 5: Prediction _____

Use the light meter to measure the light level by the window and by the door.

The light level next to the window: _____

The light level next to the door: _____

Be sure to return the light meter to Station 5.

Station 6: Prediction _____

Hold the wind meter so it catches the breeze the fan makes.

The wind speed is _____mph.

Now, change the height level of the wind meter. Predict whether the speed will change. Was your prediction correct?

Increase/decrease the speed of your fan; you know that this action will affect your reading, but see if you can replicate the speed of another fan setting by changing the height of the wind meter. What did you discover?

Name: _____

Student Reflection: Measure Up!

1. Why is it important to hold the thermometer at the top of the instrument?

2. On a hot day, it feels so good to catch a breeze. Explain why you feel cooler when perspiration evaporates from your body. How does this sensation relate to the psychrometer?

3. Under what conditions will evaporation not take place? What are the consequences?

4. Did all of your classmates get the same abiotic readings? Why or why not?

5. Why are abiotic factors such as the air temperature, soil temperature, wind speed, light and moisture levels, and humidity important in an ecosystem?

6. Design a data chart of your own to accurately collect abiotic data over time and from place-to-place.

Teacher Page

Student Reflection Suggested Responses: Measure Up!

1. Why is it important to hold the thermometer at the top of the instrument?

   By holding it at the top, the temperature is not influenced by body temperature.

2. On a hot day, it feels so good to catch a breeze. Explain why you feel cooler when perspiration evaporates from your body. How does this sensation relate to the psychrometer?

   The evaporation of water from the body (perspiration) pulls heat away from your body. This is an adaptation and one of the human body's defenses against overheating. The principle is the same with the sling psychrometer; water evaporating from the wet bulb cools the thermometer to get a differential from which relative humidity is calculated—the higher the humidity, the less the differential.

3. Under what conditions will evaporation not take place? What are the consequences?

   If humidity nears or reaches 100%, the body (and the wet bulb) has no differential and evaporation; thus, cooling does not take place. This is why we feel hotter on a humid day than a day with the same temperature, but lower humidity.

4. Did all of your classmates get the same abiotic readings? Why or why not?

   If in the same general area, relative humidity should be very close; however, stepping into a woodland/forested area only meters away from an open pond or prairie can result in a change. Human error can also prevail if the psychrometer is not in motion long enough, readings or math are incorrect, or the bulb dried out too quickly.

5. Why are abiotic factors such as the air temperature, soil temperature, wind speed, light and moisture levels, and humidity important in an ecosystem?

   Abiotic factors are critical in environmental studies—especially studies where natural ecosystems are compared with cropland, commercial landscaping and residential lawns. Native area organisms are better adapted to climate fluctuations.

6. Design a data chart of your own to accurately collect abiotic data over time and from place-to-place.

Charts will vary. Communicate expectations prior to this project.

Abiotic Study

How do abiotic factors affect biotic factors in an ecosystem?

Topic: A study of the nonliving components of an ecosystem

Time Needed: Onsite Field Experience

Brief Lesson/Lesson Set Description:
Students will compare the environmental (weather/climate) and soil conditions of the prairie, forest or woodland, and a pond area. Following the field experience, students will use historical Fermilab abiotic data to observe weather trends.

Science and Engineering Practices: Planning and Carrying Out Investigations; Analyzing and Interpreting Data

Crosscutting Concept: Cause and Effect

INVESTIGATION

Objectives: Students will:

- Cooperate within a team to record data accurately.
- Analyze and interpret data to provide evidence for how environmental factors influence the growth of organisms.
- Predict the abiotic trends of each ecosystem visited; revisit these predictions following the field experience, and use evidence to explain the accuracy of the predictions.
- Considering soil as a natural resource and using firsthand and researched data, draw conclusions regarding the dramatic shift from prairie to farming in Illinois.
- Draw conclusions based on evidence about why plants grow where they do.
- Construct an argument supported by empirical evidence that changes to the physical or biological components of an ecosystem affect populations.

Narrative/Background Information:
The term *abiotic* refers to a nonliving factor in an environment; e.g., light, water, temperature, etc. Some ecosystems separated by elevation, distance, and/or geographical elements are expectedly different. For example, the abiotic conditions of an ocean shore differ significantly from that of tundra on a mountain. These different ecosystems have very different environments, and the organisms living at these sites have adapted to the environment.

However, it is possible for ecosystems in close proximity to experience different abiotic conditions. Prairie remnant and restoration ecosystems, especially since the mid-1800s when most of the prairie fell to the settlers' plows, often exist in very close proximity to other ecosystems such as woodlands, forests and ponds. In this case, many abiotic

factors such as the amount of rainfall are remarkably similar. Yet, these ecosystems are, in many ways, dissimilar.

The organisms living in the ecosystems are evidence of this dissimilarity. In the prairie, different plants bloom from mid-spring through the fall. In the forest next to the prairie, we primarily observe early spring wildflowers. The plants found in these two ecosystems are different even though the two ecosystems may be right next to each other. Why is this? There must be reasons why the two ecosystems contain such different plants. In this study, the students collect the abiotic data that might help explain these differences.

Soil Building (See also *Life in a Log – Soil Structure.)*
One important abiotic factor in an ecosystem is the soil. Therefore, students should know about how soil is formed. The land areas of the earth once were primarily barren rock with no soil cover. Winds, rains, ice (glaciers), and water constantly acted upon these exposed rocky masses. The rocks began to break down. When the first land plants (pioneer plants) moved onto the land, they were small and adapted to hold onto rock surfaces. The weathering actions of the physical forces along with the chemical influences of the early plants continued the breakdown of the rocks; plants died and their bodies added nutrients to the soil in the making that gave it some of the properties we look for in productive soil. After a long period of time, all of these forces produced soil pretty much like the soils of today. Soil building is still going on in many places, and some aspects of the process can be observed.

Mosses and lichens were among the first pioneer plants, though any plant that makes way for an ecosystem may be considered a pioneer. Mosses and lichens are adapted to living on rock surfaces, and they contribute to the disintegration of the rocks over long periods of time as part of the soil building. You can find exposed rocks or boulders in wooded areas and adjacent places. Many will already have begun to break down and will have lichens and mosses attached as well as some other plants that managed to find a place to grow in a tiny crevice or in an accumulation of materials in a depression or cavity on the rock's surface. The nature of the nutrients, including the minerals found in the soil, is a key to the types of plants that will find success in that area.

Soil building, even when promoted by the action of plants, is dependent on abiotic conditions. Wind, temperature, water, and sunlight all contribute to the abiotic nature of an ecosystem. In this activity, students examine some of the qualities of the soil as well as weather information in an effort to understand the qualities that contribute to a healthy ecosystem.

Water-Holding Capability (See also *Life in a Log – Soil Structure.)*
Soil is a major reservoir of water needed by organisms. Depending on the soil composition, its structure enables it to hold enormous quantities of water that fall as rain or snow. Soils differ in their ability to hold water. The texture of the soil also depends on the soil's composition. Though many substances make up soils, there are only three primary soil textures: sandy (small inorganic particles of rock and minerals), loam

(primarily organic products of decomposition), and clay (extremely tiny particles of inorganic material).

The soil percolation test demonstrates the water-holding capacity of the soil in a particular area. It is advisable, when practical, to select several sites in the immediate area around the test site. Areas that consistently dry out faster generally have a different plant species than areas that are typically wetter.

Combination soils with all three textures and plenty of loam, along with their plant cover, can absorb and hold much more water than extremely sandy soils. Clay can be nearly impervious to water and is effectively used as a natural base for landscaped ponds. Soil that is primarily clay will not support the same plant populations as soils containing a significant portion of loamy soil.

See the activity *Soil Texture* for a “down and dirty” soil texture experience.

Soil Chemistry (Optional)

The soil pH is very important to the plants of any ecosystem because proper pH determines which nutrients will be soluble and, therefore, available to the plants. This is because plants can only take in nutrients that are dissolved in water. If the pH is wrong, then a nutrient might be present in the soil but not dissolved in the water around the plant and therefore cannot be taken in by the plant. At or near 6.7, the nutrients most plants need are soluble and, therefore, available. However, some plants such as certain coniferous trees that require more acidic (lower pH) conditions thrive in a soil pH that is lower than 6.7 while other plants require a slightly higher pH; pH extremes are typically lethal to living organisms.

The soil supplies the needed nutrients for the plants in both forest and prairie ecosystems. Unfortunately, the Fermilab prairie, like most modern prairies, is not a virgin prairie with the thick rich soil common to prairies of the past. This area had been farmed for many years, thus altering the soil. Before the emergence of agriscience, farmers did not know that the soil nutrients would eventually deplete. Today, modern farming methods replace nutrients that once were naturally returned to the soil by the prairie organisms.

Three of the most important nutrients for good plant growth are nitrogen (N), phosphorus (P), and potassium (K). Nitrogen is essential for proper plant cell metabolism and protein formation. Nitrogen gives plants their dark green color and helps the growth of leaves and stems. Phosphorus is a soil nutrient responsible for the formation of healthy roots. Phosphorus also encourages the blooming of flowers, seed formation, resistance to disease, and helps the plant withstand weather extremes. Potassium is a soil nutrient that stimulates flowering and helps produce sugar and starch during photosynthesis.

Soil contains microorganisms, decaying organic matter, earthworms and other insects. Soil is a living environment. The earthworms and insects aerate the soil and add to the organic matter of the soil through their waste and when their bodies decay.

Dirt is basically dead soil. It does not contain any of the above. You can add organic matter (compost) to dirt to revitalize it. The organic matter will provide food for beneficial microorganisms so that the ecological system can regenerate.

Prior Student Knowledge Expectations:

- General understanding of soil structure (Connection: *Life in a Log – Soil Structure*)
- Ability to utilize measuring methodology (Complete *Measure Up!* activity.)
- Willingness to take time and work accurately to collect complete data sets
- General understanding and acceptance of collaborative behaviors

Possible Preconceptions/Misconceptions: Students may believe that:

- Abiotic conditions within an area are generally the same. (Stepping into a woodland or forest from a prairie can yield dramatic differences, especially if it is a sunny day.)
- Abiotic conditions are generally the same from year to year within a season. (Studying archived weather data from the Fermilab website shows temperature and precipitation trends that tend to change often from year to year.)
- Abiotic factors are key to soil building.
- Soil is soil—essentially the same within an ecosystem.
- Fertile soil from different parts of the world has different essential components and all are dependent in large part on abiotic factors for its structure. (Fertile soil capable of growing plants all has the same essential ingredients—living organisms, nutrients from decomposition, minerals from rock structures, moisture (water), and organic by-products.)
- Soil is DIRT! In fact, dirt is depleted soil.
- Soil is a nonliving substance. (Soil is very much alive, teeming with microorganisms and invertebrates.)
- Soil remains soil over vast periods of time. (That depends on what is grown. Natural areas tend to replenish themselves, but areas that are farmed or landscaped need diligent care to maintain.)

Vocabulary: abiotic, atmosphere, biotic, data, drought, eutrophication, forest floor, humus, infiltration, percolation, precipitation, radiation, transpiration, water cycle

Materials:

- Student data sheets
- For each group:
    - Thermometer
    - Wind gauge
    - Psychrometer
    - Light intensity meter
    - Soil moisture meter
    - Soil percolation tube

    - Water supply
    - Waste container
- Soil test kit with laminated instructions
- Stopwatch or wristwatch
- Meter stick
- Access to Fermilab historic weather data: http://www-esh.fnal.gov/pls/default/Weather.html

ENGAGE:
As field scientists, students experience taking data in various ecosystems.

EXPLORE:
Process: *At school prior to Fermilab field trip*

1. Determine whether you will include the optional soil experiences: *Soil Chemistry* (included in this activity) and *Soil Texture* (separate activity) on the school site. These options are NOT part of the Fermilab docent experience.
2. Familiarize the students with the processes of soil building as noted in the background section of this activity. Relate these processes to the abiotic factors influencing ecosystems.
3. Instruct the students in the use of the meters and gauges used in the activity by referring to student sheet provided in this activity.
4. Test for pH by making a mixture of a small amount of soil, adding water to almost fill the container. Cap the container and shake. Test with pH paper and compare to the pH scale.
5. Instruct students in data collection procedures as experienced in *Measure Up!* Emphasize accuracy and complete data records.
6. Encourage students to highlight or star particularly interesting data as they conduct their field study. These could be unexpected readings, readings that do not jive from trial to trial, or simply points of interest. Remind students to acknowledge human error.
7. Debrief, emphasizing that the data collected represents a very small sample. Encourage students to investigate long-term abiotic data on the Fermilab website at http://www-esh.fnal.gov/pls/default/Weather.html.
   Fire website isn't direct: http://www.fnal.gov/cgi-bin/ecology/burn and http://www.fnal.gov/ecology/map/fmadisplay.shtml?FILE=fmadata&ICOL=3&Scheduled

EXPLAIN:
Prior to the Fermilab field trip (or alternative field experience), instruct students to predict abiotic trends at all sites to be monitored. Bring these predictions to the field sites. After the field experience, ask students to compare their predictions with the actual readings. How do they compare? Students will offer explanations based on the field experience as to why they were accurate or not. As explanations emerge, misconceptions or inaccuracies will be evident.

ELABORATE:
Ecosystem services are the important benefits for human beings that arise from healthy functioning ecosystems (Costanza). A few selected relevant services are listed. Ask students to consider one of these services (a different service for each group) and describe a connection with their abiotic survey. How might longer-term data assist in the land management of these areas?

Consider:

- Gas regulation (production of oxygen) – **MS-LS1-6; MS-LS2-3; MS-ESS2-4**
- Climate regulation – **MS-LS1-5; MS-PS3-4**
- Disturbance regulation (storm protection/flood control) – **MS-LS2-4; MS-ESS3-3**
- Water regulation – **MS-ESS2-4**
- Erosion control/sediment retention – **MS-LS2-4; MS-ESS3-3**
- Soil formation – **MS-LS2-3; MS-ESS2-4**
- Nutrient cycling** (storage, nutrient cycling, biochemical breakdown) – **MS-LS2-3**
- Pollination – **MS-LS2-4; MS-LS1-8**
- Biological control (trophic-dynamic relationships/keystone species) – **MS-ESS3-3**
- Refugia (habitat for migration/visiting species) – **MS-LS2-1; MS-LS2-2**
- Food production – **MS-LS2-1**
- Raw materials (biofuels) – **MS-LS1-6; MS-LS2-3; MS-ESS2-4**

**Concepts beyond middle level

Web Links
Fermilab website: http://www-esh.fnal.gov/pls/default/Weather.html
Fire website isn't direct: http://www.fnal.gov/cgi-bin/ecology/burn and http://www.fnal.gov/ecology/map/fmadisplay.shtml?FILE=fmadata&ICOL=3&Scheduled

EVALUATE:
Formative Monitoring: Use Student Reflection questions for discussion throughout the investigation.

Summative Assessment: After enough practice, students could be assessed on how they analyze the data collected. Use Student Data Collection Sheet.

Elaborate Further/Reflect/Enrichment: Ask students how this data could apply to the work of a field ecologist.

Name: _____

Student Data Collection Sheet

ABIOTIC STUDY – General Abiotic Analysis

In the prairie and the pond, different flowers bloom from the spring through the fall. In the woodland next to the prairie, we often observe only the spring wildflowers. The plants found in these three ecosystems are different even though the ecosystems are close by. Why is this? There must be some reason why the three ecosystems contain such different plants. In this study, you will collect the abiotic data that might help explain the plant differences.

Factor	**Prairie**	**Woodland**	**Pond**
Temperature in Celsius			
1 meter above ground	_____	_____	_____
15 centimeters above ground	_____	_____	_____
Ground level	_____	_____	_____
5 centimeters below surface	_____	_____	_____
Wind	_____	_____	_____
Humidity	_____	_____	_____
Light Intensity	_____	_____	_____
Soil Moisture	_____	_____	_____
Percolation Test	_____	_____	_____

How did the diversity of the woodland, prairie, and pond compare? Where did you find more plant species in the same sized area? (Woodland, prairie, or pond?) Using your data, explain why you believe this phenomenon occurred.

Field Notes and response to prediction: Use the back of the page.

ABIOTIC DATA COLLECTION

Names: _____

Hypothesis – Prairie and Forest: _____

_____

PRAIRIE

Prairie Atmospheric Conditions

	Site 1	Site 2	Site 3	Average
Light Intensity*				
Wind Speed	mph	mph	mph	mph
Relative Humidity	Wet: ºC Dry: ºC %:	Wet: ºC Dry: ºC %:	Wet: ºC Dry: ºC %:	%

*For light intensity use A = 1, B = 2, etc., for averaging purposes.

Prairie Soil Conditions

	Site 1	Site 2	Site 3	Average
1 meter above	°C	ºC	ºC	ºC
15 centimeters above	ºC	ºC	ºC	ºC
Ground level	ºC	ºC	ºC	ºC
5 centimeters below surface	ºC	ºC	ºC	ºC
Soil moisture				

Soil Percolation: minutes per liter _____

FOREST

Forest Atmospheric Conditions

	Site 1	Site 2	Site 3	Average
Light Intensity*				
Wind Speed	mph	mph	mph	mph
Relative Humidity	Wet: ºC Dry: ºC %:	Wet: ºC Dry: ºC %:	Wet: ºC Dry: ºC %:	%

Forest Soil Conditions

	Site 1	Site 2	Site 3	Average
1 meter above	°C	ºC	ºC	ºC
15 centimeters above	ºC	ºC	ºC	ºC
Ground level	ºC	ºC	ºC	ºC
5 centimeters below surface	ºC	ºC	ºC	ºC
Soil moisture				

Soil Percolation: minutes per liter _____

Psychrometer Differential Table – Wet Bulb/Dry Bulb

Dry-Bulb Temperatures (^{0}C)	Difference between Wet-Bulb and Dry-Bulb Temperatures																			
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
0	81	64	46	29	13															
2	84	88	52	37	22	7														
4	85	71	57	43	29	16														
6	86	73	60	48	35	24	11													
8	87	75	63	51	40	29	19	8												
10	88	77	66	55	44	34	24	15	6											
12	89	78	68	58	48	39	29	21	12											
14	90	79	70	60	51	42	34	26	18	10										
16	90	81	71	63	54	46	38	30	23	15	8									
18	91	82	73	65	57	49	41	34	27	20	14	7								
20	91	83	74	68	59	51	44	37	31	24	18	12	6							
22	92	83	76	69	61	54	47	40	34	28	22	17	11	6						
24	92	84	77	71	62	56	49	43	37	31	26	20	15	10	5					
26	92	85	78	72	64	58	52	46	40	34	29	24	19	14	10	5				
28	93	85	78	73	65	59	53	48	42	37	32	27	22	18	13	9	5			
30	93	86	79	74	67	61	55	50	44	39	35	30	25	21	17	13	9	5		
32	93	86	80	75	68	62	57	51	46	41	37	32	28	24	20	16	12	9	5	
34	93	87	81	76	69	63	58	53	48	43	39	35	30	28	23	19	15	12	8	5

Name: _____

Student Reflection: Abiotic Study

1. Why do we find different species of plants living in these two ecosystems?

2. In the prairie the spring flowers are usually short followed by taller summer blooming plants and then very tall fall blooming plants. Why do you think this is?

3. In the woodland we do not find this layering effect of flowers to the degree that we do in the prairie; we often only find spring wildflowers. Why do you think this is?

4. How does the water-holding capability of the prairie, woodland and pond soils compare?

5. What are some possible reasons for these differences?

6. Was there any difference in the soil pH between our three ecosystems?
   If so, what was it?

7. If there was a difference, which ecosystem had a pH closer to the ideal?

8. High wind, low relative humidity and high temperatures all cause water to be lost from plants. In order to survive in an area like this, the plants must be specially

adapted. In which of our two ecosystems would we probably find more plants adapted to prevent water loss? _____

Explain your response.

9. Why do you think so few plants grow on the woodland floor?

10. Construct an argument supported by the data evidence you gathered to suggest that changes to the physical or biological components of an ecosystem affect populations. Share your points with the class. Are all in agreement? What aspects of the beliefs of others are acceptable to you and why?

11. Examine historic weather and fire data on the Fermilab website. How does your data support trends evident in the Fermilab database? Why is your class data less reliable?

12. At Fermilab, typically only the prairie areas are burned. What role(s) might fire play in the abiotic conditions on the soil in the Fermilab prairies?

Language Arts Common Core Connector

Think about your sensual observations of the abiotic conditions in the pond, woodland and prairie. With a partner, brainstorm your experiences and make a list of descriptive words for the plants in these ecosystems. Create a Haiku for the prairie and another for the forest using descriptors from your observations.

<u>Haiku</u>

- 3 lines of 5, 7 and 5 syllables
- Emphasis on syllables – NO RHYME

Example:

The deep, dark forest
Fragrant, humid air hangs low
Biting insects—SCRAM!

Teacher Page

Student Reflection Suggested Responses: Abiotic Testing

1. Why do we find different species of plants living in these two ecosystems?

   Responses will vary. Expect the student to relate abiotic factors and adaptations within the response.

2. In the prairie the spring flowers are usually short followed by taller summer blooming plants and then very tall fall blooming plants. Why do you think this is?

   Responses will vary. Expect the student to understand that this is an expected progression related to the blooming time of plants. Spring bloomers commit much energy to their early blooming schedules and typically do not grow as tall as the later bloomers.

3. In the woodland we do not find this layering effect of flowers to the degree that we do in the prairie; we often only find spring wildflowers. Why do you think this is?

   Responses will vary. Expect the student to include an understanding of the differences in the abiotic factors in the spring when the leaves are still buds as opposed to the summer when the leaves are fully developed. Consider also the canopy effect of the tree leaves shading the understory and woodland floor.

4. How does the water-holding capability of the prairie, pond and woodland soils compare?

   Responses will vary significantly depending on the amount of recent rain. Under the best of circumstances, the prairie soil retains water better than the forested areas at the peak of the season.

5. What are some possible reasons for these differences?

   Responses will vary. Expect the student to note the nearly impenetrable prairie root system (hard to push the device into the ground), comparative consistency of the prairie soil, and protection of the prairie soil from abiotic elements by the dense prairie plants.

6. Was there any difference in the soil pH between our two ecosystems? If so, what was it?

   Responses will vary.

7. If there was a difference, which ecosystem had a pH closer to the ideal?

   Responses will vary. Generally, the prairie soil' is closer to the 6.7 ideal pH.

8. High wind, low relative humidity and high temperatures all cause water to be lost from plants. In order to survive in an area like this, the plants must be specially adapted. In which of the ecosystems would we probably find more plants adapted to prevent water loss? _____

   Explain your response.

   The prairie forbs and grasses are more directly in contact with abiotic factors than the understory of the forest. Sunlight, wind, precipitation, and temperature extremes are more intense on forbs and grasses lacking the protection of trees.

9. Why do you think so few plants grow on the woodland floor?

   Responses will vary. Expect the student to relate abiotic factors such as lack of sunlight and wind for pollination to the lower diversity typically found in the woodland.

10. Construct an argument supported by the data evidence you gathered to suggest that changes to the physical or biological components of an ecosystem may affect populations. Share your points with the class. Are all in agreement? What aspects of the beliefs of others are acceptable to you and why?

    Responses will vary. Expect at least one example of an abiotic factor change and the specific cause/effect relationships between this abiotic factor and organisms.

11. Examine historic weather and fire data on the Fermilab website. How does your data support trends evident in the Fermilab database? Why is your class data less reliable?

    Responses will vary. Expect at least 2–3 connections to one factor based on student-generated and Fermilab data, understanding that the student data is very limited due to numerically small samples and human/instrument error.

12. At Fermilab, typically only the prairie areas are burned. What role(s) might fire play in the abiotic conditions on the soil in the Fermilab prairies?

    Responses will vary. Expect evidence that the student understands that when the prairie burns down, the soil level is better exposed to the warmth of the sun and direct effect of precipitation. (See *Fire Ecology*.)

Language Arts Common Core Connector
Think about your sensual observations of the abiotic conditions in the pond, woodland, and prairie. With a partner, brainstorm your experiences and make a list of descriptive words for the plants in these ecosystems. Create a Haiku for the prairie and another for the forest using descriptors from your observations.

Haiku
- 3 lines of 5, 7 and 5 syllables
- Emphasis on syllables – NO RHYME

Example:

The deep, dark forest
Fragrant, humid air hangs low
Biting insects—SCRAM!

Expect a degree of sophistication as determined by the teacher and communicated to the student prior to assigning this task.

What's the Weather?

How do abiotic factors affect biotic factors in an ecosystem?

Topic: To discover prior knowledge of ecosystems and ask questions for further research

Brief Lesson/Lesson Set Description:
Students explore data collection techniques and analyze the data to find patterns in weather across different cities. Students then compare these patterns to the climate expectations for the cities.

Science and Engineering Practice: Analyzing and Interpreting Data

Crosscutting Concept: Patterns

INVESTIGATION

Objectives: Students will:
- Collect and record weather data.
- Interpret data and make inferences about climatic effects.
- Compare weather patterns for different parts of the country.
- Predict the effect of climatic changes on prairie plants.

Narrative/Background Information:
The climax plant community has integrated all the environmental factors of its habitat; it is the fundamental response to the controlling condition. Among these factors are weather, soil and topography.

Weather information is readily available through newspapers and broadcasts. The National Oceanic Atmospheric Administration (NOAA) provides complete weather information for given areas near major airports that serve as weather recording stations. For example, the Chicago area has O'Hare Airport collecting and recording extensive amounts of weather data.

As weather systems move through an area, relationships such as that between high-pressure systems and precipitation are easily graphed and compared. More critical than the day-to-day weather we observe are the seasonal trends and climatic factors in an area. For example, if a prairie naturally receives a significant amount of precipitation in the winter and spring and a particularly dry winter and spring arrives, the prairie may have an unusual season.

Fortunately, prairie plants are adapted for severe weather conditions such as extraordinarily wet, dry, cold, and/or hot weather. Seasonal anomalies such as that extraordinarily dry winter and spring will not typically kill a prairie. Rather, other trends may appear such as an imbalance of forbs to grasses or the failure of certain plants to

flower or even grow. Access in Fermilab's weather information website, http://www-esh.fnal.gov/pls/default/weather.html, and using it in conjunction with data available from Fermilab's SIMply Prairie website, http://ed.fnal.gov/data/life_sci/prairie/, allows for some interesting correlations and possible research questions.

Yet, the resiliency of prairie plants is profound. Plants dormant for generations (and quietly "sleeping" beneath the surface) can suddenly appear above ground when the appropriate conditions are presented. Such is the case in many old cemeteries where prairie plants, mowed for generations or diminished by chemicals to promote lawn grass, are allowed to simply grow.

Prior Student Knowledge Expectation:

- Students should begin the lesson recognizing that there are different aspects to weather and it is not defined by precipitation alone.

Possible Preconceptions/Misconceptions:

- Weather and climate are not the same things.
- Students may struggle with the concept of humidity and its relation to barometric pressure.
- Students may assume that all types of cloud cover indicate future precipitation.

Vocabulary: climate, climax plant community, weather

Materials:

- Newspapers/Internet access
- Weather instruments such as a thermometer, rain gauge and anemometer may be used to collect school weather data.

ENGAGE:
Make a cloud activity.

Obtain a clear 1- to 2-liter pop bottle filled with about 2–3 centimeters of water. Cap the bottle tightly and shake it to distribute water vapor throughout. Quickly light a match, uncap the bottle and drop the match into the bottle. With the cap tightly secured, squeeze the bottle. A cloud will form. Ask students why they believe this phenomenon occurred. Squeeze again and the cloud will disappear. Continue until someone comes up with the idea that air pressure, humidity and clouds are related.

EXPLORE:
Process:

1. Give students a partner and ask students to record the weather for a selected city. Ask students to record the high and low temperatures, barometric pressure, relative humidity, and other weather conditions such as cloudy, rain, snow, etc. Record this information for a period of 14 days including weekends.

2. Make a line graph using your data. For example, use one line (red) for the high temperatures and a second line (blue) for the low. Since the date is the independent variable, it should be on the horizontal (X) axis. The temperature, the dependent variable, should be on the vertical (Y) axis. Check the range of the numbers needed to complete the graph. Barometric pressure, for example, has a different set of numerical indicators than does temperature; to compare barometric pressure and, for example, humidity, indicators on both the left and right vertical (Y) axis of the graph are needed. The horizontal (X) axis always depicts the time factor; in this case, the date.

3. Research the climate of your selected city. Include temperature, precipitation, and other important factors of climate.

4. Research the major landforms that surround the city. Discuss how these landforms may influence climate.

EXPLAIN:
Discuss the patterns that you see in the 14 days of weather data taken. Correlate the weather data to the expectations of what the weather should be based on the climate of the city.

ELABORATE:
Engage students in an examination of weather relationships. They should see, for example, that barometric pressure generally influences temperature and humidity. (The higher the pressure, generally the lower the humidity, for example).

Engage students in a discussion about how the climate of the studied city might be altered depending on the restoration of natural areas.

EVALUATE:
Formative Monitoring: Monitor student work with a focus on data collection and the way students use the ideas of weather and climate.

Summative Assessment: N/A

Elaborate Further/Reflect/Enrichment: Create graphs of the data collected; use these graphs to compare the high and low temperatures, for example, of several cities studied by students in the class. Discuss the differences between wildlife found in different cities and link those differences to differences in weather.

Choose an animal or plant to study and explain the adaptations these living things have to manage the weather throughout the year in a given city.

Name: _____

Student Reflection: What's the Weather?

1. What are some of the weather conditions that affect the ecosystems of your area?

2. What patterns did you see during the designated days to record data?

3. Make some predictions about what the weather will be like one month after the weather data was taken.

4. Were there any days when the weather data that was taken was surprising? What explanation can you give to explain this?

5. What adaptations might plants need to live in the climate of your city?

6. What adaptations might animals need to live in the climate of your city?

7. What factors influence the weather (short term) and climate (long term) in your city? Explain how these factors contribute to the weather and climate.

Choose a plant that lives in the city you studied. Write a story noting the climatic extremes and weather conditions this organism must endure to live here year-round.

Teacher Page

Student Reflection Suggested Responses: What's the Weather?

1. What are some of the weather conditions that affect the ecosystems of your area?

   Responses will vary.

2. What patterns did you see during the designated days to record data?

   Responses will vary.

3. Make some predictions about what the weather will be like one month after the weather data was taken.

   Responses will vary. Students should take into consideration the typical seasonal changes for the area. Remind students to note whether the last week for which data was collected is a typical week for that season.

4. Were there any days when the weather data that was taken was surprising? What explanation can you give to explain this?

   Responses will vary.

5. What adaptations might plants need to live in the climate of your city?

   Responses will vary.

6. What adaptations might animals need to live in the climate of your city?

   Responses will vary.

7. What factors influence the weather (short term) and climate (long term) in your city? Explain how these factors contribute to the weather and climate.

   Responses will vary. Students should include information for both weather and climate.

Choose a plant that lives in the city you studied. Write a story noting the climatic extremes and weather conditions this organism must endure to live here year-round.

Expect a degree of sophistication as determined by the teacher and communicated to the student prior to assigning this task.

Estimating Percentages

How do abiotic factors affect biotic factors in an ecosystem?

Lesson Number 1 in a Series of 3

Topic: Improving estimating skills

Brief Lesson/Lesson Set Description:
In an effort to determine growth and diversity trends in an ecosystem, ecologists engage in population surveys. These studies then serve as trend markers that inform scientists of population/diversity trends. Since it is time-consuming and tedious to count every plant in these surveys, scientists employ skills sets to help with their efforts. Estimating the number of organisms in an area is a critical tool for field biologists and ecologists. Students will practice estimating percent cover of different plants within a meter square area using sections of colored paper. (Prerequisite for *Quadrat Study: School Lawn* and *Quadrat Species Sampling – Plants and Invertebrates*)

Science and Engineering Practice: Using Mathematics and Computational Thinking

Crosscutting Concept: Scale, Proportion and Quantity

INVESTIGATION

Objectives:
- Estimate percentage of area covered using only visual skills.
- Verify their accuracy with actual measurements.
- Transfer skills to quadrat study.

Narrative/Background Information:
Estimation is an essential skill in field study. While exact data and calculations are preferred, they are sometimes impractical when trying to determine trends in the natural world where the elements are not necessarily stationary and/or exactly the same from place to place or time to time. Furthermore, there are circumstances where the span of time is a factor and the luxury of an extended period to study a population is limited. For this reason, many field scientists employ estimation strategies to establish some of their data such as a quadrat study.

Taken individually, these data may be flawed. However, when compiled with thousands of data samples from the same area, trends appear. Students, when compiling data of this nature, will likely make errors. In the scientific world, human error is an unfortunate reality. Scientists understand that probability (the law of averages) always wins—when there are enough samples. (Refer to FQI materials in *Resources*.)

Over the years, tens of thousands of students have contributed to the plant database at Fermilab. For the most part, these students have come to Fermilab well prepared for

their roles as student researchers. The data they collect is authentic AND put to use. Until 2016, these data were collected during field trips only from prairie Plot 16B at Fermilab. Beginning in 2016, other ecosystems such as woodlands and pond areas have been included. These data would not be as valuable if the students were ill prepared for the quadrat study. For this reason, the activities *Estimating Percentages* and *Quadrat Study: School Lawn* are mandatory prerequisites for the onsite quadrat activity.

Prior Student Knowledge Expectations:

- Competence in the *concept* of percentage. Consider practice with the online skill builder pages at http://ed.fnal.gov/ntep/f98/projects/fnal/student/skills/quadrat.shtml.
- Ability to work quickly, accurately and efficiently within a limited time frame
- Ability to use logic when applying understanding of percentage to a meter square
- General understanding of collaborative behaviors

Possible Preconceptions/Misconceptions:

- Estimating percentage is an easy task. (In reality, many adults struggle with this challenging skill.)
- The estimation must be correct. (No . . . It's an *estimation*. It needs to be completed quickly; precise measurements are generally not an option.)
- Lack of faith in probability (Large bodies of data can indicate trends; outliers that may skew a small sample are offset by outliers on the opposite end of the scale.)

Vocabulary: canopy, estimate, percentage, quadrat, understory

Materials:

- Transparencies – Quadrat and Data Sheet
- Meter stick
- Masking tape
- Colored paper of different dimensions (Red, green, yellow, blue, and orange; fabric or laminated paper will last longer.) For example:
    - 10 – 5x5 cm
    - 10 – 10x10 cm
    - 10 – 20x20 cm
    - 10 – 30x30 cm
    - 10 – 40x40 cm
    - Several irregularly cut colored sheets

ENGAGE:
Enthusiastically set the task up as a class challenge with no individual winners/losers.

EXPLORE:
Practice in determining percent cover within a meter square using colored paper to represent common plants. For this exercise, prairie plants are used. Woodland plants

will differ. Pond surveys will not necessarily use a quadrat, but percentages are still relevant.

Process:

1. When cutting out the paper squares, make sure that each color has some squares of every size. Then write on each square the appropriate prairie plant name. For example:
    - Indian Grass – red
    - Compass Plant – green
    - Prairie Dock – yellow
    - Big Bluestem – blue
    - Butterfly Weed – orange

2. Using the masking tape and the meter stick, make six quadrats on the classroom floor. They should be one-meter square.

3. Place the colored squares randomly from quadrat to quadrat. DO NOT cover every square centimeter. Bare area represents bare ground. Take care to make sure all quadrats are different. Use no more than three squares of any one color. Calculate the percent cover, but do not yet reveal this figure to the students.

4. Lay out the squares in some quadrats very simply with no overlapping or extending beyond the meter square.

5. Explain the purpose of this activity by describing a quadrat study. Students may find the estimating percentages online example helpful prior to engaging in the classroom activity at http://ed.fnal.gov/ntep/f98/projects/fnal/student/skills/quadrat.shtml.

6. Assign students to groups. At each quadrat, students must estimate the percentage of area covered by each color. Allow each group at least 3–4 minutes at each quadrat before instructing them to move to the next.

7. When the students have estimated the percent cover at all the quadrats, assign each group to one of these SIMPLE quadrats and using meter sticks, have them determine the actual area for each color. (Remind students that for the simple quadrats, the total for all colored areas should not exceed 100%. The difference between the total of colored squares and 100% equals the percentage of bare ground.)

8. As a class, compare the estimates to the actual percentages.

9. After the class has completed the simple quadrat percentages sheet, arrange the colored sheets so that some of the squares overlap and allow at least one square to be positioned partially out of the circle. Randomly place the irregularly shaped

colored sheets in the quadrats as well.

10. Address the percent cover for the overlapping colored sheets as follows: Each square is equal to 1% coverage. Include the total area each covers, even if other plants are above it. If the total area a plant takes up is less than one square, record it as 1. Don't worry if your total percent coverage is more than 100% because leaves from a taller plant can hover over a smaller plant, occupying the same square in the grid. In the field, a plant that has a portion outside the quadrat is ONLY counted if the main stem of the plant is within the quadrat. And then, only the percent of the plant within the confines of the quadrat counts.

11. Debrief as a class using the Student Reflection sheet.

EXPLAIN: The charts serve as a visual explanation of the concept of percentage. As students complete the charts, monitor progress. If a team is stumped, encourage them to “send a scout” to another team. Encourage students to make the critical connection between area cm^2 and percentage on their own. Avoid the temptation to simply tell them the relationship. In the class discussion/debriefing, ensure that this relationship is clear with further examples, as needed.

ELABORATE:
An individual enters a grocery store with a budget of $200 to spend and a long grocery list. Not wanting to go over budget and realizing that there will be sales tax, the person carefully selects items. By rounding the price of the item to the nearest 50 cents and mentally carrying the sum as items are placed in the cart, the person suddenly stops shopping and checks out. The total is $191.10. How did estimation help with this task? How do you use estimation in your life?

EVALUATE:
Formative Monitoring: After students have a chance to individually answer questions, they should participate in a group sharing followed by a class discussion to solidify their understanding of this topic and clear up any misconceptions. Be open to the type of questions asked by students as they struggle to understand the concepts in different contexts.

Summative Assessment: Student assignment: Imagine that you are the teacher and a new student arrives the day of the Fermilab field trip. Write a set of rules for estimating percentages for the student to study on the bus. Construct these rules to help this student be a successful part of a quadrat team.

Elaborate Further/Reflect/Enrichment: What further questions do students generate?

Name: _____

Student Reflection: Estimating Percentages

1. It can be challenging to estimate percentages! What surprised you the most about this activity?

2. When you used the data grid with the 1% squares, what helped make your task easier? What tricks did you learn?

3. How might you apply this skill to an actual quadrat study? In what ways may the natural quadrat be easier and/or more difficult?

4. When you compared your estimations to your classmates, how did you do? Why?

5. What were the primary sources of error in your estimations?

6. How might you improve your estimation strategies?

7. Describe at least two issues you may encounter in an actual field study. How will you deal with these issues?

Teacher Page

Student Reflection Suggested Responses: Estimating Percentages

1. It can be challenging to estimate percentages! What surprised you the most about this activity?

   Responses will vary. At first, students may experience frustration. Many of the students are surprised by the amount of bare ground present as well as how the task becomes simpler when the concept of 100% is applied to the strategy.

2. When you used the data grid with the 1% squares, what helped make your task easier? What tricks did you learn?

   Responses will vary. Students should recognize that the grid is divided into decimeter increments. Each square decimeter (10 cm x 10 cm = 100 cm or 1 meter square.) Thus, each grid square = 1/100th of a meter or 1%. As students report the rationale of their explanation, concept gaps or misunderstandings will be revealed.

3. How might you apply this skill to an actual quadrat study? In what ways may the natural quadrat be easier and/or more difficult?

   Responses will vary. Expect students to present concrete suggestions. Take time in class to discuss these ideas and provide insights as needed. For example, someone may suggest that the foliage might be dense and obstruct the view to the lower level of the plot. Remind them that they will kneel down to part the plants to identify and count the understory.

4. When you compared your estimations to your classmates, how did you do? Why?

   Responses will vary. Expect specific comparisons based on observed evidence.

5. What were the primary sources of error in your estimations?

   Responses will vary. Human error in misjudging percent cover and/or unable to understand the protocol for more complex quadrats. Restate the need for uniform field protocol for surveys.

6. How might you improve your estimation strategies?

   Responses will vary. Expect thoughtfully considered ideas noting especially the need for practice.

7. Describe at least two issues you may encounter in an actual field study. How will you deal with these issues?

   Responses will vary. Students should recognize that sometimes plants grow in different levels and overlap other plants in a plot; or are outside the plot but have foliage within the plot; or have stems inside the plot with foliage extending on the outside; or are merely remnants of a prior season. Each of these circumstances has a set protocol. Take time to reiterate if needed.

Candle Eating

How do abiotic factors affect biotic factors in an ecosystem?

Topic: Improving observation and inference skills

Brief Lesson/Lesson Set Description:
Most students will assume that the potato is a candle because of the well-placed clues. Students will review why they make assumptions and then what they can do to stop those assumptions during scientific investigations.

Science and Engineering Practice: Obtaining, Evaluating, and Communicating Information

Crosscutting Concept: Cause and Effect

INVESTIGATION

Objectives:
- Appreciate the importance of careful observation as opposed to assumption by association: inference.
- Recognize that events or items are not necessarily what they appear to be and can create a misconception if not thoroughly understood.
- Relate the importance of observation skills from a scientific perspective.

Narrative/Background Information:
Students are often quick to jump to conclusions without the appropriate background and understanding. In this context, Webster defines "inference" as: **a:** the act of passing from one proposition, statement, or judgment considered as true to another whose truth is believed to follow from that of the former; and **b:** the act of passing from statistical sample data to generalizations (as of the value of population parameters) usually with calculated degrees of certainty.

This activity is designed to fool the student observers into believing that a potato carving is actually a candle. This ploy is useful throughout the school year as students again and again accept what they consider to be obvious without thorough investigation. When such an occurrence takes place, simply state, "Remember the potato candle."

Prior Student Knowledge Expectations: N/A

Possible Preconceptions/Misconceptions:
This entire lesson is built on misconceptions; use the fact that students take your clues and jump to conclusions as an advantage.

Vocabulary: assumption, inference, observation

Materials:

- One extra long potato
- Lemon juice, Fruit Fresh, or other color preservative (if potato is prepared more than 30 minutes ahead of time)
- One paring knife or apple corer
- Several hazelnuts (filberts)—NOT dry roasted (Brazil or any other high-fat content nuts work too.)
- Matches

ENGAGE:
The activity is the engagement.

EXPLORE:
Process:
Prior to class:

1. Pare potato into candle shape. (Dip in Fruit Fresh or lemon juice to retain color.)
2. Wrap in plastic or place in a plastic bag until ready to use. Carve a wick out of a hazelnut. Hazelnuts have enough oil to support flame. Place on potato candle by creating a small X-shaped incision in the top of the potato shape and inserting the more pointed end of the nut wick into the incision.
3. Darken the room and display “candle” to the class by coming into the room with it lit. Ask, “Who has a birthday today?” Do not allude to the object as a candle; you want the students to make this inference.
4. Whether or not someone has a birthday, blow out the flame, bite off top of the candle—wick and all, and eat it. (NOTE: The flame is usually small, but it is advisable to collect a little saliva on your tongue to extinguish the flame completely before biting off the top. You probably won’t want too big of a bite.)
5. After the shock has subsided, ask for oral observations.
6. After typical “candle-like” observations have been offered, discuss the observations that led students to believe it was a candle—even though it was never referred to as such.

EXPLAIN:
Engage students in a discussion using responses from questions 1–7 on the Student Reflection sheet.

ELABORATE:
Ask students to write a short story about a time when someone made an inference that created a problem. Ask them to explain how making inferences can be dangerous in science investigations.

EVALUATE:
Formative Monitoring: Create a class discussion that focuses on why students came to the conclusions they did when they saw the burning “candle.” Process with students how assumptions can be both helpful and harmful during scientific research.

Summative Assessment: N/A

Elaborate Further/Reflect/Enrichment: N/A

Name: _____

Student Reflection: Candle Eating

1. What caused the class to believe that the potato was a candle?

2. Looking back, what questions would you have asked to avoid making an assumption that this was a candle?

3. Suggest occurrences in nature that are not what they seem to be. Name at least two.

4. What are the effects of a scientist that is not a good observer?

5. What strategies can you use to be a good observer?

6. When is it appropriate to make inferences? When might it be dangerous?

7. What are the effects of researchers making too many inferences?

Teacher Page

Student Reflection Suggested Responses: Candle Eating

1. What caused the class to believe that the potato was a candle?

   Responses may vary, but students may suggest the following:
   - *The teacher mentioned someone's birthday.*
   - *The "candle" was the right color, share, etc. . . .*
   - *The "candle" was lit.*

2. Looking back, what questions would you have asked to avoid making an assumption that this was a candle?

   Responses may vary.

3. Suggest occurrences in nature that are not what they seem to be. Name at least two.

   Responses may vary.

4. What are the effects of a scientist that is not a good observer?

   Responses may vary. The dictionary definition of observer states: to watch carefully, especially with attention to details or behavior for the purpose of arriving at a judgment.

5. What strategies can you use to be a good observer?

   Responses may vary.

6. When is it appropriate to make inferences? When might it be dangerous?

   Responses may vary. Students should recognize that some inferences might be beneficial, but others can create dangerous situations.

7. What are the effects of researchers making too many inferences?

   Responses may vary. Students should recognize that a mistaken identification or conclusion could impact future research.

Quadrat Study: School Lawn

How do abiotic factors affect biotic factors in an ecosystem?

Lesson Number 2 in a Series of 3

Topic: Improving estimating skills and applying those skills to completing a quadrat study on a small scale with easily identified plants

Brief Lesson/Lesson Set Description:
Students will become more familiar with techniques needed to complete a quadrat field study, understand the importance of sampling, exercise and improve observation skills, create a chart quadrat, and apply the concept of species diversity to ecological investigations. (Prerequisite for the *Quadrat Study*)

Science and Engineering Practice: Using Mathematics and Computational Thinking

Crosscutting Concept: Scale, Proportion and Quantity

INVESTIGATION

Objectives: Students will:

- Understand the importance of sampling in science.
- Construct a quadrat study using appropriate protocol.
- Exercise and improve observation skills.
- Create a chart quadrat.
- Apply the concept of species diversity to prairie investigation.

Narrative/Background Information:
It is often unrealistic for a scientist to count every organism in his/her research area. What scientists often do is to work with a sample, a small section or plot of their research area. From their samples, scientists can then estimate many things about their research area without having spent all the time necessary to count each organism. As in *Estimating Percentages*, the samples with which you will work will again be a meter on each side (a one-meter square quadrat). From these samples, you will discover a great deal of information about your school ground ecosystem. What initially appears to be a monoculture may surprise you and your students!

Taken individually, these data samples may be flawed. However, when compiled with many data samples from the same area, trends appear. Students, when compiling data of this nature, may make errors. In the scientific world, human error is an unfortunate reality. However, scientists understand that probability (the law of averages) always wins—when there are enough samples.

Over the years, visiting students have contributed to the plant database at Fermilab. Considering the vast amount of data collected, the errors of the student researchers

tend to be balanced, especially in the broader inquiries such as following general trends: the ratio of grasses to forbs over time and the overall diversity of the student prairie as it matures. As the database expands to include woodland and pond species, exciting new information will continue to benefit the natural ecosystems of the area and your students will be contributors to this database.

Students come to Fermilab well prepared for their roles as student researchers. The data they collect is authentic AND put to use. These data would not be as valuable, however, if the students were ill prepared for the quadrat study. For this reason, the activities *Estimating Percentages* and *Quadrat Study: School Lawn* are mandatory prerequisites for the onsite quadrat activity.

Prior Student Knowledge Expectations:

- Competence in the concept of percentage
- Ability to use logic when applying understanding of percentage to a meter square area
- Ability to extrapolate using a small representative sample
- General understanding of collaborative behaviors

Possible Preconceptions/Misconceptions:

- Many different species (plant and animal) may be represented in what appears to be a monoculture of grass.
- The estimation must be correct (No . . . It's an *estimation*. It needs to be completed quickly; precise measurements are not an option.)
- What you see is what you get . . . Many students are amazed by the activity they observe when they separate the grasses and get to the bare ground.
- Much of what appears to be a uniform lawn actually has a significant amount of bare ground.

Vocabulary: canopy, estimate, percentage, quadrat, understory

Materials: (per student group)

- Stakes, string, rubber mallet
- Two meter sticks
- Small metric ruler
- Student data sheet
- Common Insect Orders Guide (See *Resources*.)
- Weed Field Guide sheet (See *Resources*.)

ENGAGE:

Ask students to describe what they observe as they pass by the lawn area at their school. If the school does not have a lawn and you take them to a nearby green space, what is there? Probe for details. Ask students to write a few sentences predicting what they believe they will see when they engage in the quadrat study.

EXPLORE:
Practice in determining species identification of plants and animals and percent cover within a meter square of the school lawn

Process: In this exercise, students will work in groups of four using a chart quadrat of one square meter.

1. Pose these questions to the students: You have just been given the task of finding out how many dandelions or how many blades of grass are on your school grounds. How would you go about finding out? Which task would be more difficult? Why?
2. Inform the students that this problem is similar to the problems scientists face all the time. How many whooping cranes are in existence? How many deer in a forest preserve? How many compass plants are in a parcel of prairie? Acknowledge that students might solve your problem by getting down on hands and knees and counting every dandelion on the school grounds. (This might take you a very long time, but if done carefully would give you a precise answer.) Ask students to try to invent another method that would suit the purpose.
3. Describe "quadrat," how it is used, and how one is made.
4. Show the students where to set up their quadrats, but if noting invertebrates, do #9 before documenting the plants. (NOTE: It is ***not*** important that the students know the names of all the plants in the school's lawn. Have each group of students assign each type of plant with a number, letter, or a name they make up, and provide a rough sketch and verbal description of the plant if they do not know its name.
5. Using two meter sticks and the student data sheet, have the students map the location of the plants in their quadrat. Record the grasses using the crosshatching code.
6. Do this for all of the plants except the grasses; these should be represented with crosshatching. (Use horizontal crosshatching to represent the first type of grass, then vertical and various angles if your students can determine that there are other types of grass present.) Again, provide a rough sketch and verbal description of the plant if they do not know its name.
7. Once the grasses have been recorded, the students will use the meter sticks to get the exact location for each of the other plants and indicate their locations on the recording page using the proper symbols. (Students need to get an accurate count for each species present in their quadrat and record this on the plant code sheet. For our purpose, we will count each stem of grass as a separate plant. This can be modified to counting clumps to prepare students for their work in the field. If there is simply too much grass to count this way, count the grass in a half or a quarter or a hundredth of your quadrat and multiply by the appropriate number.)
8. Students can now determine the percent of cover for each species and record it on their recording page.
9. Students should note invertebrates entering, leaving or simply existing within the quadrat. They will not know every one of them, but encourage students to draw

what they observe and compare the body form to the images on the Common Insect Orders Guide.

EXPLAIN:
Students collect data and record their findings on a grid. This process is evidence of student understanding. If team members do not agree or the instructor does not see correlation with the actual quadrat, students must defend their grid or adjust to properly represent the organisms present.

ELABORATE:
When doing an actual ecosystem study at Fermilab, students enter their data into a computer that calculates an importance value and floristic quality (FQI). These values tell us how important a plant is to the area and the relative quality of the ecosystem in terms of diversity. Determine which plant you *think* is the most important plant in your study. Ask students to think also about the floristic quality of the quadrat. Is a high FQI desirable in a school lawn? Explain your view from the perspective of a lawn care professional and an ecologist. (See FQI materials in *Resources*.)

EVALUATE:
Formative Monitoring:
Students should be able to create a diagram of the plants in their lawn quadrat as well as estimate the percent cover for the types of plants in their quadrat. Less emphasis should be put on correct identification and more emphasis on the process and questions that students ask their group members as they work.

Summative Assessment:
Write a verbal description of at least three of the plants found in your quadrat. After you have completed your description, access a field guide and:

- Identify your plants.
- Compare your descriptions with the ones provided in the guide.
- Re-examine your actual plants and see if you agree with the guide. Did you capture the critical attributes necessary to make a conclusive identification?

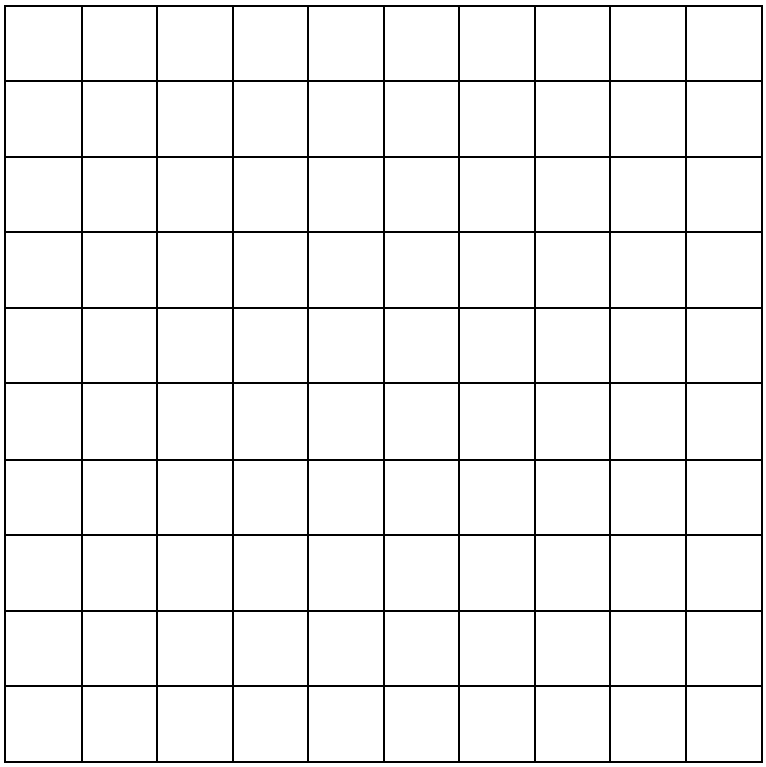
Elaborate Further/Reflect/Enrichment:
Ask students to revisit the predictions they made about the experience. What did they discover? What further questions do students generate?

Research the possibility of challenging the monoculture mindset of a typical school. Even an urban setting can be conducive to container gardening. What ideas do students have to diversify your school's outdoor areas?

Name: _____

Quadrat Study: School Lawn

1 m^2 quadrat, scale 1 cm = 10 cm



Name: _____

Student Reflection: Quadrat Study: School Lawn

1. Species diversity is very important to the stability of an ecosystem. For example, a meter square in a mature prairie may hold 25 or more different plant species. If many different species are present, then the loss of one or two may not have a great *immediate* effect. If species diversity is low, the loss of one or two could have a major impact. Calculate the species diversity for your quadrat by counting the number of different types of plants you found. Species diversity = _____ per square meter. What does this data tell you about the ecosystem studied?

2. If you found the diversity in the lawn quadrat to be low, what explanation can you give to support the validity of that data?

3. How could you calculate how many of each type of plant are on your entire school grounds?

4. Scientists do not base their calculations on just a few quadrats as you just did. Instead, they will use the data from many quadrats. Why do you think they do this?

5. How is maintenance and care different when maintaining a healthy lawn than it is when maintaining a healthy natural area?

6. It takes a lot of energy to maintain a healthy lawn. What makes natural areas easier to manage once they are established?

Write a verbal description of at least three of the plants found in your quadrat. After you've completed your description, access a field guide to:

- Identify your plants.
- Compare your descriptions with the ones provided in the guide.
- Re-examine your actual plants and see if you agree with the guide.

Teacher Page

Student Reflection Suggested Responses: Quadrat Study: School Lawn

1. Species diversity is very important to the stability of an ecosystem. For example, a meter square in a mature prairie may hold 25 or more different plant species. If many different species are present, then the loss of one or two may not have a great *immediate* effect. If species diversity is low, the loss of one or two could have a major impact. Calculate the species diversity for your quadrat by counting the number of different types of plants you found. Species diversity = _____ per square meter. What does this data tell you about the ecosystem studied?

   Samples will vary. Ask students to compare data and note anomalies. Students should justify all responses.

2. If you found the diversity in the lawn quadrat to be low, what explanation can you give to support the validity of that data?

   Answers will vary. Students should indicate that practices in lawn care tend to keep diversity low as well as how much humans utilize the area.

3. How could you calculate how many of each type of plant are on your entire school grounds?

   Answer will vary. Accept logical responses.

4. Scientists do not base their calculations on just a few quadrats as you just did. Instead, they will use the data from many quadrats. Why do you think they do this?

   More samples reduce the impact of human error and natural anomalies because these situations tend to offset one another within a large set of data.

5. How is maintenance and care different when maintaining a healthy lawn than it is when maintaining a healthy natural area?

   Answers will vary. Accept logical responses.

6. It takes a lot of energy to maintain a healthy lawn. What makes natural areas easier to manage once they are established?

   Answers will vary. Accept logical responses.

Write a verbal description of at least three of the plants found in your quadrat. After you've completed your description, access a field guide to:

- Identify your plants.
- Compare your descriptions with the ones provided in the guide.
- Re-examine your actual plants and see if you agree with the guide.

Expect a degree of sophistication as determined by the teacher and communicated to the student prior to assigning this task.

Quadrat Species Sampling – Plants and Invertebrates

How do abiotic factors affect biotic factors in an ecosystem?

Lesson Number 3 in a Series of 3 (if completed in Set 1); also found in Research section

If completed within the Research section, note that skill builders, *Estimating Percentages* and *Quadrat Study: School Lawn*, are prerequisites.

Topic: Utilizing estimating skills, identifying plants, recognizing the relationship between specific plants, invertebrate and other animal populations and collecting data to indicate health of an ecosystem by looking at the biodiversity of an ecosystem

Brief Lesson/Lesson Set Description: ***(Connection to Fermilab Natural Areas)***
Students will engage in quadrat sampling, a land management surveying technique. Plants and animals, especially invertebrates, within a meter square will be observed, identified or categorized, and counted. Special note will be taken to establish relationships and interactions between organisms to identify adaptations and behaviors.

Species sampling is integral to the ongoing wellbeing of the Fermilab natural areas. After establishing a baseline of what exists in an ecosystem, ongoing monitoring is essential to assess the health and progress or decline of the area. Noting which species are evident in a study site from year-to-year and sometimes season-to-season enables researchers to predict future trends, enrich and/or take preventative measures as deemed appropriate. Longitudinal data is a critical component of land management. (See *Resources – Land Management* documents.)

Science and Engineering Practice: Using Mathematics and Computational Thinking

Crosscutting Concept: Scale, Proportion and Quantity

INVESTIGATION

Objectives: Students will:

- Investigate the floristic quality, species diversity and importance value of plants on a designated plot.
- Observe and record invertebrate activity on the plot.
- Interpret these data over time to draw conclusions about the progress of woodland, pond and/or prairie restoration as well as the affinity of specific invertebrates to specific plants. NOTE: Prairie data is available from 1992. Woodland, pond and invertebrate data will be available beginning in 2017.
- Write a concise summary of these findings.
- Apply these findings to other comparable restoration sites—recognizing that weather, fire and other abiotic factors influence the ecosystems.

- Determine past trends and speculate about future trends using current and historic data.

Narrative/Background Information:

Plants

The student quadrat studies on the Fermilab site were originally completed only in prairie sites. The prairie land presently on site at Fermilab is reminiscent of the original tallgrass prairie that once covered 400,000 square miles of the Midwest and around 40,000 square miles in Illinois. Currently, over 1,100 acres of prairie has been planted on the Fermilab site. This reconstruction process has been in progress since 1975. As prairie plants have been added, careful notice has been taken as to the progress and the succession of these plants. This survey has been accomplished via plot observation and by quadrat studies executed primarily by middle level students. The *Particles and Prairies* data began in 1992 and provides a wealth of information representing thousands of quadrats. Long-term data coupled with abiotic measurements is critical in determining trends. The quadrat sampling is now expanded to include woodlands, ecotones and pond species. Even sessile or slower-moving pond organisms can be surveyed using a quadrat method.

A quadrat is an area of predetermined size (Fermilab uses M^2), ideally selected randomly to avoid bias, which is used to survey the organisms within its confines. Plants, insects and other organisms may be recorded, noting abundance, surface area covered and/or any other data desired. Relationships and interactions between organisms are often revealed by careful observation of the quadrat.

One of the goals of the quadrat study is to determine the importance value of any given species. Importance value is calculated by considering the relative dominance + relative frequency + relative density. Importance value is not simply asking which organism is present in the greatest number; it involves much more criteria. For example, what if one organism is much larger than another or common only in one location? The importance value gives a more accurate picture of which organisms have the greatest impact. This information is critical when trying to predict future trends and better succeed in managing ecosystems.

Species diversity reflects how many different species are present. In a healthy natural area, we may find hundreds of different species. Restored natural areas can take a long time to approach this number. In time, maintenance methods and natural succession may increase the species diversity of native plants and invertebrates and decrease the diversity of invasive species. A common indicator of the maturity and health of a natural area is its species diversity. Quadrat studies help to quantify these trends.

Ecologists at Fermilab are especially interested in floristic quality or FQI. FQI (Floristic Quality Index) formula is: (mean of coefficients of conservation (C) of all the plants found) times (the square root of the number of species (N) in that area). Per Swink and Wilhelm ([1]Swink, 1994), the FQI is an indication of native vegetative quality for an area: 1–19 indicates low vegetative quality, 20–35 indicates high vegetative quality, and

above 35 indicates “Natural Area” quality. FQI is the indicator used to measure the success of restorations on Fermilab.

[1]Literature cited: Swink, F. and G. Wilhelm. 1994. *Plants of the Chicago Region*, 4th ed., Indiana Academy of Science, Indianapolis.

***Refer to the Resources section for more information about the FQI and the formula used to calculate Floristic Quality Index and the importance of abundant data to establish a reliable ecosystem analysis.*

FQI is calculated in the same manner for prairies, woodlands and wetlands. The native mean C is also an indication of native vegetative quality. For the 2015 Fermilab prairie quadrats, with mean of C = 7.6, N = 47, there is an FQI = 52, which is considered diverse in native plants. As students collect data from woodlands and ponds, longitudinal data for those ecosystems will provide ongoing information to support these areas.

Invertebrates

As students collect plant data, they also will observe invertebrates within the quadrat. Notable specimens such as bumblebees, butterflies, dragonflies, etc., within close proximity to the quadrat may also be recorded as *observed*, but not counted with the data.
(See Quadrat Invertebrate Data student sheet.) It is important to make careful note of which invertebrate is visiting specific plants. This relationship is integral to understanding the interactions within the ecosystem. It is also linked to biodiversity; the more diverse the plant community, the more diverse the invertebrate community.

The wings, legs and mouthparts of the invertebrate hold clues as to its niche. A leaf-chewing invertebrate has different adaptations than a predatory organism, most dramatically in the mouthparts. Invertebrates that feed solely on vegetation are primary consumers, dependent frequently on a specific plant, such as monarch butterflies and milkweed. Monarch larvae prefer the fleshy leaves of the milkweed plants and are often found on plants of the milkweed genus Asclepias. Interestingly, mature female monarchs subsist on a liquid diet, including nectar from many species of forbs, juicy fruits and even a picnic watermelon slice. Male monarchs have been known to absorb minerals through their feet in an act known as “mud-puddling.”

At one time, there were at least eight species of bumblebee species foraging on the Fermilab ecosystems. Tongue length plays a major role on which bumbles are found on specific plants. For example, only the long-tongued bumblebees such as *Bombus pennsylvanicus*, frequent the Monarda plant. The long tongue of this species can reach deep into the individual vase-like corollas of this forb. The short-tongued *Bombus affinis* prefers the centers of disc forbs like multiflora rose and sunflowers.

Invertebrates are critical elements in an ecosystem serving as pollinators, decomposers, nutrient providers, eliminator of pests, food for other organisms, and all-

around fascinating critters. In the Fermilab ecosystems, invertebrates *native* to the area fulfill an important niche and are to be guarded. Unfortunately, exotic (non-native) invertebrates often are evident, notably the Asian beetle. This iridescent beetle causes tremendous damage to many plants, especially showy tick trefoil.

Other Organisms

Ecosystems are not composed only of plants and invertebrates. Fish and amphibians are present in the ponds, lakes and streams; reptiles, including a variety of snakes and turtles, are occasionally seen; birds adapted to wetlands, woodlands and prairies are prolific; and mammals abound, though all students may see is the evidence of their presence. Scat, tracks, matted grass or browse lines imply deer in an area. Students should be aware and document indications that other animals have been in an ecosystem, remembering that many animals move from ecosystem to ecosystem depending on their needs. Deer, for example, hang out in woodlands during the heat of the day, graze and often bed down in the prairie, and drink where there is fresh water. All the organisms play specialized roles within the ecosystems. (See *Trophic Interactions and Food Webs* – Set 3.)

Abiotic Factors

Organisms, both plant and animal, are highly dependent on abiotic factors. As students collect biological data, they should also record as many abiotic details as possible, including but not limited to time of day, weather conditions, soil temperature and saturation level, light intensity, etc. (See *Abiotic Study* – Set 1.)

History

Many of the organisms found on a site are influenced by the history of the site. Is the plot a virgin site, in succession phase or fully restored? Much of the Fermilab campus was once farmland and homesteads. Prior to that period, it was mostly prairie. Historical information is available on the Fermilab website at http://history.fnal.gov/prehistory.html. (See resource *Fermilab: Past, Present and Future – Introduction.*)

Prior Student Knowledge Expectations:

- Complete *Estimating Percentages* and *Quadrat Study: School Lawn* from Set 1.
- Familiarity with the characteristics of the most common plants and invertebrates in the ecosystem
- Ability to use a field guide and/or key to assist in identification
- General understanding of collaborative behaviors

Possible Preconceptions/Misconceptions:

- Underestimation of the diversity in a flourishing ecosystem
- Unfamiliarity with the strength of the form vs. function factors/interconnections of organisms
- Underestimation of the importance of abiotic factors in the balance of nature

Vocabulary: canopy, estimate, percentage, quadrat, understory, FQI, niche

ENGAGE:
Students have prior knowledge gained from the estimating percentages and lawn quadrat activities. Ask students to share in their research teams what they feel might be the biggest challenges as they work in a natural ecosystem. How do they plan to overcome these challenges? After a brief discussion, show the video and ask students if the challenges they suggested need to be amended. How will they meet these challenges? https://www.youtube.com/watch?v=sCs1d8GLzKU

Quadrat
This is a field experience involving identifying and counting plants within a meter square using scientific protocols; collecting and using data over time to recognize and predict trends.
This investigation may be completed in conjunction with the Invertebrate and Other Animals segment that follows.

Materials: (per student group)
- Meter square quadrat
- Meter sticks (at least 2)
- Small metric ruler
- Flora Field Guide
- Quadrat Data sheet
- 1 decimeter square
- Access to "Report Your Data: Find Your Teacher/Leader" on the Fermilab website: http://eddata.fnal.gov/lasso/quadrats/teacher-q3.lasso

Process:
1. Complete *Estimating Percentages* and *Quadrat Study: School Lawn* from Set 1.
2. Access the data collection link website and review data resources.
3. Familiarize students with the quadrat procedures found at http://ed.fnal.gov/data/life_sci/data/prairie_watch.html.
4. Students will work in groups of three or four. Prior to the lab, establish student roles. Assign one student as recorder, one as counter, and commission everyone to a collective effort to identify plants.
5. Proceed to a natural area site. Use a "random site generator" (hurled Frisbee, hat, etc.) to identify student quadrats. Open and place quadrat meter square tool on selected area.
6. If requested, students will carefully note invertebrates and their habits within their quadrat on the Quadrat Invertebrate Data sheet using available identification tools.
7. Using meter sticks and the following data sheets, students will map the location of the plants in their quadrat, drawing the most abundant first.
8. Once plants are drawn, students will use the meter sticks to get the exact location of each larger plant within the quadrat.
9. Before students complete the plant sheets, remind them to informally note on the Quadrat Invertebrate Data sheet any invertebrates on and around specific plants within the quadrat. Informally note also other animals and/or evidence of their

recent presence. Organisms and/or evidence of organisms beyond the quadrat are notable as observations, but will not be part of the formal data.

10. Students will generate an accurate count for each plant present in their quadrat and record this on the code sheet. (This will be easy for the larger individual species; more difficult for the abundant species.) For very abundant organisms such as grasses, we count each soil surface clump as a separate plant. If there is simply too much to count this way, count a representative 1% section of your quadrat and multiply by the appropriate number of similarly covered sections as learned in the *Quadrat Study: School Lawn*.
11. Determine the percent cover for each plant species.
12. Enter into the computer the number of different species of plants found in the quadrat and the estimated percent cover. Repeat this procedure for the number of different non-native (weed) species found. The computer will use the class data and calculate the importance value and species diversity for each.

Invertebrates and Other Animals

Field experience involving identifying and counting invertebrates within a meter square using scientific protocols and collecting data to contribute to a database that will be accessed by students and ecologists in the years to come; observation of other animals by actual sightings and/or evidence helps students make inferences about relationships/interactions.

This investigation may be completed in conjunction with the quadrat study.

Materials: (per student group)

- Meter square quadrat
- Meter sticks (at least 2)
- Small metric ruler
- Invertebrate Field Guide/ID materials, including Common Insect Orders Guide
- Bug boxes and magnifiers
- Student sheets – Quadrat Grid; Quadrat Invertebrate Data; Other Animal Evidence
- 1 decimeter square
- Access to data collection tool on the Fermilab website: TBA

Process:

1. Complete *Estimating Percentages* and *Quadrat Study: School Lawn* from Set 1.
2. Access the data collection link website and review data resources.
3. Familiarize students with the invertebrate observation procedures found at TBA.
4. Students will work in groups of three or four. Prior to the lab, establish student roles. Assign one student as recorder, one as counter, and commission everyone to a collective effort to identify invertebrates.
5. Proceed to a natural area site. Use a “random site generator” (hurled Frisbee, hat, etc.) to identify student quadrats. Open and place quadrat meter square tool on selected area.

6. Students will note invertebrates and their habits in their quadrat on the Quadrat Invertebrate Data sheet.
7. Enter observations on other animals on the Other Animal Evidence sheet. Short essay questions may be completed back in the classroom.
8. Using meter sticks and the grid data sheet, students will map the location of invertebrates and/or animal evidence in their quadrat, noting the specific plant(s) they are visiting.
9. Students will attempt to get an accurate count for each insect order and other invertebrate and record this on the data sheet. Remind them to look under leaf litter above the soil.

EXPLAIN:
Encourage students to share plant/invertebrate/other animal sightings and/or evidence observations and the interrelationships perceived with other teams. Collectively, compare data and offer explanations for similar/dissimilar observations. Students working in the same ecosystem should compare data to make a generalization about the diversity in that ecosystem using the data from all samples.

ELABORATE:
Ecosystem services associated with this lesson:

- Disturbance regulation
- Water regulation
- Soil formation
- Pollination
- Biological control
- Refugia (safe habitat for organisms endangered or threatened)
- Food production
- Raw materials

How might ecosystem population and biodiversity studies relate to each ecosystem service?

EVALUATE:
Formative Monitoring: Students report their data at the conclusion of the activity, sharing successes and challenges, as each quadrat is different. The Student Reflection questions can be a driving factor in these discussions. It may be beneficial to project a picture of the quadrat or share the drawings so students can visualize the plant growth and learn from each other.

Summative Assessment: Based on your understanding of relationships and interactions, design a community based on your quadrat that could be self-sustaining. Make note of everything needed and the connections between each organism and abiotic components as well as to one another.

Elaborate Further/Reflection/Enrichment: What further questions do students generate?

Research specific invertebrate/plant relationships; what form/function connection(s) are revealed? Based on your research, specifically what do you predict would happen if one or the other of these organisms disappeared?

Name: _____

Quadrat Study: Reconstructed Prairie

1 m^2 quadrat, scale 1 cm = 10 cm

Please do not remove meter sticks and quadrat marker until your docent has checked your work and initialed here. _____

Quadrat Number Assigned by Computer _____

School	Date	Teacher	Recorder's Name

Key	Prairie Plants	Number	%	Key	Invasive Plants	Number	%
	Prairie Grasses				**Invasive Forbs**		
	Big Bluestem			1	Black Raspberry		
	Indian Grass			2	Daisy Fleabane		
	Little Bluestem			3	Wild Carrot		
	Prairie Cord Grass			4	Sweet Clovers (tall)		
	Switch Grass			5	Yarrow		
				6	Curled Dock		
	Prairie Forbs			7	Common Ragweed		
A	Saw-toothed Sunflower			9	Ground Cherry		
B	Black-eyed Susan			10	Tall Goldenrod		
C	Compass Plant			11	Common Milkweed		
D	Prairie Dock			12	Clovers (ground)		
E	Wild Bergamot			13	Thistle		
F	Showy Tick Trefoil			18	Hairy Vetch		
G	Yellowish Gentian			19	Hairy Aster		
K	Culver's Root			27	Drummonds Aster		
L	Blazing Star			28	Dandelion		
M	Mountain Mint			30	Heal-all		
N	New England Aster			31	Evening Primrose		
O	Nodding Wild Onion						
P	Pale Purple Coneflower						
Q	Wild Quinine						
R	Rattlesnake Master						
S	Stiff Goldenrod						
T	Tall Coreopsis						
U	Purple Prairie Clover						
V	White Prairie Clover						
W	Rosinweed				**Unlisted Invasive Plants**		
X	White Wild Indigo			34	Unlisted Grass-Like		
Y	Yellow Coneflower			33	Unlisted Oval Leaf		
Z	Cup Plant			32	Unlisted Round Leaf		
b	Bush Clover			35	Unlisted Triangular/Pointed Leaf		
d	Compass Dock Hybrid						
f	Foxglove Beardtongue						
g	Golden Ragwort						
r	Balsam Ragwort						
	# of Types of Prairie Plants Found				# of Types of Invasive and Unlisted Plants Found		

Date _____ **Names:** _____

Weather _____

Quadrat Invertebrate Data Sheet

Type of Invertebrate (Name/Sketch/Describe)	**Location of Invertebrate** (On Plant - Name Plant/ On Ground/On Web/Etc.)	**Abundance**	**Interaction between Plant and Invertebrate** (Pollinating/Eating/Etc.)

Type of Invertebrate (Name/Sketch/Describe)	**Location of Invertebrate** (On Plant – Name Plant/ On Ground/On Web/Etc.)	**Abundance**	**Interaction between Plant and Invertebrate** (Pollinating/Eating/Etc.)

Student Team Data Sheet – Other Animal Evidence

What evidence of other animals did you note in your ecosystem? Based on evidence, what animals do you think were in the area? Use the back of the page if needed.

ANIMAL	EVIDENCE SKETCH/DESCRIPTION

List at least five relationships/interactions that you think brought the animals to your site.

1. _____
2. _____
3. _____
4. _____
5. _____

Use another page if necessary to complete this page.

Select the relationship/interaction that you believe is the most significant and explain why you believe this to be true.

_____

_____

_____

_____

_____

_____

_____

_____

What do you believe could happen to the ecosystem if this animal leaves the area?

_____

_____

_____

_____

_____

_____

_____

_____

Suggest a plan to help ensure ongoing health and biodiversity in your ecosystem based on your understanding of why ecosystem relationships/interactions are important. Evaluate all the plans, noting the most practical and effective parts of each plan.

_____

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_____

Name: _____

Student Reflection: Quadrat Species Sampling – Plants and Invertebrates

1. If data has been collected at the Fermilab prairie, compare your class data with the data from 1992. What has stayed the same? What has changed? Why do you believe this is so?

2. If your data was collected at another natural area, how does the diversity compare with the existing prairie data? How do you explain your findings?

3. The natural world is filled with relationships and interactions. Which interaction(s) and/or relationship(s) did you witness? Why are those relationships important?

4. Comparing data from the prairie to prior years, how do you think the prairie ecosystem is doing this year? What could account for your findings? If you collected data from a woodland or pond site, how do you think that site looked 10 years ago? Support your response. [HINT: Check the Fermilab website for fire data (prairie), prevailing weather conditions, and/or evidence of other disturbance.]

5. Based on historic data, if you feel it was a more or less productive year than prior years, explain whether you believe it was due to environmental or genetic factors.

6. What were the abiotic conditions on the day(s) you observed and collected your data? How might these conditions have altered, deterred or enhanced your findings?

7. Consider your quadrat and mentally remove the most prominent organism. What do you think would occur within the first day? Month? Decade? Why would it matter?

8. Imagine that climate change boosts the average temperature each month over ten years by 3 degrees. What do you believe will happen to the existing organisms? Utilize historic data from the Fermilab website to support your claim.

9. Why do we care? What ecosystem services does the ecosystem you surveyed provide? Why are these services important?

Design a plan to use the relationships between plants and insects to promote a restoration project for the ecosystem you studied. Summarize your plan in several paragraphs.

Teacher Page

Student Reflection Suggested Responses: Quadrat Species Sampling – Plants and Invertebrates

1. If data has been collected at the Fermilab prairie, compare your class data with the data from 1992. What has stayed the same? What has changed? Why do you believe this is so?

   Answers will vary. Explanations should be supported with data.

2. If your data was collected at another natural area, how does the diversity compare with the existing prairie data? How do you explain your findings?

   Answers will vary. Explanations should be supported with data.

3. The natural world is filled with relationships and interactions. Which interaction(s) and/or relationship(s) did you witness? Why are those relationships important?

   Answers will vary. Correct identification of relationships is essential.

4. Comparing data from the prairie to prior years, how do you think the prairie ecosystem is doing this year? What could account for your findings? If you collected data from a woodland or pond site, how do you think that site looked 10 years ago? Support your response. [HINT: Check the Fermilab website for fire data (prairie), prevailing weather conditions, and/or evidence of other disturbance.]

   Answers will vary.

5. Based on historic data, if you feel it was a more or less productive year than prior years, explain whether you believe it was due to environmental or genetic factors.

   Answers will vary. Students should support their claim with evidence.

6. What were the abiotic conditions on the day(s) you observed and collected your data? How might these conditions have altered, deterred or enhanced your findings?

   Answers will vary. Students should include a variety of abiotic data points.

7. Consider your quadrat and mentally remove the most prominent organism. What do you think would occur within the first day? Month? Decade? Why would it matter?

Answers will vary. Explanations should be supported with data.

8. Imagine that climate change boosts the average temperature each month over ten years by 3 degrees. What do you believe will happen to the existing organisms? Utilize historic data from the Fermilab website to support your claim.

   Answers will vary. Explanations should be supported with data.

9. Why do we care? What ecosystem services does the ecosystem you surveyed provide? Why are these services important?

   Answers will vary.

Design a plan to use the relationships between plants and insects to promote a restoration project for the ecosystem you studied. Summarize your plan in several paragraphs.

Use agreed-upon criteria and media approach to support the communication of science concepts and ideas to the general public.

Aquatic Diversity and Water Quality

How do abiotic factors affect biotic factors in an ecosystem?

Topic: A study of the quality of water and the diversity and macroinvertebrates in an aquatic ecosystem

Time Needed: Onsite Field Experience

Brief Lesson/Lesson Set Description:
Students will judge the quality of a body of freshwater based on the macroinvertebrates collected and the chemical makeup of water.

Science and Engineering Practices: Planning and Conducting Investigations; Analyzing and Interpreting Data

Crosscutting Concept: Stability and Change

INVESTIGATION

Objectives: Students will:

- Identify aquatic animals and count the types (aquatic species diversity).
- Evaluate the relative water quality of a stream or a pond based on chemical and physical tests as well as species present (water quality).
- Recognize the correlation between the types of organisms found and the quality of the water.

Narrative/Background Information:
The question of water quality on the Fermilab site is of considerable interest to biologists, physicists, and ecologists. Water is of great importance to the physicists of Fermilab because it is the primary cooling source for computers, accelerators, and the Central Utility Building. The source of this water comes principally from precipitation that falls on the site that is then collected and contained in the Industrial Cooling Water pond system. In a normal year, precipitation accounts for approximately 78 billion gallons of water collected.
During periods of drought, additional water for the system may also come from other sources including groundwater collected from the NuMI tunnel, water pumped from Fox River, or a deep onsite well.

The water on the Fermilab site is cycled year-round and parts of the water system do not freeze. Cycling the water also helps the summer water temperatures to stay reasonably cool. However, an unnaturally warm environment sometimes exists in portions of the lab. This may promote eutrophication, a condition in still ponds, which results in an imbalance between plants and animals. Eutrophication generally is due to the natural aging process coupled with the addition of certain types of runoff. Unnatural warmth, fertilizers from surrounding farms, and industrial pollution are all contributing

factors. Higher goose populations result in elevated nutrient loads, which is also a concern.

Aquatic Diversity

While the geese are among the most widely recognized wildlife noted at Fermilab, hundreds (perhaps thousands) of other species, primarily invertebrates, thrive on site. Many of these are evident in the water system. Fish, crayfish, salamanders, and frogs are found sitewide. An examination of macrobiotics (organisms large enough to be seen by the naked eye) reveals a myriad of water-dwelling organisms collected in dip nets. An investigation of rocks just below the riffle (where water tumbles over an obstruction such as a rock or dam) reveals evidence of even more animal life.

A wide diversity of organisms generally indicates better water quality. However, the specific types present need to be considered because some organisms are more tolerant of pollution than others. The benthic species criteria that students use at Fermilab consist of four categories of organisms. Level I organisms demand a nearly pristine environment. Level IV organisms live in relatively impure waters. Most of the organism indicators found at Fermilab are in level II. Check out this website for information about benthic species and their importance to monitoring water quality. https://www.epa.gov/national-aquatic-resource-surveys/indicators-benthic-macroinvertebrates

The actual biomass or amount of living material may increase due to pollution, but the diversity generally goes down. An example of this phenomenon is extensive algae growth on a still pond. When algae get out of hand, other life forms cannot obtain essential nutrients, gases, and/or sunlight. Some organisms cannot survive and their decomposition may add to the distress of the pond. Regular monitoring of the living organisms in a water source is a reliable method to evaluate the quality of water in the system.

Water Quality

Chemical analysis is another way to monitor water quality. However, it reveals the chemical values for a system at only one place and time. The water collected on a particular day in the spring may not indicate a chemical imbalance or toxic condition that was present earlier. However, a change in diversity of species could be a sign of a problem. Chemical analysis generally includes many tests, among which the most common are dissolved oxygen, nitrate, phosphate, and pH level.

Oxygen enters the water through plant photosynthesis and by diffusion from the atmosphere. It is removed by animal and plant respiration and the decomposition of organic matter. The temperature, the amount of plant biomass, the depth of light penetration, the flow velocity, and the amount of organic material to be decomposed affect the amount of dissolved oxygen in a body of water.

High nitrate concentrations may mean pollution from fertilizers, sewage, animal waste, or the natural decay of dead organisms. At Fermilab, the adjacent farm fields and high

goose population increases the importance of monitoring the nitrate concentration. Nitrates and phosphates accelerate the eutrophication process. Nitrate levels indicating a concentration above 0.30 parts per million (ppm) is considered high and can contribute to excessive algae growth.

Phosphates enter the water from the same sources as nitrates. A phosphate concentration that exceeds an annual average of 0.015 ppm can contribute to excessive algae growth as well. If the reading is greater than 0.1 ppm, the water has probably become polluted from outside sources.

Most natural bodies of water capable of sustaining life have pH values ranging from 5.0 to 8.5. The water systems of Fermilab are generally within normal.

A Secchi disk is used to measure the turbidity of a body of water. The turbid waters decrease light penetration into water, thereby reducing the area available for submerged aquatic plants to grow. Lower Secchi disk readings would indicate very clear water and a small amount of suspended matter. Readings are used to compare light penetrations between different bodies of water or the same body over a period of time. There are no absolute “good” or “bad” readings.

Prior Student Knowledge Expectation:

- Quality observations are key when identifying macroinvertebrates; students should pay special attention to all body parts of the macros.

Possible Preconceptions/Misconceptions:

- Students often rush through the identification process and incorrectly identify organisms.
- Students are often confused by nymph and larva stages of macroinvertebrates. A life cycle mini-lesson on incomplete and complete metamorphosis would be beneficial.
- Students can be quick to think a water sample does not contain anything living. Students need to take the time to look at what is moving after their samples have been collected and pick through all the vegetation carefully.
- Students do not always read directions; this can lead to serious problems during chemistry labs. Students should be urged to read through all directions before following any of the steps.

Vocabulary: aquatic, complete metamorphosis, cycles, ecological niche, edge effect, entomologist, incomplete metamorphosis, larva, life cycle, metamorphosis, molting, parts per million, population, Secchi disk, sediment, species, turbidity, wetlands

Materials:

Macroinvertebrate Study:

- Aquatic Organisms Field Guide
- Student Aquatic Diversity Data sheet

- Causes and Effects of Water Chemistry sheet
- Sampling equipment, such as nets, trays, assorted containers
- Plastic tubs, white
- Magnifying lenses
- Eyedroppers
- Forceps
- Fermilab Site Map

Chemical Testing
- Water quality test kit
- Thermometer
- Meter sticks or tape measure

Responsibilities:
Docent:
- Provide equipment for collection.
- Provide all chemicals for water testing.
- Facilitate activity on field trip.
- Help students stay on task.

Teacher:
- Appropriate preparation
- Provide data sheet for each research group.
- Help students stay on task.
- Debrief after trip.

ENGAGE:
As field scientists, students have a chance to experience taking data in various ecosystems. Ask students to come up with their own protocol for different parts of this data collection and have them participate in a discussion on the safety guidelines when conducting fieldwork. Also, ask students to identify group members' strengths and assign tasks and leadership roles to each member of the group depending on those strengths. Most students have not been in the field and do not know what to expect.

EXPLORE:
Process:
<u>General</u>
- At each sampling site, it is necessary to constantly monitor students' behavior. Students are not to go into the water and any rocks that are examined should be returned to their original location.
- Ideally, these activities should be repeated at other sites or at different times of the year. At least one water source should be a running stream. If only one field trip site is feasible due to time constraints, a site near school might provide an interesting comparison.

Aquatic Diversity

- After placing about five centimeters of water into the plastic trays, students should collect as many animals as possible and place them into the trays. Look on and under rocks and logs. Some organisms will be attached to these substrates.
- Students should complete the Aquatic Diversity Data Collection sheet. Some of these data will not be available until they have completed the chemical test in the lab.
- When the observations are completed, all of the organisms should be carefully returned to the stream or pond.

Water Quality

- Water qualities will be done at the pond site guided by the docent.
- Follow the water test kit instructions precisely! Monitor the students closely.
- Students will have the opportunity to test the pH and the dissolved oxygen levels during lab time.

The movement of water within an ecosystem helps maintain high water quality. The pond at the Lederman Science Education Center is aerated to help prevent stagnation and improve the oxygen levels in the pond. This is not a natural condition. If a flowing stream is available for students to observe, they can measure water velocity in a more natural setting. To measure the water velocity, mark a ten-meter distance on the shore. Measure the amount of time it takes a floating object (small stick) to go the ten meters. With a sweep second hand, determine the exact time it takes the object to travel the ten-meter distance. Then divide ten meters by the number of seconds; this gives you the velocity of the water in meters per second.

EXPLAIN:
Students should be able to make a statement about the health of the studied body of water based on the variety, or lack thereof, of macroinvertebrates and the results of the water chemistry test. Students might use the Causes and Effects of Water Chemistry sheet to determine

ELABORATE:
Construct a food web with the organisms you identified. Make sure to have a producer.

EVALUATE:
Formative Monitoring: Student data collection sheet

Summative Assessment: After enough practice, students could be assessed on how they analyze the data collected.

Elaborate Further/Reflect/Enrichment: N/A

AQUATIC DIVERSITY DATA COLLECTION SHEET

Name_____

Hypothesis:

Water Temperature _____ **Air Temperature** _____ **Free Chlorine** _____

Total Chlorine _____ **Hardness** _____ **Alkalinity** _____ **pH** _____

Organism (Sketch/Describe)	Abundant (more than 10) Common (3–10) Sparse (1 or 2)	Possible Identification	Adaptations

Organism (Sketch/Describe)	Abundant (more than 10) Common (3–10) Sparse (1 or 2)	Possible Identification	Adaptations

Name: _____

Student Reflection: Aquatic Diversity and Water Quality

1. Did the sampling site(s) have a high or low degree of diversity? Justify your response.

2. A variety of different kinds of plants and animals are usually an indication of a healthy ecosystem. What evidence did you see that makes you believe your site(s) is a healthy (or unhealthy) environment for the living creatures in the area?

3. Do you think the diversity changes with the seasons? How could you find out?

4. Why are the ecologists concerned with water quality?

5. How might the water quality be maintained and/or improved?

6. If you notice abnormally high or low readings at your site(s), what explanation can you provide?

7. What strategies would you use to make the water at the site(s) a better environment for living organisms and/or maintain the existing health of the ecosystem?

You have just explored the aquatic diversity and water quality of a water system. Compile the data collected by your classmates and conduct further research on the Internet to discover more about water environments. Design a plan for maintaining and/or improving an existing water system such as a neighborhood pond or stream. Discuss the audience intended for your plan and how you would communicate this information and share your work.

Teacher Page

Student Reflection Suggested Responses: Aquatic Diversity and Water Quality

1. Did the sampling site(s) have a high or low degree of diversity? Justify your response.

   Responses will vary. Expect the justification to quantify the student's interpretation of "high" and "low."

2. A variety of different kinds of plants and animals are usually an indication of a healthy ecosystem. What evidence did you see that makes you believe your site(s) is a healthy (or unhealthy) environment for the living creatures in the area?

   Responses will vary. Expect a minimum of three details to justify the student's response.

3. Do you think the diversity changes with the seasons? How could you find out?

   Responses will vary. Some students may believe that, like migrating birds, invertebrates also retreat to warmer climates in the winter. Research suggestions such as winter macroinvertebrate studies or monthly stream monitoring may be offered.

4. Why are the ecologists concerned with water quality?

   Responses will vary. Students should understand that the water quality impacts other organisms—including humans!

5. How might the water quality be maintained and/or improved?

   Responses will vary. Expect specific, logical suggestions.

6. If you notice abnormally high or low readings at your site(s), what explanation can you provide?

   Responses will vary. Human error should not be discounted.

7. What strategies would you use to make the water at the site(s) a better environment for living organisms and/or maintain the existing health of the ecosystem?

   Responses will vary. Expect specific, logical justification.

You have just explored the aquatic diversity and water quality of a water system. Compile the data collected by your classmates and conduct further research on the Internet to discover more about water environments. Design a plan for maintaining and/or improving an existing water system such as a neighborhood pond or stream. Discuss the audience intended for your plan and how you would communicate this information and share your work.

Expect a degree of sophistication as determined by the teacher and communicated to the student prior to assigning this task.

How do abiotic factors affect biotic factors in an ecosystem?

MS-LS2-1. Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.

MS-LS1-5. Construct a scientific explanation based on evidence for how environmental and genetic factors influence growth of organisms.

MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

In the space below, summarize the data of an organism population, plant or animal that was observed in one of the ecosystems. Data can be used for just one ecosystem or from a combination of ecosystems studied.

What does this data tell you about the populations of the ecosystem at this time of the year?

_____

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What environmental resources were observed that can support this population? Environmental resources include anything that an organism may need to survive.

_____

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In the space below, summarize the data of the abiotic factors that was collected.

What does this data tell you about the abiotic factors at this time of the year?

_____

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Develop an explanation for how the abiotic data taken on the ecosystem affects the populations found in the ecosystem, both positively and negatively. Use the data that was collected to support the explanation.

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Meteorologists predict an exceptionally rainy and cool summer. Average rainfall is predicted to be twice the normal amount and average high temperatures will be 10-15 degrees cooler than normal. Make a prediction for how these abiotic changes will affect this population in your ecosystem. Back up the argument with data from your study.

_____

_____

_____

The area around your studied ecosystem is being developed. Although the ecosystem will be preserved, there will be two strip malls on either side of the ecosystem with parking lots and roads bringing increased traffic to the area. There are concerns about increased heat from the surrounding blacktop and massive runoff of water during rainfalls. Make a prediction for how these abiotic changes will affect the populations in your ecosystem. Back up the argument with data from your study.

Sightless Drawing

How do biotic factors increase the likelihood of survival in an ecosystem?

Topic: Communicating and interpreting verbal directions

Brief Lesson/Lesson Set Description:
This activity is skill building and can be done in several places and several times throughout the unit to increase skills in the areas of communication.

Science and Engineering Practice: Obtaining, Evaluating, and Communicating Information

Crosscutting Concept: Scale, Proportion, and Quantity

INVESTIGATION

Objectives:
- Interpret verbal directions and construct a drawing to match the describer's design—without seeing the design.
- State how scientists are affected by the consequences of poorly stated directions.
- Recognize and state the attributes of clearly stated directions.

Narrative/Background Information:
It is common for individuals to assume that verbal directions are clear and easily interpreted by others. This activity drives home the individuality of our interpretations. It allows students to focus on areas within their personal verbal communication style that may need refinement.

Possible Preconception/Misconception:
- Students may not have the necessary vocabulary to describe geometric objects.

Vocabulary: To be determined by students after one or two trials are complete. Students should understand that vocabulary is essential to the description.

Materials:
- Design cards
- Images of selected prairie plants
- Paper
- Pen or pencil

ENGAGE:
Ask students to think about a time when they tried to describe something to someone and were not successful.

EXPLORE:
Process:

1. Organize students in pairs—back to back.
2. Distribute design cards (copy a set from materials provided) to one member of the pair. The student NOT given a card is the drawer and should not look at the design.
3. As a class, discuss if there is any vocabulary students should not use when describing or if the drawer is able to ask questions of the person describing the image. Clarify the types of questions allowed (Example: only yes/no questions).
4. The students with the design card will verbally describe the design while the other students draw his/her interpretation.
5. When completed, students compare card and drawing.
6. Reverse roles and repeat.
7. Repeat the activity again, this time using a prairie plant in place of an image on the design cards.

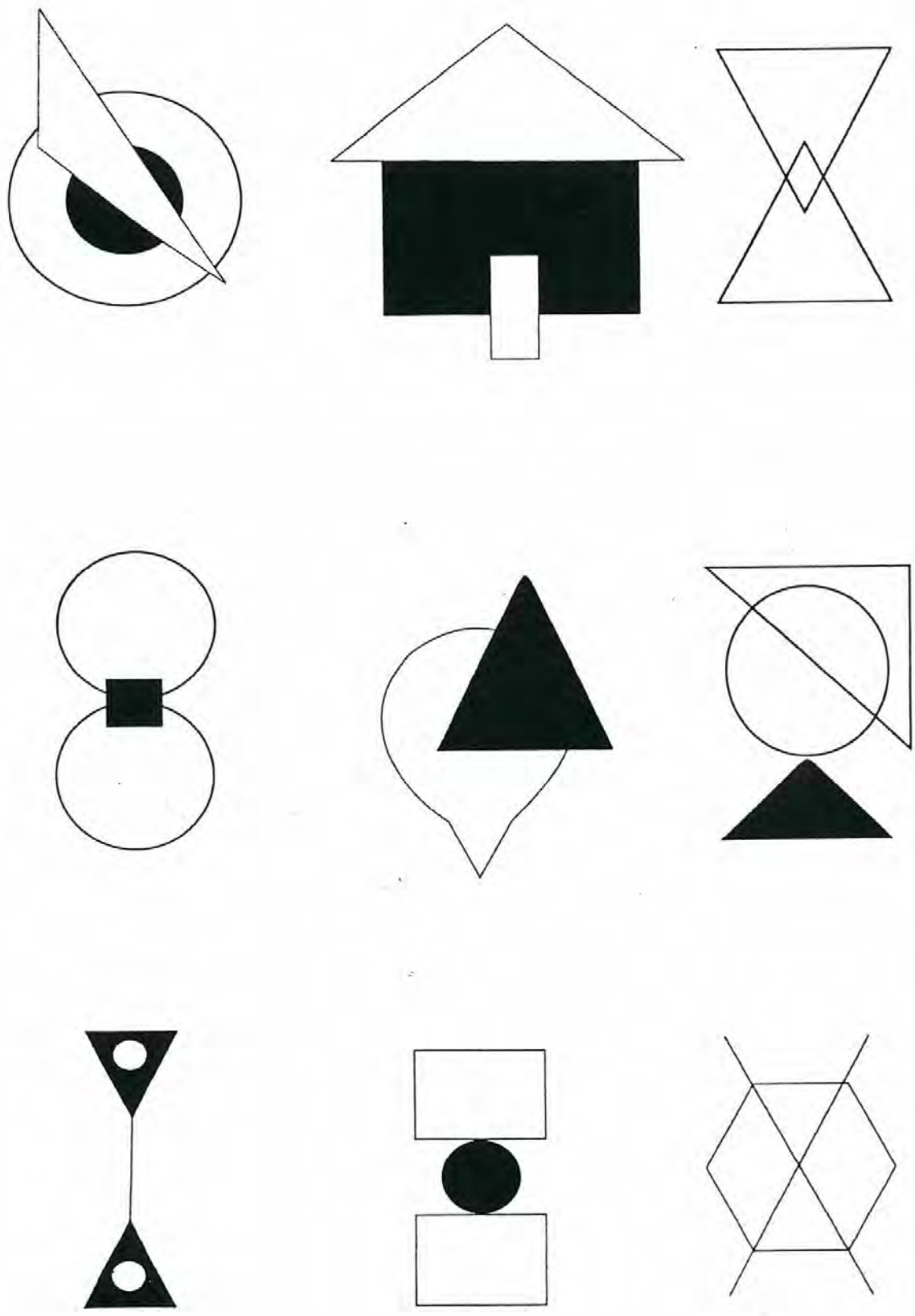
EXPLAIN:
Engage students in a discussion using responses on the Student Reflection sheet.

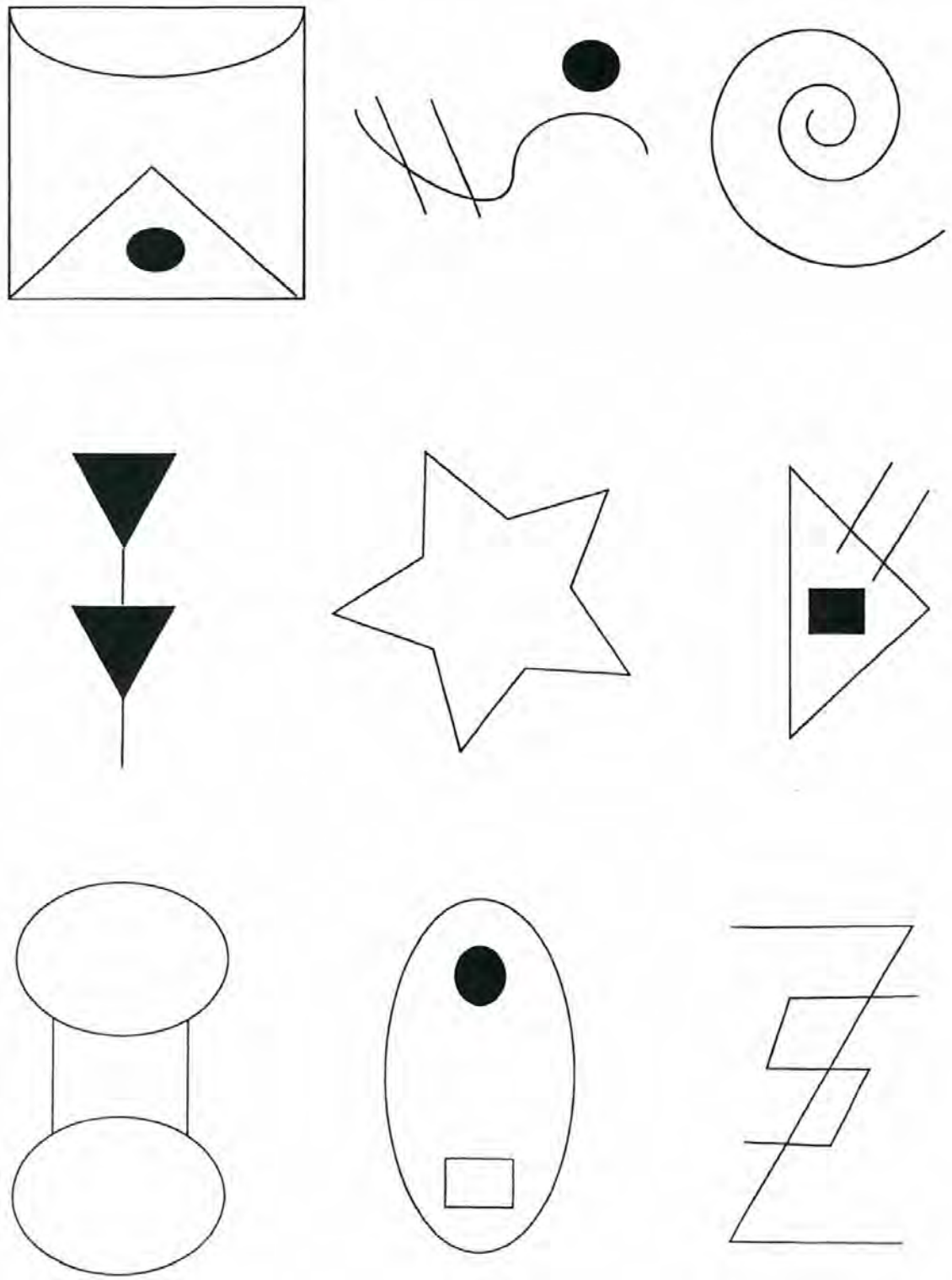
ELABORATE:
Ask students to complete the section on the Student Reflection sheet. Come to a class consensus on which details are necessary when writing a description of a plant and what details are not.

EVALUATE:
Formative Assessment: Students' descriptions from the first time through this activity to the last can be compared to identify changes in scientific vocabulary used, descriptive statements, and the process used in describing the image.

Summative Assessment: N/A

Elaborate Further/Reflect/Enrichment: N/A





Name: _____

Student Reflection: Sightless Drawing

1. How accurate were you in describing your image? What could you have changed to describe your image better?

2. Thinking about using the sightless drawing cards, explain the differences between the drawing from the first time the activity was completed and the second time? Which was more successful?

3. What strategies did you use to describe your image to the drawer?

4. What questions did you ask or want to ask while you were drawing?

5. How important is using a common vocabulary when communicating in science? Use evidence from this activity to support your answer.

6. How did you describe the size of your image to the drawer?

7. In what ways is it necessary for a scientist to be a good describer and a good receiver of directions?

Write a detailed description of a prairie plant (no drawings allowed) and challenge a partner to identify that plant using the Fermilab Plant Prairie database (http://eddata.fnal.gov/lasso/plant_search/search_kids.html) or other field guide.

Teacher Page

Student Reflection Suggested Responses: Sightless Drawing

1. How accurate were you in describing your image? What could you have changed to describe your image better?

   Responses will vary. Expect a clearly stated rationale.

2. Thinking about using the sightless drawing cards, explain the differences between the drawing from the first time the activity was completed and the second time? Which was more successful?

   Responses will vary. Expect a clearly stated rationale.

3. What strategies did you use to describe your image to the drawer?

   Responses will vary. Expect a clearly stated rationale.

4. What questions did you ask or want to ask while you were drawing?

   Responses will vary. Expect a clearly stated rationale.

5. How important is using a common vocabulary when communicating in science? Use evidence from this activity to support your answer.

   Responses will vary. Expect a clearly stated rationale.

6. How did you describe the size of your image to the drawer?

   Responses will vary. Most students will indicate that the familiar structures were easiest to describe—especially if the structure could be likened to another familiar concept, such as "about the size and shape of a toaster waffle."

7. In what ways is it necessary for a scientist to be a good describer and a good receiver of directions?

   Responses will vary. Expect a clearly stated rationale.

Write a detailed description of a prairie plant (no drawings allowed) and challenge a partner to identify that plant using the Fermilab Plant Prairie database (http://eddata.fnal.gov/lasso/plant_search/search_kids.html) or other field guide.

Calico Beans

How do biotic factors increase the likelihood of survival in an ecosystem?

Topic: To improve students' classification skills

Brief Lesson/Lesson Set Description:
Students begin to explore how they would group organisms to make a system of classification that can be used by others.

Science and Engineering Practice: Developing and Using Models

Crosscutting Concept: Structure and Function

INVESTIGATION

Objectives: Students will:
- Categorize and group beans based on physical characteristics.
- Compare and contrast how others create a classification system.
- Evaluate classification schemes and judge which ones are most reliable.
- Compare categorizing of beans by physical characteristics to classification of plants and animals.

Narrative/Background Information:
Many students are fixated on getting the correct answer. However, in science, as in many other aspects of life, several different solutions to a problem may be acceptable. In the case of scientific classification, known as taxonomy, many an argument has been settled only after many years of discussion.

This exercise allows students to practice classification skills. They will discover that many different classification schemes are workable to individual students. However, they may also discover that when attempted by others, some of these schemes are flawed. So it is with the classification of organisms. Many factors and interpretations must be considered before a classification system is universally acceptable.

Prior Student Knowledge Expectations: N/A

Possible Preconception/Misconception:
- Students may have a difficult time accepting that there is more than one right answer.

Vocabulary: classification, categorizing, characteristic, critical attribute

Materials:
- Minimum of 15 different types of beans and seeds for each student
- Copier paper

- Pen or pencil

ENGAGE:
Teacher spills a bag of beans on the desk. “Oh, what a mess! How will I organize all these beans?”

EXPLORE:
Process:
1. Instruct students to fold a piece of copier paper into sixths.
2. Mix beans and distribute a handful to each student.
3. Instruct students to group like beans on sections of paper. Be sure to use at least four sections.
4. Label sections according to specific characteristics used to categorize beans. Examples: smooth, white, spotted, round
5. When all students have completed their bean classification, have them mix up their beans again. The students should then exchange papers and use their classmate’s classification system to classify the beans.
6. Return the papers to their owners. Record all appropriate responses.
7. Compare rationales and discuss.

EXPLAIN:
Engage students in a discussion using responses on the Student Reflection sheet.

ELABORATE:
Ask students to group beans, but do not write a title or category name down. Another group will then try to identify the title of each group by the similarities the beans share.

Formative Assessment: Introduce a new bean and ask students to place it into one of their groups using their system.

Summative Assessment: N/A

Elaborate Further/Reflect/Enrichment: N/A

Name: _____

Student Reflection: Calico Beans

1. Did everyone categorize in the same manner? Why or why not?

2. Was anyone “wrong”? Is everyone able to justify his/her category?

3. In science, give an example of how living things are classified by how they look.

4. What are some disadvantages of using only appearance to classify living things?

5. How do biologists use classification to identify and study plants and animals?

6. What do you think scientists do if they cannot agree on a classification system?

7. What do scientists do if they discover a new species that does not fit into their current classification system?

Take a second look at your first classification scheme. After completing the activity, did you decide to change your scheme? If not, write a letter to your teacher justifying your original position. If you discovered a better way to classify your beans, write a letter to your teacher describing what you will do differently.

Teacher Page

Student Reflection Suggested Responses: Calico Beans

1. Did everyone categorize in the same manner? Why or why not?

   Responses will vary.

2. Was anyone "wrong"? Is everyone able to justify his/her category?

   Responses will vary. Students should recognize that different interpretations translate into a variety of justifiable schemes.

3. In science, give an example of how living things are classified by how they look.

   Responses will vary. Students may suggest folding laundry, putting away dishes and silverware, cleaning a room, etc.

4. What are some disadvantages of using only appearance to classify living things?

   Scientists need a universally accepted classification system to, among other reasons, communicate effectively, work collegially, and avoid error.

5. How do biologists use classification to identify and study plants and animals?

   Biologists use set characteristics specific to the organism. The classification categories for plants and animals include: kingdom, phylum, class, order, family, genus, and species. This system begins with the broadcast of descriptors at the kingdom level and the most discreet at the species level. In fact, many genus levels have species so similar that the average person cannot tell them apart!

6. What do you think scientists do if they cannot agree on a classification system?

   The scientific community has wrestled with this dilemma since the science of classification, taxonomy, began. Researchers continually try to prove—or disprove—that two very similar organisms are the same by careful observation, comparison, analysis, and collaboration.

7. What do scientists do if they discover a new species that does not fit into their current classification system?

   Response will vary.

Take a second look at your first classification scheme. After completing the activity, did you decide to change your scheme? If not, write a letter to your teacher justifying your

original position. If you discovered a better way to classify your beans, write a letter to your teacher describing what you will do differently.

The Key to the Keys

How do biotic factors increase the likelihood of survival in an ecosystem?

Topic: Students explore how scientists classify living things through a series of classification activities, including creating their own dichotomous key.

Brief Lesson/Lesson Set Description:
This is an introduction to the classification system used in biology as well as using taxonomic keys.

NOTE: The *Critical Attributes – Prairie Plants and Invertebrates* activity is advised prior to engaging in this activity.

Science and Engineering Practice: Developing and Using Models

Crosscutting Concept: Systems and System Models

INVESTIGATION

Objectives: Students will:
- Successfully use taxonomic keys.
- Demonstrate the purpose and functionality of taxonomic keys.
- Create and test taxonomic keys.

Narrative/Background Information:
Classification is an orderly system used by scientists to keep track of plants, animals, and other specimens. They don't want to confuse a horse with a donkey or a garter snake with a rattlesnake! Every kind of plant or animal belongs to a unique group known as its *species*. Similar species belong to a larger, yet still closely related group called a *genus*. For example, dogs and wolves, though they have many similar characteristics, are two separate and distinct species. We know they are closely related because they belong to the same genus (Canis) and the same *family*, canines, or Canidae.

Families belong to larger groups, too. Similar families form *orders*, which fall into similar *classes*. Humans and gorillas are in the same order and are a part of Class Mammalia. They are mammals, just like dolphins, raccoons, and other animals that nurse their young. The classes of organisms that have more general characteristics in common are part of the same *phylum.* Mammals, birds, reptiles, amphibians, and fish are all chordates. They have backbones. Phyla with the same very, VERY general characteristics are part of the same *kingdom*. Humans are part of the same kingdom as insects—the most numerous and diverse animal of all!

Classification of Humans	
Kingdom	Animalia
Phylum	Chordata
Class	Mammalia
Order	Primata
Family	Hominidae
Genus	Homo
Species	Sapiens

An easy way to remember the classification scheme is with this sentence: **K**ing **P**hillip **C**ame **O**ver **F**or **G**inger **S**naps.

Note that the scientific name for human beings is *Homo sapiens*. Every human being, regardless of race or ethnicity, belongs to the group *Homo sapiens*. The name *Homo sapiens* is an example of binomial nomenclature. The first term in this classification system—in this case—*Homo*, is the organism's generic name or genus. The second word, *sapiens*, is the organism's specific name or species designation. Most of these terms are Latin. Organisms are frequently referred to by both their scientific names (Latin) and common names. (Homo sapien = human being). When using the Latin name, notice that only the genus is capitalized.

The term *species* has its origins in the ancient Latin language, where it means “kind.” A definition of species is a group of interbreeding organisms that do not ordinarily breed with members of other groups. There may be 30 million different species living on the Earth. According to Smithsonian, of these species, only about 900,000 have been classified. https://www.si.edu/Encyclopedia_SI/nmnh/buginfo/bugnos.htm

In 1753, a scientist in Sweden named Carolus (Carl) Linnaeus thought of an orderly system for classifying plants and animals. He was aware that there were millions of different kinds of plants and animals in the world. Keeping track of all of these organisms was a pretty confusing problem, especially since there were scientists and interested observers all over the globe identifying organisms and naming them with little respect to a formal protocol. This action contributed to what we refer to today as the *common names* of organisms. An obvious problem with this strategy is that the common name for the ubiquitous raccoon changed from area to area. Linnaeus was among the first to group all organisms according to a two-part name (binomial) using the genus and species. Evolution theories influenced modern classification. Even today, scientists argue about the best category to place organisms. Modern classification systems are much more complicated than Linnaeus’ first system, having many levels of hierarchical organization.

A taxonomic key is a printed document that allows an observer to identify an organism or an object that they may never have seen before, or whose identity is not known. Use the *Basic Guidelines for Using a Taxonomic Key* to help you understand how keys work.

Basic Guidelines for Using Taxonomic Keys

- Read both choices even if the first seems to be a good choice. The second choice may be even better! Remember that there are variations between organisms of the same species. For example, do you look exactly like the person next to you? You are both Homo sapiens.
- Do not base your identification on an unusual or atypical specimen. Living organisms are always variable to some degree, so it is wise to not base your conclusion on a single specimen observation. Study several specimens to determine the average characteristic pattern.
- NEVER GUESS when using a taxonomic key!
    - Understand the meaning of the terms involved in the descriptions. Use resources to clarify definitions of terms you do not know.
    - Measurements are important! Use calibrated scales such as meter sticks to make certain your specimen fits the description.
    - Locations and ranges where a certain specimen is typically found are valuable pieces of information. Use maps and other appropriate resources to help identify your specimen.
- Use a hand lens or microscope to clearly show the feature you need to see—especially when very small specimens or critical attributes are concerned.
- Sometimes you will become confused or will seem to have "hit a wall" in your search. Try all options at that point and see if you can get back on track. If you cannot, it is possible that an earlier choice was incorrect. Trace your steps back to find your error.
    - Research more detailed descriptions for each species in order to make your final choice.
    - Try to find images of the organism and/or its characteristic parts to clarify the characteristic.
- ALWAYS challenge your findings. Ask another person to verify your species identification. Look at a variety of images and detailed descriptions of the specimen to help ensure accuracy.

Prior Student Knowledge Expectations:

- General understanding of critical attributes of organisms
- Ability to use measuring tools
- Willingness to carefully follow directions
- General understanding and acceptance of collaborative behaviors

Possible Preconceptions/Misconceptions:

Students may believe that:

- All plants/insects look alike.
- Keys are tools used only by scientists.
- Taxonomic keys are difficult to use.
- An organism within a species is identical to another one of the same species.

Vocabulary: classification, dichotomous key, kingdom, phylum, class, order, family, genus, species

Materials:

- Paper and pencils
- *Basic Guidelines for Using a Taxonomic Key* (Background Information)
- *Sample Super Sandwich Key* (Student Handout)
- *Common Fermilab Site Prairie Grass and Forb Identification Keys* (*Resources*)
- Prairie plant herbarium mounts (created at Fermilab or provided)

ENGAGE:

Ask the class, "Who has/had a sandwich in their lunch today? What kind of sandwich? (If not many types are noted, continue to request sandwich types until you have at least 8–10.)

EXPLORE:

Process:

- Engage students in a discussion of different kinds of sandwiches, documenting on the chalkboard some different types (bologna, PB&J, Sloppy Joe, tuna salad, hamburger, hot dog, ham, grilled cheese, etc.).
- Establish a class list of favorite sandwiches. *TIP: Keep the list to 8–10 types of sandwiches; everyone works with the same list.*
- Present the Super Sandwich Key model. (See data.) Examine the scheme as a class, noting the hierarchy of sandwich attributes. (Which are more general? Which attributes are discrete?)
- Ask students to design a key to classify their class sandwich selections. ONLY sandwiches mentioned in class discussion should be included. *Emphasize* that there are many different ways to present a classification scheme. Reflect back on background information.
- Allow students to work in teams of 3–4. Inform students that each will sign the finished plan, ensuring appropriate interactions during the exercise.
- Request that the classification method include a brief description of each sandwich, noting obvious differences.
- Have teams exchange models and note differences and similarities. What was appealing about each model? Were there any problems?
- After students have completed comparing their plans, present the Super Sandwich Key model again. Request that they compare their plan with the model. Again, note differences and similarities—keeping in mind that the class list will differ from the sample.
- If time allows, encourage the class to agree upon a preferred plan, recognizing that in biology, scientists from all over the world must agree on a common classification protocol.
- Engage students in a discussion using responses on the Student Reflection sheet.
- Present the *Common Fermilab Site Prairie Grass and Forb Identification Keys* with sample prairie specimens (herbarium mounts or school site prairie parcel).

- Have students key the herbarium-mounted or school prairie site plants.

EXPLAIN:
Students will reinforce the concept of taxonomic keys as they create and defend their key. As designs are reported and checked, the students will rectify misunderstandings.

ELABORATE:
Extensions:
1. Complete the *Calico Beans* activity. Instruct students to prepare a key for the beans. Engage students in a discussion about differences and similarities in these keys.
2. Take off one shoe and place it in a pile in the center of the room with one shoe from each student. Use your classification skills to create a key for the shoes.

Web Links
Convention on Biological Diversity
https://www.cbd.int/gti/taxonomy.shtmlhttps://www.cbd.int/gti/taxonomy.shtml
Explore this informational site and discover why taxonomy is important not only for keeping organisms ordered, but in combatting invasive species. (Teacher background)

Carl Linnaeus Biography
http://www.ucmp.berkeley.edu/history/linnaeus.htmlhttp://www.ucmp.berkeley.edu/history/linnaeus.html
Learn about the father of classification from this biographical site from UC Berkeley.

Animal Classification
http://faculty.fmcc.suny.edu/mcdarby/Animals&PlantsBook/History/02-Explaining-Life-Classification.htm
Written on a higher level, this Fulton-Montgomery Community College site explains the five animal kingdoms and follows the classification lineage from kingdom to species.

EVALUATE:
Formative Monitoring: See student sheets.

Summative Assessment: A wide variety of activities can gauge student understanding of these concepts, including creating another key using actual living organisms, using a key to identify the scientific name of a living organism, creating and evaluating protocol for using a classification system when a new organism has been identified and identifying and rectifying the limitations of the current classification system.

Elaborate Further/Reflect/Enrichment: N/A

Super Sandwich Key Model

NOTE: This is merely an example. How else might you build a key for these types of sandwiches? Try to improve upon this model!

1. Filling between two slices of bread **(Go to 2.)**

    1. Filling served on a bun **(Go to 3.)**

2. Meat filling **(Go to 4.)**

    2. Non-meat filling **(Go to 5.)**

3. Hamburger meat served on a round bun **(Go to 6.)**

    3. Processed meat served on a long bun – **Hot dog**

4. Processed meat – **Bologna**

    4. Non-processed meat **(Go to 7.)**

5. Filling composed of salty and sweet substances – **Peanut butter and jelly**

    5. Filling yellow or white dairy product – **Cheese**

6. Solid ground beef patty – **Hamburger**

    6. Loose ground beef with tomato-like sauce – **Sloppy Joe**

7. Non-processed (fresh meat)

    7a. Sliced white meat – **Turkey**

    7b. Sliced reddish meat – **Ham**

    7c. Sliced brown meat – **Beef**

Name: _____

Student Reflection: Student Super Sandwich Key

Add or subtract lines and/or adjust the format if necessary. Limit to 10–12 types of sandwiches. Remember, different interpretations are not necessarily wrong!

1a. _____

1b. _____

2a. _____

2b. _____

3a. _____

3b. _____

4a. _____

4b. _____

5a. _____

5b. _____

6a. _____

6b. _____

7a. _____

7b. _____

8a. _____

8b. _____

9a. _____

9b. _____

Name: _____

Student Reflection: The Key to the Keys

1. Why were there differences among the keys created within the class? Was there any “most correct” key? Explain your response.

2. Did the descriptive information in your key go from general to more specific, or specific to more general? Explain the pattern that you observed.

3. Taxonomists are scientists who create classification keys. Sometimes they do not agree on the way a key is designed. What might be some reasons for argument?

4. What are the benefits to using a common system of classification? What are the limitations?

5. You and your class have created and examined many different keys and have decided on the one that best classifies your list of sandwiches. Imagine that you want to add a new favorite sandwich, marshmallow/pickle, to the key. How would you add that selection to the key?

6. What do you suppose would happen if a taxonomist discovers a new species? How would that affect an established key?

Summarize what you have learned by explaining, in writing, how to use a taxonomic key. Don’t peek at the guidelines! Explain how these understandings will help you with your prairie studies.

Teacher Page

Student Reflection Suggested Responses: The Key to the Keys

1. Why were there differences among the keys created within the class? Was there any "most correct" key? Explain your response.

   Individual interpretations make the art of keying subjective. This is the reason why taxonomists spend so much time discussing the validity of their placement of an organism in a key. It is possible, though not common, for an organism to be moved from one place on a key to another as research is gathered and analyzed. Taxonomy is subject to modification—just like every other discipline in science.

2. Did the descriptive information in your key go from general to more specific, or specific to more general? Explain the pattern that you observed.

   The students' keys should go from general to specific.

3. Taxonomists are scientists who create classification keys. Sometimes they do not agree on the way a key is designed. What might be some reasons for argument?

   Responses will vary. Students may suggest different interpretations of observation data, anomalies from specimen to specimen within a species, and failure to properly communicate with one another.

4. How do you think scientists come to an agreement?

   Extensive review, multiple reviewers, and considerable discussion are needed to resolve arguments. In recent years, DNA evidence has assisted in resolving taxonomic issues.

5. You and your class have created and examined many different keys and have decided on the one that best classifies your list of sandwiches. Imagine that you want to add a new favorite sandwich, marshmallow/pickle, to the key. How would you add that selection to the key?

   Responses will vary. Expect a logical and workable response.

6. What do you suppose would happen if a taxonomist discovers a new species? How would that affect an established key?

   Responses will vary. Depending on where in the key this species diverged from the continuum, there could be great or little impact. Expect a logical and workable response.

Summarize what you have learned by explaining, in writing, how to use a taxonomic key. Don't peek at the guidelines! Explain how these understandings will help you with your prairie studies.

Expect a degree of sophistication as determined by the teacher and communicated to the student prior to assigning this task.

Pinecone Search

How do biotic factors increase the likelihood of survival in an ecosystem?

Topic: Observing and describing skills

Brief Lesson/Lesson Set Description:
This activity is skill building and can be done in several places and several times throughout the unit to increase skills in the areas of communication.

Science and Engineering Practice: Obtaining, Evaluating, and Communicating Information

Crosscutting Concept: Structure and Function

INVESTIGATION

Objectives: Students will:

- Recognize that different people can categorize characteristics differently.
- Practice observation skills by identifying objects based on physical characteristics.
- Associate characteristics with classification in nature.

Narrative/Background Information:
It is common for humans to "see" some items as all the same and not pay attention to distinctive characteristics. Insects within a species, for example, may all appear identical. Ants on an anthill all look alike. But, do they? Might ants be as different from one another as humans? Challenge students to think about the qualities that make organisms alike and different. Be sure to mention the qualities that are not naturally a characteristic of an organism. An insect or crustacean may have lost a leg to a predator. A plant that should manifest an alternate leaf structure may have lost distinguishing leaves that were consumed by an insect. A naturally brown-haired, blue-eyed teen may have become a brown-eyed blonde, thanks to contact lenses and hair coloring. Allow students to brainstorm these ideas prior to the pinecone activity and reflect on this idea again after the experience.

Prior Student Knowledge Expectations: N/A

Possible Preconceptions/Misconceptions:
Students may struggle with identifying distinguishing characteristics at first as well as using their descriptions to find their pinecone. Students may need several experiences before they see growth in their observations and descriptions.

Vocabulary: observation, description, characteristics, critical attribute

Materials:

- Pinecones (one per student)
- Paper
- Pen or pencil

ENGAGE:
Ask students to discuss how they would describe themselves to someone who has never seen them.

EXPLORE:
Process:

1. Distribute one pinecone per student, preselecting pinecones that are as homogeneous as possible.
2. Instruct students to verbally and pictorially describe their pinecone. Students should not be allowed to mark their pinecones in any way.
3. Collect all pinecones and place them around the room, spacing them far enough apart so that students can rotate through and look at each one without being crowded.
4. Students must identify and claim their own pinecones from the descriptions that they wrote.
5. Collect the pinecones again and place them around the room. Ask students to exchange papers and try to find another student's pinecone from the written description.

EXPLAIN:
Engage students in a discussion about how they were able to claim their own pinecone.

ELABORATE:
When trying to identify one individual from an entire species, come to a class consensus on which details are the most important.

Formative Monitoring: The more times students participate in this process, the better their descriptions will become. Students may not be able to identify for certain whether they have their pinecone but can identify which characteristics they used during the identification process.

Summative Assessment: N/A

Elaborate Further/Reflect/Enrichment: N/A

Name: _____

Student Reflection: Pinecone Search

1. What are some characteristics common to all pinecones?

2. Describe specific characteristics you used to separate your pinecone from the others.

3. What advantages would there be to having differences in pinecones?

4. In what ways do we use physical characteristics to classify plants and animals?

5. How do physical characteristics give us clues to the function of the structure?

6. Why is it important to observe closely to identify differences in individual species?

Observe a set of common organisms of the same species that generally all look the same, for example, dandelions or ants. Write a description of a single individual such that this individual might be distinguished from others within the set. Is it easier to distinguish these individuals from one another than individuals of a different species, for example, humans? Explain.

Teacher Page

Student Reflection Suggested Responses: Pinecone Search

1. What are some characteristics common to all the pinecones?

   Expect responses that indicate coloration, texture, shape, size, etc.

2. Describe specific characteristics you used to separate your pinecone from the others.

   Responses will vary. Expect specificity! Students should note at least three suggestions.

3. What advantages would there be to having differences in pinecones?

   Responses will vary.

4. In what ways do we use physical characteristics to classify plants and animals?

   Responses will vary. Expect specificity! Students should note characteristics that are naturally common to an organism, such as leaf anatomy or tooth type and arrangement. Remind students that some characteristics change unnaturally, such as marks form attempted predation or, in the case of humans, hair color or the results of plastic surgery.

5. How do physical characteristics give us clues to the function of the structure?

   Responses will vary.

6. Why is it important to observe closely to identify differences in individual species?

   Responses will vary.

Observe a set of common organisms of the same species that generally all look the same, for example, dandelions or ants. Write a description of a single individual such that this individual might be distinguished from others within the set. Is it easier to distinguish these individuals from one another than individuals of a different species, for example, humans? Explain.

Critical Attributes – Prairie Plants and Invertebrates

How do biotic factors increase the likelihood of survival in an ecosystem?

Topic: A deep look at characteristics of organisms that are used to define species

Brief Lesson/Lesson Set Description:
Students will observe plants and invertebrates to distinguish qualities and characteristics that are unique to their species (plants) or order (insects). Other invertebrates may be noted and compared. This activity is an excellent precursor to the *Quadrat Study* set.

Science and Engineering Practice: Analyzing and Interpreting Data

Crosscutting Concept: Patterns

INVESTIGATION

Objectives: Students will:
- Recognize and describe discrete differences in similar organisms.
- Note critical attributes that distinguish species.
- Acknowledge and explain why some organisms of the same species may differ in appearance, but maintain the same critical attributes.
- Identify abiotic factors in an area that could affect the growth/health of an organism.
- Observe organisms and note specific adaptations that help assure survival in the selected environment.
- Speculate as to the future of certain organisms over time with consideration of global warming or local disturbances.

Narrative/Background Information:
Living organisms have certain qualities that distinguish them from nonliving entities.

Living organisms:
1. Need energy/resources to perform life processes.
2. Respond and adapt to their surroundings.
3. Reproduce.
4. Develop and grow.
5. Are made up of one or more cells

Beyond these basics, living organisms, particularly higher-level organisms have distinguishing characteristics that define their place within taxonomy. For plants, this can mean position of leaves on a branch, shape of the stem/leaves, number of petals on flowering parts, and so much more. In the invertebrate world, distinguishing between species becomes even more complex. Beetles, for instance, are the largest order of insects with between 350,000 and 400,000 species. For insects, a simple graphic profile

of the orders is useful. If students can properly place an insect within an order, they are successful. (See Common Insect Orders Guide.) Other invertebrates may be generally identified with the assistance of field resources.

Integral to success is observation and use of resources. Experts revert to field guides and dichotomous keys when engaging in field study. What do we really *see* when we observe organisms in nature? Subtle differences such as the serration pattern on the edge of a leaf or the color of abdominal segments (tergum) on a bumblebee can define a species.

Prior Student Knowledge Expectations:

- Basic vocabulary to describe critical attributes
- General differences between insects, spiders, and other invertebrates
- Familiarity with the general characteristics of the most common plants and invertebrates in the ecosystem
- Observation skills and ability to notice detail. (Consider using the *Pinecone Search* activity first.)
- Ability to use a field guide and/or key to assist in identification
- Willingness to verbally describe, journal or sketch the organism/s with its defining attributes
- General understanding of collaborative behaviors

Possible Preconceptions/Misconceptions:

- All plants and “bugs” look the same.
- Minute details may be the only way to distinguish similar organisms.
- Students may underestimate the diversity of a flourishing ecosystem.
- Students may not realize the strength of the form vs. function factor nor interconnections of organisms.

Vocabulary: critical attributes, characteristics, invertebrate, head, thorax, abdomen, various plant vocabulary

Materials: (per student group)

- Natural specimens to observe
- Field guides and/or online resources
- Critical Attributes – Prairie Plants and Invertebrates data sheet
- Drawing paper and pencil
- Common Insect Orders Guide

ENGAGE:

Capture student interest by providing specimen for examination such as herbarium mounts, insect/invertebrate collections (invite students to share a collection of their own), or consider a web quest.

EXPLORE:

Process:

1. Observe organisms and find them in field guides or online resources.
2. Identify organisms. (For insects, identification at the order level is sufficient)
3. Take notes on critical attributes (Plants: Veins parallel, palmate, etc.? Leaves alternate or opposite? What else? Invertebrates: Winged invertebrate? Number of legs? Description of mouthparts? What else?) Note example(s) provided.
4. Get your teacher's initial (TI) as you progress.
5. Draw in pencil; carefully note critical attributes. (Do not worry about perfect drawings. Do the best you can, but carefully label and describe what you have drawn.) Complete as many as you are able.
6. Exchange with a partner who will verify analysis and drawing.

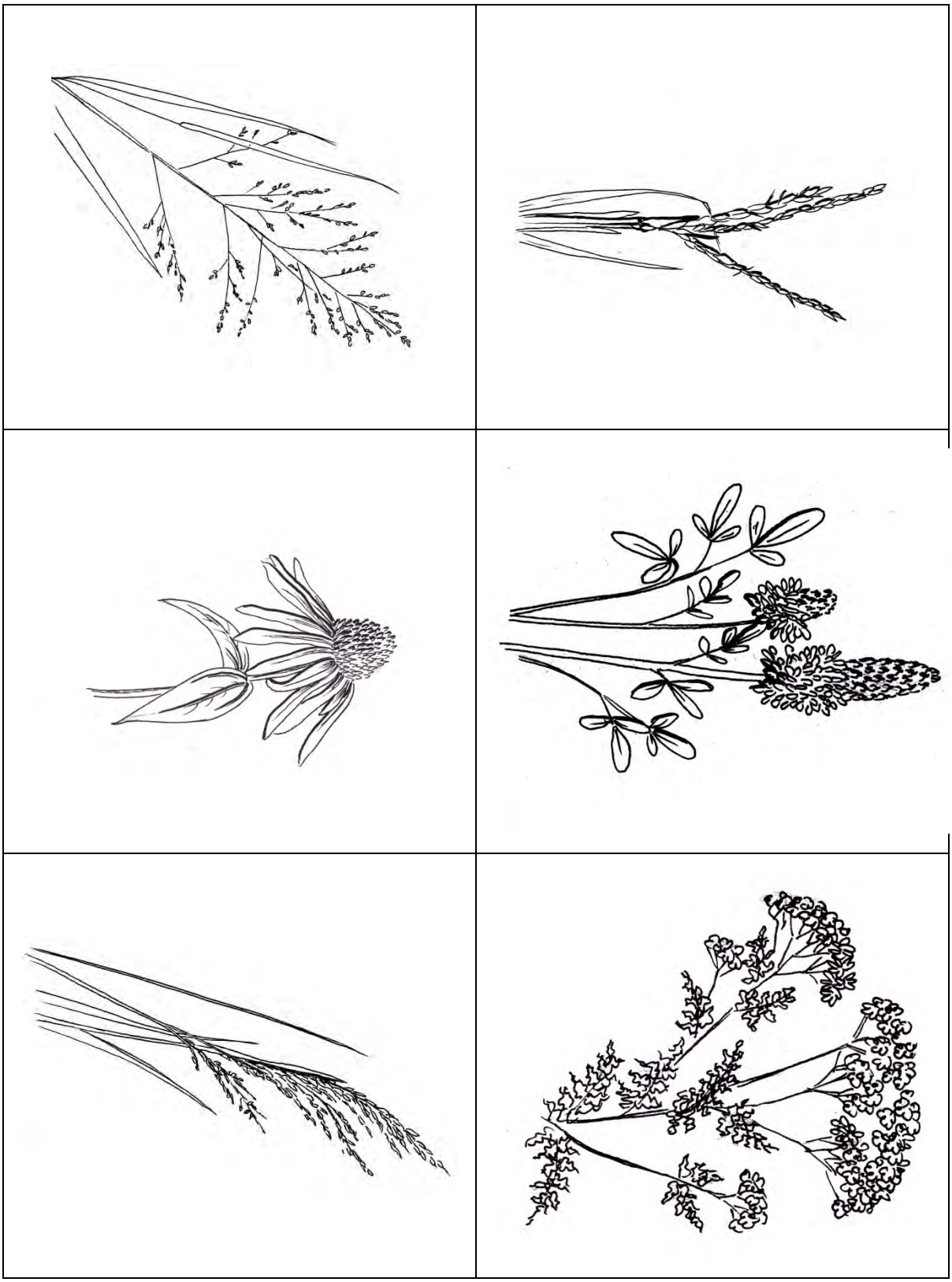
EXPLAIN:
As students share their drawings with classmates, encourage them to explain their rationale for their identifications. If there are discrepancies, challenge students to observe more closely and come to consensus about the organism.

ELABORATE:
Students will better appreciate the form/function of organisms relative to pollination and survival in general. This exercise offers a strong correlation to adaptations and organism survival in changing conditions such as climate change, water availability, disturbance and biological control. Challenge students to speculate about the ongoing ability of a specific organism to survive if the climate gets warmer or cooler/wetter or drier over time. How might the population of an organism observed be impacted based on its critical attributes?

EVALUATE:
Formative Monitoring: Use Student Reflection questions for discussion throughout the investigation.

Summative Assessment: Based on your understanding of relationships and interactions, design a perfect organism that can withstand anything nature (or humankind) throws at it. Make note of everything needed by the organism and the connections between each organism and the environment.

Elaborate Further/Reflect/Enrichment: What further questions do students generate? Research specific invertebrate/plant relationships such as monarch butterfly and milkweed or aphids, ants, and specific plants; what form/function connection(s) are revealed? Based on your research, specifically what do you predict might happen if one or the other of these organisms disappeared?



Name: _____

Critical Attributes – Prairie Plants and invertebrates

Directions:

1. Observe plant or invertebrate specimens and find in field guide.
2. Identify and take notes on critical attributes (Plants: veins parallel, palmate, etc.; leaves alternate or opposite. Invertebrates: patterns, color, etc.; 0, 2, or 4 wings). The first example is done for you.
3. Get your teacher's initials (TI) as you progress.
4. Draw in pencil (be sure to draw critical attributes), then color with colored pencil. (See example, Figure 1.) Complete as many specimens as time allows.
5. Exchange with a partner who will verify the analysis and drawing.
6. Use back of page for more attributes if needed.

Grasses	Critical Attributes
1. Big Bluestem **TI**	• Inflorescence in threes • Inflorescence grows in threes from stalks at the top of the plant. • Inflorescence looks like a turkey's foot.
2. **TI**	
3. **TI**	
4. **TI**	
Forbs	**Critical Attributes**
5. **TI**	
6. **TI**	
7. **TI**	
8.	

TI	
9. **TI**	
10. **TI**	
Invertebrates	**Critical Attributes**
1. **TI**	
2. **TI**	
3. **TI**	
4. **TI**	

Name: _____

Student Reflection: Critical Attributes – Prairie Plants and Invertebrates

1. The natural world is filled with relationships and interactions. How might the critical attributes of your organism(s) help the organism survive and withstand the natural elements?

2. What patterns did you see as you studied the organisms? What information do these patterns give you?

3. Which organisms do you believe are interrelated? Support your belief with evidence.

4. Why do some plants verified as the same species differ in size or coloration although the critical attributes are the same?

5. Why do we care? What ecosystem service(s) does the organism(s) you studied provide? Why are these services important? (Refer to the Ecosystem Services List in *Resources*.)

Teacher Page

Student Reflection Suggested Responses: Critical Attributes – Prairie Plants and Invertebrates

1. The natural world is filled with relationships and interactions. How might the critical attributes of your organism/s help the organism survive and withstand the natural elements?

   Responses will vary. Close observation is imperative. Students should relate understanding of form/function relationships within an organism and the compliment attributes of other organisms. Interdependency is often related to critical attributes of organisms. For example, long tongued butterflies and bumblebees tend to visit forbs with deep corollas. Additionally, organisms are equipped to withstand environmental forces such as wind, rain/drought, heat/cold, etc. Drastic, quick changes to the biological or physical components of an ecosystem can affect the populations.

2. Which attribute do you feel best distinguishes the organism? Why is this so?

   Responses will vary. Students should consider the niche of the organism in the response.

3. Which organisms do you believe are interrelated? Support your belief with evidence.

   Responses will vary.

4. Why do some plants verified as the same species differ in size or coloration although the critical attributes are the same?

   Responses will vary. Students should relate to biological or physical components of an ecosystem that can affect the populations and/or the individuals within that population. Lack of certain soil nutrients, drought or other physical factor and/or non-native invasions or unnatural predation can affect individuals within a population or the population at large.

5. Why do we care? What ecosystem service(s) does the organism(s) you studied provide? Why are these services important? (Refer to the Ecosystem Services List in *Resources*.)

   Responses will vary. Expect direct relation to one or more ecosystem services.

Adaptations

How do biotic factors increase the likelihood of survival in an ecosystem?

Topic: How adaptations of organisms help promote survival

Brief Lesson/Lesson Set Description:
Students emulate the feeding strategies of various animals in an effort to relate the structure and function of specific organism's feeding adaptive characteristics. By engaging in an exploration of human limitations, adaptations of body parts for a specific purpose is realized. These adaptive qualities are evidenced across ecosystems.

Science and Engineering Practices: Planning and Carrying Out Investigations; Analyzing and Interpreting Data

Crosscutting Concept: Cause and Effect

INVESTIGATION

Objectives: Students will:

- Compare the ability of a human to eat certain foods to the abilities of specific organisms.
- Identify and explain the adaptations of these organisms to succeed in their niche.
- Explain the structure and function of these adaptations and give examples of other adaptations.
- Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.
- Speculate and construct a scenario that may occur in a selected organism with a specialized adaptation if abiotic conditions change.

Narrative/Background Information:
The term adaptation has several meanings in the biological world. Webster defines adaptation biologically as adjustment to environmental conditions in this manner: *modification of an organism or its parts that makes it more fit for existence under the conditions of its environment.* The adjustment of living matter to environmental conditions and to other living things in an organism's lifetime is called <u>physiological adaptation</u>. In a population over many generations, it is referred to as <u>evolutionary adaptation</u>. The ability to adapt is a fundamental property of life, and it is used as a distinction between living and nonliving matter.

Various animals and plants are adapted for securing their specific food needs as well as for surviving the extremes of temperature and of water supply in different biomes. Animals are anatomically adapted for locomotion (movement from place to place) and plants exhibit adaptations for securing themselves to certain soil types. Certain aquatic animals live in the ocean depths and are so specialized to withstand the great pressure that they explode when brought to sea level.

A very basic example of adaptation involves observing the beaks of birds, which vary in shape and size according to their diet. A seed-eating bird such as a finch will exhibit a very different beak than a bird such as an owl that feeds on small mammals. The short, broad finch beak is like a powerful short lever, capable of great strength to crack tough seed coats. Eagles, hawks and owls typically have a curved, sharp beak to rip apart prey. A purple martin's long, narrow beak is perfect for eating insects. The finches of the Galapagos Islands depict successful adaptation to a new diet as a result of changes in the vegetation of their area. Charles Darwin and many scientists since have relied on the studies of these finches to explain evolutionary adaptation.

The feet and legs of birds also show adaptive qualities. A delicate bobolink likes to perch on the tops of the slender stems of tall prairie plants while geese have webbed feet, perfect for paddling through the water. The sharp, curved talons of a bird of prey aid in grabbing and holding prey for capture and flight to the nest.

Adaptive coloration is observed in many animals. This is why it is hard to see the delicate green katydid in the green foliage of the prairie or the dull brown of the dung beetle that frequently is seen on the fecal material deposited by other animals. Among social insects, like ants and bumblebees, the individuals are highly adapted to perform specific functions within the hill or hive such as tending to the larvae, foraging for food, and protecting the queen. Adaptive coloration in the form of mimicry is found in the viceroy butterfly, a smaller, but similarly colored insect version of the monarch. Though different species, birds avoid feeding on it because it looks so much like the bitter monarch.

Adaptations in the natural world are a matter of life and death. Organisms not capable of migrating to a more favorable environment or that cannot adapt quickly enough to their surroundings have greatly diminished chances for survival.

Prior Student Knowledge Expectations:

- Selected research ecosystem and a list of organisms common to that ecosystem
- General understanding of the concept of a niche within an ecosystem and the interrelationships of organisms within that ecosystem
- Ability to use common sense to relate to the metaphorical adaptations presented
- Willingness to perhaps look silly and enjoy the exploration
- General understanding and acceptance of collaborative behaviors

Possible Preconceptions/Misconceptions:

- Without the conveniences of refrigerated food, thermostats, and protective clothing, survival is a constant struggle for organisms in the natural world. (NOTE: Some human populations struggle for survival on a daily basis.)
- Humans need tools to complete some of the tasks performed by other animals.
- The loss of a keystone species can disrupt an ecosystem to the point that it disappears.

Vocabulary: adaptation, variation, trait, niche

Materials:

- Natural food samples such as a banana, an orange, a shelled peanut (do not give students a hard nut that will break teeth!), an ear of corn in the husk, an egg, etc. A juice box with no straw is not a natural food source, but is a good product to depict the need of some organisms, such as mosquitos, for piercing mouthparts.
- Newspaper or other means of containing a mess
- Lab aprons, if available
- Safety goggles, depending on the likelihood of eye damage
- Adaptations Student Data sheet

ENGAGE:

Play (or replay) the *Hawk and Squirrel* video.
https://www.youtube.com/v/XBEyCr5AoIshttps://www.youtube.com/v/XBEyCr5AoIs
Instruct students to note at least three adaptations for survival for both organisms. Compare responses in class discussion.

EXPLORE:

Process:

1. Review the definitions of *adaptations* and *niche* by asking students to think of the adaptive characteristics of common ecosystem inhabitants such as the following: bumblebee (pollen sacs/straw-like tongue); meadow vole (mouse-like animal with teeth designed to crack seeds); meadowlark (bird with beak designed to capture insects); garter snake (able to hide due to protective coloration, ability to squeeze victims, and a jaw that partially dislocates to enable it to swallow victims whole); deer (flat molars to grip vegetation); raccoons (tooth structure with sharp incisors, long canine and flat molars, an omnivore tooth structure befitting an animal that is an opportunistic feeder—eats whatever is available); and a salamander (amphibian with a wide mouth useful in swallowing prey whole) to get food. Ask them to decide who may eat whom (think about the young, egg, and larval forms, too) and how have these organisms adapted to survive.
2. Divide the class into teams of 3–4 students.
3. Place a different type of food in front of each group. (See Student Data sheet.) Invite students to bring in natural foods of their choice, if desired.
4. Challenge the teams to think of ways they can eat the food—*without using their hands!* They will document ideas on the Student Data sheet.
5. Try it! Does it work? Why or why not? Remind students to be careful! (No broken teeth or bent braces)
6. Instruct students to record the name of animals that eat this item and indicate how the animals are adapted to consume it effectively. Within the group, ask students to discuss what these animals have in common.
7. Debrief as a class. Are there ideas from another group that work better?
8. Complete the Student Reflection sheet.

EXPLAIN:
Students will demonstrate their understanding via formative assessment questions, class discussion and the Student Data sheet.

ELABORATE:

- Explore the Galapagos finches and follow the research trends from Darwin to the present.
- Research the complications for the ecosystems of the world as a result of global climate change.

EVALUATE:
Formative Monitoring: Use Student Reflection questions for discussion throughout the investigation.

Summative Assessment: How do adaptations and pollination relate? Identify pollination adaptations in plants and animals. What adaptations in each organism contribute to successful pollination?

Elaborate Further/Reflect/Enrichment: N/A

Adaptations Student Data

Team Number: ____ Team Members: _____

Type of food: _____

Strategies Planned: (Document all strategies suggested. Remember: ***NO HANDS!!!***)

_____

_____

_____

_____

Class Data Collection				
Team Number	**Food**	**Strategies you used to eat the food**	**Other animals that eat this food**	**Commonalities (similar adaptations) of these animals**
1				
2				
3				
4				
5				
6				
7				

Name: _____

Student Reflection: Adaptations

1. Which, if any, of your planned strategies worked? Why were some methods unsuccessful?

2. What additional physical traits may have made your task easier?

3. In the wild, many animals thrive on foods such as you attempted to eat. How do <u>they</u> eat these foods? Specify the structure and function of the adaptations exhibited by these animals.

4. Are the adaptations a physical part of the animal or are they more of a learned behavior that the animal uses? Explain.

5. Some organisms are known to inhabit multiple ecosystems. A deer, for example, may be found in a forest, a prairie, or around a pond. The deer's predators move from ecosystem to ecosystem as well. Construct an explanation that predicts patterns of interactions among other organisms across multiple ecosystems. Remember that some plants also can be found growing in multiple ecosystems.

6. Select one animal from your personal list. Itemize other ways this animal has adapted to its environment.

7. Plants also have adaptations. Select one plant from the ecosystem you are studying and list at least three adaptations for this plant. Describe the structure and function of these adaptations in a chart that you construct.

Biological Engineering Connections:

- Speculate and construct a scenario that may occur in a selected organism with a very specialized adaptation if abiotic conditions change. Outline an argument for intervention to rescue the endangered organism. What do you believe should/should not be done?

- Imagine that you are on another planet very different from Earth. Describe the atmosphere, landmasses, temperature ranges, and any other interesting attribute of one location on this imaginary planet. Include the types of food that might be available to the organisms found here. Design an organism that could survive here. Draw the organism and describe the structure and function of its adaptations.

Teacher Page

Student Reflection Suggested Responses: Adaptations

1. Which, if any, of your planned strategies worked? Why were some methods unsuccessful?

   Responses will vary.

2. What additional physical trait or traits may have made your task easier?

   Responses will vary. Expect responses to reflect thoughtful consideration and specificity.

3. In the wild, many animals thrive on foods such as you attempted to eat. How do <u>they</u> eat these foods? Specify the structure and function of the adaptations exhibited by these animals.

   Responses will vary. Expect responses to include specific examples such as great apes eat bananas using their fingers to peel the fruit much like humans, but rodents use their sharp teeth to penetrate the fibrous peel.

4. Are the adaptations a physical part of the animal or are they more of a learned behavior that the animal uses? Explain.

   Responses will vary. This differentiation may be difficult for some students. In many cases, such as the bumblebee, it may be a combination. Bumblebees differ in physical characteristics from one species to another. Some long-tongued bumblebees forage on deep corolla forbs, extending the tongue to reach the nectar. Short-tongued bumblebees are frequently found on composite forbs and roses, gathering pollen from the flatter, more accessible centers. In this case, both physical and behavioral characteristics are clearly evident. Most pollinators instinctively know if a plant has already been visited by sensing pheromones left behind.

5. Some organisms are known to inhabit multiple ecosystems. A deer, for example, may be found in a forest, a prairie, or around a pond. The deer's predators move from ecosystem to ecosystem as well. Construct an explanation that predicts patterns of interactions among other organisms across multiple ecosystems. Remember that some plants also can be found growing in multiple ecosystems.

   Some plants such as the very common Queen Anne's lace can be found in multiple ecosystems such as prairie, woodland, pond and forest ecotone (edge) areas. These plants are popular with a variety of invertebrates. The relationship

is all about the food sources available.

6. Select one animal from your personal list. Itemize other ways this animal has adapted to its environment.

   Responses will vary. Expect responses to reflect thoughtful consideration and specificity.

7. Plants also have adaptations. Select one plant from the ecosystem you are studying and list at least three adaptations for this plant. Describe the structure and function of these adaptations in a chart that you construct.

   Responses will vary. Expect responses to appear in chart form. It is important that students design their own charts. An example is provided, but acknowledge other designs that exhibit the information in an effective organizational model.

Prairie Dock		
Adaptation	**Structure**	**Function**
1. Big leaves	Large and wide with a rough surface	Collect maximum energy from sun; tough, rough surface protects leaf
2. Tall stem	Forbs rise high above the prairie.	Accessibility to insects for pollination
3. Deep roots	Reach deep into the prairie soil.	Obtain water even in drought; firmly secure the plant and keep the plant alive even if cut or burned.

Biological Engineering Connections:

- Speculate and construct a scenario that may occur in a selected organism with a very specialized adaptation if abiotic conditions change. Outline an argument for intervention to rescue the endangered organism. What do you believe should/should not be done?

- Imagine that you are on another planet very different from Earth. Describe the atmosphere, landmasses, temperature ranges, and any other interesting attribute of one location on this imaginary planet. Include the types of food that might be available to the organisms found here. Design an organism that could survive here. Draw the organism and describe the structure and function of its adaptations.

Seed Adaptations for Survival and Dispersal

***How do biotic factors increase the likelihood of survival in an ecosystem*?**

Time Needed: 1–2 class periods

Topic: To discover characteristics of seeds that impact plant survival

Brief Lesson/Lesson Set Description:
Students will examine a variety of common seeds, noting adaptations for survival, and investigate different mechanisms of dispersal. Students will discuss adaptations for different prolonged, harsh conditions and apply their findings to create an engineered design for a "super seed" capable of withstanding environmental elements and more efficient disbursal to help ensure success.

Science and Engineering Practices: Developing and Using Models; Engaging in Argument from Evidence

Crosscutting Concepts: Patterns; Scale, Proportion, and Quantity; Structure and Function

INVESTIGATION

Objectives: Students will:

- Differentiate mechanisms of seed dispersal.
- Observe sets of seeds and hypothesize how these seeds are dispersed.
- Analyze how certain plants and animals have adapted to the environment.
- Construct an explanation of some interactions of organisms within and across ecosystems to promote success of the organisms.
- Diagram the seeds' adaptations, compare with other students studying other ecosystems to document similarities and differences.
- Create a design for a "super seed," capable of withstanding the elements and more efficient disbursal to help ensure success.

Narrative/Background Information:
Wildlife interactions contribute to the diversity and organism success of ecological systems. One compelling example is the process of seed dispersal. Animals carry many seeds, whether in the coats of fur-bearing animals or carried and dropped by some birds as they travel and drop feces. Other seeds are adapted to be carried or scattered by wind, water, or gravity. These strategies help plant species expand their territories. The role of insects in pollination is highly significant. Bumblebees and butterflies are common pollinators, but a closer look reveals countless insect/plant relationships critical for fertilization. However, insects have a lesser role in seed dispersal.

It's not all about dispersal. Certain abiotic conditions are needed for some seeds to germinate even if dispersal to a good location is successful. Some seeds require a

process called scarification to germinate. Scarification means to cut or soften the wall of (a hard seed) to hasten germination. Certain herbivorous birds eat berries and fruits with seeds that are scarified by the gastric juices of the birds. Seeds eaten by birds may be distributed some distance from the original plant. Many of these seeds will not germinate without this process, so the bird fulfills two vital roles for the population: scarification and disbursal.

Some seeds require fire to germinate. The bur oak is an example of this phenomenon. Since prairie fires are no longer common, measures are being taken to artificially introduce fire to bur oak seeds in an effort to promote germination. The fire is a form of scarification, but it does not disperse the seed very far from the tree. Bur oaks are historic prairie savanna trees—often rising up on the plains as single trees or members of a fairly widespread cluster. The thick bark of the bur oak serves as insulation, so when those very hot, but quick prairie fires swept across the plains, this tree was rarely severely harmed. Seeds that have fallen from the tree may be carried by animals such as squirrels and other rodents and buried. Perfect—unless the animal eats the seed first!

Another consideration for some seeds, particularly seeds from plants that endure a cold, long winter, is the process of seed dormancy. Seeds fall to the ground and are semi-insulated by leaf litter and snow. Brutally cold winters with little snow cover can be hard on certain plants because they get too cold for too long. Relatively warm winters can be problematic, as seeds have not had the opportunity to properly experience this natural dormancy and the tiny seed embryo can germinate prematurely. If the seed begins to grow before conditions are appropriate and a hard freeze occurs, the seed may be lost.

If the conditions are favorable and the seed has been disbursed to a proper location, a plant begins to grow and produce new seeds. It is important to recognize that the vast majority of seeds produced never actually germinate. They must be deposited in a suitable place, survive unfavorable abiotic conditions, and not be consumed by an animal.

<u>Common Methods of Dispersal</u>:

- Wind – ash, elm, maple, sycamore, dandelion, milkweed, goldenrod, ragweed
- Animal coats – acorn, beggar tick, magnolia, sycamore, burr, blackberries, Illinois tick trefoil
- Gravity – acorn, magnolia, hickory, needle grass
- Water – silver maple, water lilies
- Mechanical forces (spring action) – pine, touch-me-not, jewelweed
- Animal digestive systems – wild raspberries

Collect seeds for this activity from local sources using as many familiar seeds as possible. Many students have not thought about how seeds are dispersed other than purchasing a packet for planting or picking “hitchhikers” from clothing in the fall. Spend time investigating the adaptations of the seeds for dispersal, discussing the form and function of these adaptations. If commercial seeds have been treated with fungicide,

they should be washed before handling. Remind student NOT to over-handle seeds from their selected ecosystem, as they will be used for planting.

Prior Student Knowledge Expectations:

- General understanding of needs of plants: interrelationships with animals to provide or utilize certain resources; water; minerals and nutrients from soil; sunlight; chlorophyll (green plants)
- Ability to observe and make appropriate conclusions based on evidence
- Willingness to step out of a comfort zone to design a seed uniquely adapted for a fictitious ecosystem
- General understanding and acceptance of collaborative behaviors

Possible Preconceptions/Misconceptions:

- All seeds germinate if dispersed to a favorable location.
- Seeds disperse in similar ways.
- Seed dispersal occurs only in the fall.
- The size of a seed is commensurate with the size of the plant.
- Plants can adapt quickly to changing abiotic conditions.

Materials (for each station)

- Station number cards
- Native woodland, prairie and pond area seeds (Other types of seeds are OK, but natural habitat seeds are preferred.) Affix one representative seed for that station onto the station card.
- 250-ml beaker of water (or any container)
- Plant seed classification guides
- Hand lens
- Picks or probes to manipulate prairie seeds without handling
- Seed Dispersal Data sheet
- Student Seed Design sheet

ENGAGE:

Consider these video options:

http://www.wimp.com/plants-explode/ – 1:53 minutes. From the Smithsonian Channel, this quick video depicts the tremendous force of projectile seed dispersal. Do all seeds disperse so dramatically? Challenge students to find out!

https://www.youtube.com/watch?v=rhp5k5ptSx0 – 3:53 minutes. Shows a variety of seed dispersal methods. Good time lapse photography showing primarily wind and water dispersal. Ask students to think of other seeds dispersed by wind and water. Introduce gravity and animal interactions as dispersal methods.

https://www.youtube.com/watch?v=j1hRxuy1ezQ – STEMbite: Seed Dispersal – 2:36 minutes. Explores a variety of common seed dispersal methods in a residential setting.

Ask students to identify adaptations noticed in the video for the various plants. Specifically, how do these adaptations help the plant repopulate within and beyond their ecosystem? Ask students to consider the seeds that naturally fall in their neighborhood. How are these seeds adapted for dispersal?

EXPLORE:

Process:

1. Distribute the Seed Dispersal Data sheet to each student. The task is collaborative, but each student is accountable for observations. Set up as many stations as needed so that student groups of no more than 2–3 can rotate from one station to the other every 4–5 minutes and all reach at least four stations. Each station should include a station number card, the common name of the plant, seed guides or other resource accessibility, a hand lens, the scientific name of the plant, several seed samples to handle, a beaker of water to test buoyancy, and one seed affixed to the station number card.

2. At the first station, ask students to examine the seed sample presented. Request suggestions about how this particular seed may be dispersed. Inquire how they know this to be true. (Previous experience, seed structure, etc.) Provide resources for students to crosscheck if they are unsure. When confident that the students understand the task, begin the rotation.

3. Students are to complete the Seed Dispersal Data sheet as they rotate. Students may confer with previous teams at any station.

4. Encourage students to examine the seeds with the magnifying glasses and record observations. What adaptations do students believe these observations represent? For example, if the seed has feathery structures, such as a dandelion, this seed may be adapted for wind dispersal.

5. Instruct students to compare the diagrams as they rotate. It is likely that some observations differ. Encourage discussion of differences. Challenge the students to justify their drawings.

6. Have students complete the “How will the seeds survive?” section of the Student Reflection sheet. Challenge students to imagine a harsh environment such as we find in Northern Illinois during parts of the year, specifying conditions. Instruct them, as a team, to engineer a seed design to withstand a seasonal condition that extends for several seasons and provide an efficient dispersal mechanism/method. Each design must incorporate at least three adaptations. How is this seed superior (or not) to the natural seeds observed? What other considerations are needed?

EXPLAIN:

Specialized plant and animal structures affect the probability of population success. These structures allow the organisms to adapt, repopulate, and thrive in their respective

ecosystems. Seeds' abilities to successfully mature and distribute demonstrate this concept.

ELABORATE:

- Invent another seed that could survive in the soggy forest of the Big Woods during an extended rainy season. Describe its adaptations' structures and functions.
- View pollen grains under the microscope. Compare size of the pollen grain with a seed from the same plant and the size of the seed with the plant. (Consider an acorn or a mustard seed.)
- Have students bring in other seeds home and explain their dispersal mechanisms.

EVALUATE:

Formative Monitoring: Use the Student Reflection sheet for discussion throughout the investigation.

Summative Assessment: Complete the story and respond to the two *How Will the Seeds Survive?* Scenarios are provided at the end of the Student Reflection sheet.

Elaborate Further/Reflect/Enrichment: Students can extend their exploration on seed dispersal by collecting and examining seeds/pods they find around their homes and/or school. Using a magnifier, study the structures of the seeds/pods, looking for specific adaptations that promote dispersal and the success of eventual germination.

Seed Dispersal Data

Common Name_____

Scientific Name_____

Means of Dispersal_____

_____

Adaptations for Dispersal_____

_____

Common Name_____

Scientific Name_____

Means of Dispersal_____

_____

Adaptations for Dispersal_____

_____

Common Name_____

Scientific Name_____

Means of Dispersal_____

_____

Adaptations for Dispersal_____

_____

Common Name_____

Scientific Name_____

Means of Dispersal_____

_____

Adaptations for Dispersal_____

_____

Name: _____

Student Reflection: Seed Adaptations for Survival and Dispersal

1. What would happen if all of the seeds from an adult plant attempted to grow near the parent plant, instead of being scattered (dispersed)?

2. What characteristics would a seed need if it were dispersed by the wind? Gravity? Water?

3. What adaptations would a seed need if "hitchhiking" in a dog's fur dispersed it?

4. Explain how the seeds you observed have adapted to the environment.

5. How did your drawings compare to others in the class? Did all of you highlight the same dispersal adaptive features?

Imagine that you are a seed that is dispersed over a long distance. Write your story. Where did you start? Where did you end up? Include at least three interactions with the natural world along the way.

How will the seeds survive?

Northern Illinois truly has one of the harshest climates on Earth! Think about it; it can drop to well below zero in the winter with wind chills that would impress polar bears. Yet in the summer, it can reach over 100 . There are years with many feet of snow in the winter and tremendous spring rains. Then there can be a season of severe drought. Toss in a tornado or two per season and the overall picture is dramatic. Where else on earth is there a potential temperature span of over 100 and precipitation totals with such variance? And, do not forget wind—lots of wind.

Organisms native to these conditions have adapted well to the variances, but sometimes the extremes become prolonged, such as the winter of 2013–2014 when a series of polar vortices dropped us into the deep freeze for months. *Do you believe that plants suffered?* Check the Fermilab database for years before and after this harsh winter and decide for yourself. Use Plot 16B full data and compare floristic quality indices and diversity. Record your data-supported response.
http://eddata.fnal.gov/lasso/quadrats/dataset-sum.lasso

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Imagine a lengthy summer that produces temperatures in the 80–90 range extending from April through October. Precipitation is scant and winds vary from day to day from about 10 mph to over 50 mph gusts. In the space below, develop a seed design that will withstand 6–7 months of heat that is unseasonable for much of the time. Include in your design dispersal mechanisms that are practical for this condition. On the back of the page, provide a rationale for adaptations based on your understanding of plant needs.

Teacher Page

Student Reflection Suggested Responses: Seed Adaptations for Survival and Dispersal

1. What would happen if all of the seeds from an adult plant attempted to grow near the parent plant, instead of being scattered (dispersed)?

   This could create a monoculture (areas with only one predominant type of plant). Not only would this lack of diversity be a detriment to the ecosystem, young plants would be in competition with parent plants for resources which could lead to resource depletion. Student suggestions may include: the lack of diversity may impede pollination, interfere with the appropriate return of nutrients to the soil, and be rather aesthetically boring.

2. What characteristics would a seed need if it were dispersed by the wind? Gravity? Water?

   Examples include:
   - *Wind-dispersed seeds are generally light and may have fluffy appendages, such as a milkweed or dogbane plant. They may also have "wings" like a maple that can be carried by the wind.*
   - *Gravity-dispersed seeds are heavier and do not fall far from the plant. These seeds need some assistance with disbursal. Squirrels "plant" many seeds. Some seeds, like the acorn, are rounded and may roll some distance.*
   - *Some water-dispersed seeds are, interestingly, waterproof for a period of time until they are ready. Many float on the surface and are carried a long distance from the parent plant.*

3. What adaptations would a seed need if "hitchhiking" in a dog's fur dispersed it?

   Seeds that attach to animal hides (or clothing) generally have tiny hooks or similar means of attachment. Encourage students to use the magnifying glass to see these tiny appendages.

4. Explain how the seeds you observed have adapted to the environment.

   Responses will vary. Expect a logical explanation of the adaptation(s).

5. How did your drawings compare to others in the class? Did all of you highlight the same dispersal adaptive features?

Responses will vary. Expect an explanation of any disparities in the adaptation(s) noted.

Imagine that you are a seed that is dispersed over a long distance. Write your story. Where did you start? Where did you end up? Include at least three interactions with the natural world along the way.

Expect a degree of sophistication as determined by the teacher and communicated to the student prior to assigning this task.

How will the seeds survive?
Northern Illinois truly has one of the harshest climates on Earth! Think about it; it can drop to well below zero in the winter with wind chills that would impress polar bears. Yet in the summer, it can reach over 100 . There are years with many feet of snow in the winter and tremendous spring rains. Then there can be a season of severe drought. Toss in a tornado or two per season and the overall picture is dramatic. Where else on earth is there a potential temperature span of over 100 and precipitation totals with such variance? And, do not forget wind—lots of wind.

Organisms native to these conditions have adapted well to the variances, but sometimes the extremes become prolonged, such as the winter of 2013–2014 when a series of polar vortices dropped us into the deep freeze for months. *Do you believe that plants suffered?* Check the Fermilab database for years before and after this harsh winter and decide for yourself. Use Plot 16B full data and compare Floristic Quality Indices and Diversity. Record your data-supported response.
http://eddata.fnal.gov/lasso/quadrats/dataset-sum.lasso

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Imagine a lengthy summer that produces temperatures in the 80–90 range extending from April through October. Precipitation is scant and winds vary from day-to-day from about 10 mph to over 50 mph gusts. In the space below, develop a seed design that will withstand 6–7 months of heat that is unseasonable for much of the time. Include in your design dispersal mechanism/s that are practical for this condition. On the back of the page, provide a rationale for adaptations based on your understanding of plant needs.

Seeds of Flight

How do biotic factors increase the likelihood of survival in an ecosystem?

Topic: Designing solutions to a problem

Brief Lesson/Lesson Set Description:
Working in a group, students design a wind dispersal seed structure that will carry a single seed the farthest distance possible. Successful designs should be analyzed and compared to nature.

Science and Engineering Practice: Designing solutions

Crosscutting Concept: Structure and Function

INVESTIGATION

Objectives: Students will:
- Design a seedpod and analyze the design according to data.
- Compare the design to seeds that are dispersed by wind in nature to find similarities and differences.

Narrative/Background Information:
Students will find challenges with this investigation that include, but are not limited to, error on the part of the person who drops the seeds, error on the part of the students who are judging where the seed stops, and whether or not to count the seed that drops and slides along the ground. Ask students to participate in a discussion that brings these issues up and ask students to suggest solutions. Come to a class consensus on the rules of the drop prior to starting to challenge.

Prior Student Knowledge Expectations:
Students have already seen examples in the nature of seeds that are dispersed by wind. Be sure to show students as many different examples as possible and remind them to take those characteristics into consideration when designing their pods.

Possible Preconceptions/Misconceptions:
Students may want to practice their designs in front of a fan prior to the competition. The class should agree to this and to how many practice drops a group will have. Students should be given a time limit to create their designs but be reminded that they will be allowed to redesign their pod after they have collected data.

Vocabulary: independent variable, dependent variable, wind dispersal, various parts of a seed/plant depending on how detailed students' designs become

Materials:
- Lima bean – 1 per design

- Paper – 1 piece per design
- Tape – 1 roll per design
- Pair of scissors
- Box fan

ENGAGE:
Ask students to discuss how seeds are dispersed by wind and what characteristics these seeds have in common.

EXPLORE:
Process:

1. Ask students to sketch out a design that would use no more than one piece of paper and tape but will carry a lima bean the farthest in class when dropped in front of a fan. Give students a time limit of 10 minutes and ask students to complete the task with a partner.
2. Students should be allowed 15 minutes to create their pods. Students can cut or tear the paper in anyway but cannot use more than one piece of paper. Students can use as much tape as they want. The lima bean needs to stay securely in the pod.
3. Set up a box fan with measurement marked on the floor. Discuss with students how to drop each, the height that the pods should be dropped from, and how to be consistent when dropping the pods. Also, discuss when to take the measurement, when the pod first drops or when it stops moving across the ground. Note that there will be human error and ask students to brainstorm how to limit this. An example will help students visualize how the investigation will be run.
4. Identify the variables within the investigation with the class.
5. Drop the pods. (The instructor should drop the seeds.) Identify a few students to watch for the distance at which the seed drops or stops sliding.
6. Drop each seedpod three times and ask students to record their data and find the average distance.

EXPLAIN:
Engage students in a discussion about the similarities of the seedpods that traveled the farthest in the class; compare these designs with those found in nature.

ELABORATE:
Ask students to develop and conduct a similar investigation for seeds that travel by animal or by water.

EVALUATE:
Formative Assessment: Ask students to defend their design or to explain how they would redesign their pod. Students should give valid reasons for their choice.

Summative Assessment: N/A

Elaborate Further/Reflect/Enrichment: N/A

Name: _____

Student Reflection: Seeds of Flight

1. Identify some features of the seedpod that traveled the farthest.

2. How were the structures of the seedpods that traveled the farthest similar to structures found in nature?

3. Consider your own seedpod. Did the data show what you expected when you created the design?

4. How would you change your design so that your pod traveled farther than it did?

5. If this investigation were conducted outside, how would the result be different?

Teacher Page

Student Reflection Suggested Responses: Seeds of Flight

1. Identify some features of the seedpod that traveled the farthest.

   Responses will vary.

2. How were the structures of the seedpods that traveled the farthest similar to structures found in nature?

   Responses will vary. Expect students to answer with specifics.

3. Consider your own seedpod. Did the data show what you expected when you created the design?

   Responses will vary.

4. How would you change your design so that your pod traveled farther than it did?

   Responses will vary. Expect students to answer with specifics.

5. If this investigation were conducted outside, how would the result be different?

   Responses will vary. Expect students to answer with specifics. Students should focus on how plants would change the effectiveness of the seedpod.

Sustained Writing

How do biotic factors increase the likelihood of survival in an ecosystem?

Topic: Observation and writing skills

Brief Lesson/Lesson Set Description:
Students will be given an opportunity to work at heightening their observation and writing skills in a field-like experience. Students can choose their perspective (focusing on a small area or the entire environment) and share their work with others, engaging them in peer discussion on the difference of perspective and the importance of detail.

Science and Engineering Practice: Obtaining, Evaluating, and Communicating Information

Crosscutting Concept: Systems and System Models

INVESTIGATION

Objectives: Students will:

- Focus upon and observe a specific site, noting details that could be overlooked with a cursory glance.
- Compile observations through writing, detailing particulars that are similar to and different from peers.
- Describe and appreciate the intricacy of common sights.

Narrative/Background Information:
Science literacy has become a targeted component of science education. This exercise blends written communication and observation skills into an activity that can be utilized effectively several times during the year. Students can participate in this activity several times throughout a unit or throughout the year.

Prior Student Knowledge Expectations:
Students may not start this process by noticing the details of their environments and may not include details in their writing. Encourage students to start their first journal with what they notice and to reflect on their quality of writing—after sharing and participating in discussions with their peers. As students continue to write, they should engage in self-reflection often in an effort to increase the amount of detail that is included in their observing and writing. The focus should be on growth in their writing, not on the “right answer” in the first entry.

Possible Preconception/Misconception:

- It may take students several tries before they are able to block out noise and other human distraction and observe what is happening in nature around them. Although students may be working in a natural environment, the sound of a passing car or others talking may be very distracting.

Vocabulary: observation, perspective

Materials:

- ½ meter of string
- Paper or journal
- Pen or pencil

ENGAGE:
Read this statement from Robert Wilson, first director at Fermilab. Dr. Wilson expresses his passion for the natural world. How might you describe the ecosystems you visit to reflect and share the beauty of our natural areas and preserve it for the future?

"Contrary to what many of us thought when we first came to these corn fields, there is a real potential for beauty here. We need to conserve and use every tree, every bush, every patch of grass, and every body of water that we have. …

"If we do preserve what we have, and add to it, and create with imagination, then the site can become a joy to behold–a source of pride for all of us. …" Robert Rathbun Wilson

EXPLORE:
Process:

1. In an outdoor school site area, instruct students to select a spot within a designated area and, if students are focusing on a small area, use the string to make a "circle" on the ground to create a focus area. Be sure students are separated enough so they will not be distracted.
2. Instruct students to write for a minimum of 10 minutes, nonstop, describing everything within the circle. NOTE: Drawings may accompany writing, but students MUST write as much as they draw.
3. Have the students go over their own writing (or a peer's) and underline the observations that are detailed and specific.
4. Process the observations via a class discussion. Identify ways to be more specific during the next sustained writing activity.

EXPLAIN:
Engage students in a discussion using responses from questions 1–4 on the Student Reflection sheet.

ELABORATE:
Students should work on different types of writing in their journals and document their progress in different styles of writing. For examples, students can document observations using sketches, in poems or in with charts and tables. Students can set goals in order to push themselves to participate in a variety of styles and improve on their writing.

EVALUATE:
Formative Assessment: Ask students to self-assess the quality and quantity of their observations and to set goals for their next journal entry, focusing on using adjectives in their descriptions.

Summative Assessment: N/A

Elaborate Further/Reflect/Enrichment: Compare and contrast writing from several students or ask one student to write about what's inside their circle and then focus on the entire environment; compare and contrast those pieces.

Name: _____

Student Reflection: Sustained Writing

1. What perspective did you choose to write from? Why did you choose this perspective?

2. What are the benefits of writing from a whole system perspective?

3. What are the benefits of writing about just one aspect of the system?

4. Compare your observations when you began the task to those you made at the end. Which was more detailed? Why?

5. When conducting fieldwork on a specific species, how might a global look at the ecosystem be a benefit?

Teacher Page

Student Reflection Suggested Responses: Sustained Writing

1. What perspective did you choose to write from? Why did you choose this perspective?

   Responses will vary.

2. What are the benefits of writing from a whole system perspective?

   Responses will vary. Students should begin to appreciate a global perspective.

3. What are the benefits of writing about just one aspect of the system?

   Responses will vary. Students may describe more detail and keener observations.

4. Compare your observations when you began the task to those you made at the end. Which was more detailed? Why?

   Responses will vary.

5. When conducting fieldwork on a specific species, how might a global look at the ecosystem be a benefit?

   Responses will vary. The global perspective will be more likely to include interactions and relationships.

Repeat the activity throughout the unit several times with the same student in the same space or switching spaces to different ecosystems. Compare the writings.

Revive this activity periodically throughout the school year noting seasonal changes. How has this area changed? How has the writing ability/quality changed?

Baked Potato Invertebrate Trap

How do biotic factors increase the likelihood of survival in an ecosystem?

Topic: To compare and classify some invertebrates found in the soil of a particular plot

Brief Lesson/Lesson Set Description:
Students set a trap for invertebrates by setting a baked potato down on the ground and waiting a few days for the invertebrates to crawl inside the potato and become trapped. If the invertebrates are able to escape, they will leave behind trails for students to observe.

Science and Engineering Practice: Planning and Carrying Out Investigations

Crosscutting Concept: Energy and Matter: Flows, Cycles, and Conservation

INVESTIGATION

Objectives: Students will:
- Identify organisms found in the soil.
- Compare their characteristics.
- Categorize soil organisms by their body structure.

Narrative/Background Information:
The baked potato trap is a good way to discover the variety of invertebrates in a relatively small area. The numbers can be astounding! However, generally the diversity is less than a Berlese funnel collection at the same spot. The Berlese sample involves more leaf litter and soil than the potato. Furthermore, many of the carnivorous invertebrates in the soil are not attracted to the potato other than to follow prey.

Some of the organisms entering the potato are scavengers, organisms that habitually feed on refuse or carrion-dead and putrefying flesh. Therefore, students may find a concentration of invertebrates of this nature in the potato that was not evident in the Berlese.

Plan to conduct this entire activity outdoors. After a few days, the potato becomes “fragrant” and may be overwhelming in a closed classroom. Make plastic gloves available if you feel students may balk at handling the potato trap.

Prior Student Knowledge Expectations:
- Understand that there are invertebrate species that live within the soil besides ants and worms.
- Recognize that organisms leave evidence of visiting the potato and may no longer be physically present.

Possible Preconception/Misconception:

- Students may have little realization of the vast numbers and diversity of species in the soil.

Vocabulary: invertebrate, organism, abiotic

Materials:

- Baked potatoes – halved (about three halves per group)
- Location markers such as colorful flags or ribbons
- Plastic Petri dishes or other unbreakable viewing tray
- Small plastic baggies
- Dissection probes, toothpicks or skewers
- Hand lenses or dissection microscopes
- Plastic gloves (optional)
- Cubic Meter of Soil sheet

ENGAGE:

Present the graphic *Cubic Meter of Soil*. Allow students to ask questions and make predictions about what they might find in their baked potato after a few days.

EXPLORE:

Process:

1. Prepare baked potatoes and place cut side down on a section of moist soil in a shaded area. Mark the location.
2. Repeat in a different location where there is a different type of soil or different weather conditions.
3. Allow potatoes to remain in place 48–72 hours undisturbed.
4. Carefully remove potato from soil and examine. Invertebrates may have penetrated interior of potato. Look for tiny holes as well as obvious trails; use probe to examine.
5. While still outdoors, use hand lenses to observe. Classify according to type (insect, snail, worm, etc.)
6. Collect group data and build conclusions based on all soil types.

EXPLAIN:

Engage students in a discussion about the diversity of organisms found in their potatoes; include the evidence of organisms that were not seen but left behind trails in the potato.

ELABORATE:

Ask students to participate in a discussion and possible planning session for an investigation that would result in data showing the differences in soil invertebrates across different areas of the same ecosystem or ecosystems not yet explored. (Consider using ecotones as well.)

EVALUATE:
Formative Assessment: Ask students to use the data found to give an explanation of how the invertebrate population in the soil is dependent on the abiotic factors of an environment. How might the population change?

Summative Assessment: N/A

Elaborate Further/Reflect/Enrichment:
Ask students to look at all data from the class to make generalizations about the type of organisms found in a certain type of soil and predict how abiotic changes may cause changes in invertebrates found.

Name: _____

Student Reflection: Baked Potato Invertebrate Trap

1. Does there appear to be a difference in the types of organisms at each site? Describe these differences.

2. What conclusions can you draw about the differences or similarities in the three sites?

3. Compare these organisms to those discovered with Berlese funnel. How can you explain the differences that you notice?

4. What can you predict about the food web from the data you collected?

5. What benefits do these organisms provide the environment?

6. Did the type of soil make a difference in the number or type of organisms?

7. How might the abiotic factors affect the type of organisms found in the soil?

8. If you were to conduct this study again, would you do anything differently?

Research the niche of the soil invertebrates that you discovered in the potato trap. Write an open letter to your city council informing them of the need for these soil organisms in an effort to curb unneeded insect abatement (spraying and/or application of insecticides) in neighborhood parks.

Teacher Page

Student Reflection Suggested Responses: Baked Potato Invertebrate Trap

1. Does there appear to be a difference in the types of organisms at each site? Describe these differences.

   Responses will vary. Generally, the moist, shady soil produces the most diversity of invertebrates. Check the mouthparts to discover if the organisms are scavengers, herbivores, omnivores, or carnivores. Since the potato is a plant, carnivores interested in the live organisms are not initially attracted but, after time, may follow their prey into the trap.

2. What conclusions can you draw about the differences or similarities in the three sites?

   Responses will vary.

3. Compare these organisms to those discovered with Berlese funnel. How can you explain the differences that you notice?

   Responses will vary. Expect students to be detailed and look at critical attributes of organisms in their descriptions and observations. It is likely that airborne insects may be found in the Berlese samples.

4. What can you predict about the food web from the data you collected?

   Responses will vary. Expect that students are accurate in their placement of organisms and predictions of energy transfer when using a food web model.

5. What benefits do these organisms provide the environment?

   Responses will vary; coach students to get to the decomposing benefits of having these organisms present in the soil.

6. Did the type of soil make a difference in the number or type of organisms?

   Responses will vary. The moist, shady soil should produce the most invertebrates.

7. How might the abiotic factors affect the type of organisms found in the soil?

   Expect students refer to temperature, precipitation, light intensity, and soil moisture in their explanation.

8. If you were to conduct this study again, would you do anything differently?

Responses will vary.

Research the niche of the soil invertebrates that you discovered in the potato trap. Write an open letter to your city council informing them of the need for these soil organisms in an effort to curb unneeded insect abatement (spraying and/or application of insecticides) in neighborhood parks.

Airborne and Crawling Invertebrate Survey

How can biotic factors increase the likelihood of survival?

Topic: Invertebrate survey and observation

Time Needed: Onsite Field Experience

Brief Lesson/Lesson Set Description:
Students use sweep nets and field observation tools to capture invertebrates, observe, classify by order and count. The organisms will be released back into the selected ecosystem. Data charts may be debriefed in the classroom.

Science and Engineering Practices: Planning and Carrying Out Investigations; Analyzing and Interpreting Data

Crosscutting Concepts: Patterns; Scale, Proportion, and Quantity; Structure and Function

INVESTIGATION

Objectives: Students will:

- Identify some of the invertebrates native to the Fermilab ecosystems.
- Classify specific invertebrate species.
- Identify adaptations of invertebrates that help ensure their success in this environment.
- Appreciate the invertebrates' niche and its importance to the ecosystem.

Narrative/Background Information:
Flying and crawling invertebrates are vital to the success of ecosystems. They pollinate the plants, are a food source for many other organisms, and help eradicate unwanted species. The prairie can support an amazingly wide diversity of invertebrates. In fact, invertebrate diversity mirrors plant diversity to a great degree—the more different species of plants, generally the more different species of invertebrates.

With sweep nets, students will collect a tremendous number of invertebrates. Many are so small that, without the observation cloth, they might go unnoticed. It is interesting to note that many seemingly identical invertebrates are actually different species! For example, eight separate and distinct species of bumblebees forage on the Fermilab prairie as discovered during a field study:
http://ed.fnal.gov/help/prairie/Franzen/fnal_species.html.

Access http://www.earthlife.net/insects/six.html for an interesting, student-friendly website with a glossary of insect related terms.

Prior Student Knowledge Expectations:

- Basic vocabulary to describe stages of an invertebrates' life cycle
- General understanding of proper handling of invertebrates and the need for caution when trying to capture them for observation; recognition of the value of each organism within the ecosystem
- Ability to use field guides and collection/observation tools with care and respect
- Willingness to participate in the investigation unless known to have allergic reactions
- General understanding and acceptance of collaborative behaviors

Possible Preconceptions/Misconceptions:

- Many students are fearful of invertebrates, believing that all invertebrates can hurt them. In reality, few are a threat. Students should avoid trying to capture known stinging invertebrates.
- The abundance of the numbers and relative diversity of an ecosystem's invertebrate populations is staggering. Students likely have no frame of reference for the magnitude of this observation.
- Students may believe that invertebrates are expendable and that it does not matter if they are harmed. Some invertebrates are rare and/or fill a very specific niche. Care when handling or transporting organisms must be done with care and respect.
- Young invertebrates do not necessarily resemble the adult stage.

Vocabulary: niche, diversity, population, community, complete and incomplete metamorphosis life cycle stages, classification terms (See *The Key to the Keys.*)

Materials:

- Sweep nets
- Observation cloth
- Hand lenses
- Viewing boxes
- Insect Field Guides
- Student data sheets
- Optional – Field access to Internet – Insect Keys:
    - *Earthlife* – Very complete but requires careful reading and more sophisticated terminology http://www.earthlife.net/insects/orders-key.html#key
    - *Discover Life* website offers an easy to use pictorial key to identify the insect orders. http://www.discoverlife.org/mp/20q?guide=Insect_orders

<u>Optional – Aspirator (To be done at school; DO NOT BRING TO FERMILAB.)</u>

- Wide-mouth jars
- Acetone

- Cotton balls
- Glue
- Tissue

Responsibilities:
Docent:
- Provide equipment.
- Facilitate activity on field trip.

Teacher:
- Appropriate preparation
- Provide data sheet for each research group.
- Debrief after trip.

ENGAGE:
Field Experience – The investigation is the engagement.

EXPLORE:
Process:
- Students collect insects by making wide sweeps with nets, fanning out in several directions within an area.
- Grasping the center of the net to contain insects in the bottom, students carefully deposit collections on a white observation cloth.
- Examine the insects and record on the data sheet.
- Temporarily capture organisms in viewing boxes or magnifying lenses. (Inform students to resist the urge to focus light on the organisms, causing discomfort or death.)
- Use a key or field guide to identify unknown invertebrates.
- OPTIONAL: Make aspirators (killing jars), if desired, by attaching cotton balls with glue to the lid of a wide-mouthed jar, adding several drops of acetone to the cotton, tucking some tissue into the jar to keep wings intact, and collecting insects. (NOTE: Keep the lid tightly closed for several hours, as insects may revive if exposed to fresh air too soon.)

EXPLAIN:
Debrief data sheets, encouraging students to share specific adaptations noted that help the organism survive in its ecosystem.

ELABORATE:
Invertebrates provide much to an ecosystem. In fact, the ecosystem is dependent on them. How do invertebrates contribute to the following ecosystem services?

- Nutrient cycling** (storage, nutrient cycling, biochemical breakdown)
- Pollination – **MS-LS2-4; MS-LS1-8**
- Biological control (trophic dynamic relationships/keystone species) – **MS-ESS3-3**

- Refugia (habitat for migration/visiting species) – **MS-LS2-1; MS-LS2-2**
- Food production – **MS-LS2-1**

**Concepts beyond middle level

EVALUATE:
Formative Monitoring: Students report their data at the conclusion of the activity, sharing types, abundance, and adaptations of invertebrates observed. Student Reflection questions can be a driving factor in these discussions. It may be beneficial to share drawings so students can visualize the invertebrates and learn from each other.

Summative Assessment: Completion of student data sheet

Elaborate Further/Reflect/Enrichment: Students may wish to build an invertebrate collection for the classroom. For this project, consider researching invertebrates found in the area to establish target collection organisms and note the advantages of having these invertebrates as part of the ecosystem. Are there any non-native invertebrates present? How might these organisms be controlled by natural means? Determine the relative risk of using chemicals or means other than nature to keep unwanted organisms in check.
https://www.bing.com/videos/search?q=insect+sweep+net&&view=detail&mid=E20ECB1626C562D8693FE20ECB1626C562D8693F&FORM=VRDGAR

Make your own sweep nets from old tennis racquets, pillowcases and other easy-to-find materials. www.lostladybug.org/files/SweepNet09.pdf

Names: _____

Invertebrate Data Collection

Organism (Sketch/Describe)	Abundant (too many to count) Common (2 or more) Unusual (1)	Possible Identification by Order (Confirm ID if possible.)

Organism (Sketch/Describe)	Abundant (too many to count) Common (2 or more) Unusual (1)	Possible Identification by Order (Confirm ID if possible.)

Name: _____

Student Reflection: Airborne and Crawling Invertebrate Survey

1. What aspect of this field experience investigation surprised you the most?

2. Which organism appeared to be the most abundant? Why do you think this is so?

3. Describe the adaptations of your most interesting organism. How do these adaptations help the organism be successful in the ecosystem?

4. Considering this same organism, what do you believe would occur if suddenly this species disappeared from the ecosystem? Support your belief with a scientifically-based rationale.

5. If you were to describe this activity to your family, what would you say you would do differently next time?

Teacher Page

Student Reflection Suggested Responses: Airborne and Crawling Invertebrate Survey

1. What aspect of this field experience investigation surprised you the most?

   Responses will vary. Expect such ideas as abundance, diversity, etc.

2. Which organism appeared to be the most abundant? Why do you think this is so?

   Responses will vary. Expect a logical rationale.

3. Describe the adaptations of your most interesting organism. How do these adaptations help the organism be successful in the ecosystem?

   Responses will vary. Students should look at appendages, including legs, wings, exoskeleton and especially mouthparts.

4. Considering this same organism, what do you believe would occur if suddenly this species disappeared from the ecosystem? Support your belief with a scientifically-based rationale.

   Responses will vary. Students should base the belief on information that is verified, as in a field guide or reputable web source.

5. If you were to describe this activity to your family, what would you say you would do differently next time?

   Responses will vary. Expect a logical, constructive change in process.

How can biotic factors increase the likelihood of survival?

MS-LS1-4. Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of plants and animals respectively.

MS-LS2-2. Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.

Work with your chosen insect or plant organism to identify the following:

What is the most important behavior of your organism (plant or insect) that increases its odds of survival and future reproduction?

_____

_____

_____

_____

_____

Describe a relationship between your chosen insect and a plant (or plant and an insect). You may want to show your learning through diagrams as well as writing. Who benefits more from the relationship? Back up your claim with scientific reasoning and evidence from your learning during this unit.

_____

_____

_____

_____

_____

If you have chosen an insect, make a prediction about the odds of survival for your insect if an invasive plant species is introduced into your ecosystem and has depleted the plant's population that your insect depends on by half. The invasive plant utilizes the

same resources as your insect's plant but has a different color flower, different bloom time and is only half the size.

If you have chosen a plant, make a prediction about the odds of survival for your plant if an invasive insect species is introduced into your ecosystem and has depleted the native insect's population that your plant depends on by half. The invasive insect utilizes the same resources as your native insect.

_____

_____

_____

_____

_____

Everyone's Important

How do abiotic and biotic factors work together to cycle energy and resources through an ecosystem?

This activity is adapted from *Illinois Biodiversity Basics*, Illinois Department of Natural Resources, Chicago Wilderness, World Wildlife Fund.

Topic: The importance of biodiversity in supporting a healthy food web and ecosystem.

Brief Lesson/Lesson Set Description:
Students engage in an interactive game to depict the strength of a genetically diverse species population within an ecosystem community and gain an appreciation for each member of an ecosystem regardless of it size, strength, or reputation as a producer, consumer or predator. Organisms must function to benefit an ecosystem by fulfilling individual niches.

Science and Engineering Practice: Obtaining, Evaluating and Communicating Information

Crosscutting Concept: Patterns

INVESTIGATION

Objectives: Students will:

- Explain why genetic diversity is necessary for the long-term survival of a population of animals or plants and know the difference between genetic diversity and diversity of organisms within an ecosystem.
- Know and apply concepts that describe how living things interact with each other and with their environment.
- Appreciate and explain the niche of organisms within an ecosystem to provide resources for other organisms including humans.

Narrative/Background Information:
What is biodiversity? For every person you ask this question, you could get a different answer. According to *Chicago Wilderness,* "Biodiversity is a totality of genes, species, and ecosystems in a region." A healthy prairie would normally include dozens of plant species as well as habitat for various species of birds, mammals, reptiles, amphibians, insects, mites, fungi and bacteria. A healthy ecosystem will have a wide diversity of the plants and organisms. Everyone agrees that the quality of our lives depends on the diversity of the region. Prairies were once abundant in Illinois, but they were nearly destroyed by farming. As the steel plow gained popularity, farmers were able to cut through the dense root biomass of the prairie and sow their crops in the rich soil. In a matter of a generation, much of the prairie became rich farmland and the native diversity diminished dramatically. What was once a vibrant, diverse ecosystem was

becoming a series of monocultures—areas with one primary type of plant. Farms were and remain productive sources of food for humanity and a primary industry in Illinois. The lawn at your school or residence is also considered a monoculture. For the gardener, a perfect lawn means no weeds. Look more closely. Is it all grass? A seemingly perfect lawn often is not what it seems. Frequently lawns have other plants in them. A fussy homeowner might find this added diversity problematic but, in reality, a more diverse lawn could stay greener longer, especially if some of those plants are native.

Examine a small section of lawn. The roots are relatively short. This is why lawns can often be started with blankets of sod. Grass for lawns is harvested multiple times a year by machines that shave off the grass plus about 10 centimeters of soil. New topsoil may be spread at the sod farm and more grass seeds are sown. Rolls of sod are delivered prospective lawns, but what would happen if that new sod does not receive enough water? It dies and must be redone. Even after several years of growth in one location, a drought can ruin an established lawn. Interestingly, lawns with plenty of native ground clovers stay green. Ground clover is adapted for these circumstances.

Planting a monoculture such as a non-native grass lawn can be risky business. Ask any farmer whose corn, wheat or soybean crop is ruined by heat, drought, floods, pre-season frost, rootworms or locusts. Often farmers will offset possible disaster by planting various crops. A rootworm that attacks corn may not favor the wheat. If one species is taken from an ecosystem, it is bad. Surveys at Fermilab continually monitor species in the natural areas and efforts are made to restore or fortify critical species that are declining. Often other organisms can mediate the decline of a species until it comes back. But for the farmer, a lost single species crop is just that—lost.

Farmers are defenseless against extremes in weather such as floods and frost, but agricultural geneticists continually look for ways to protect crops against disease and invertebrate infestation. They also try to develop plants that are resistant to extremes in temperature and precipitation. Discovering ways to mediate these threats is the work of scientists specializing in *genetic diversity*. Genetic diversity is the totality of the genetic makeup of a species. It offers the possibility of populations to adapt to changing environments by isolating the genetic qualities that allow an organism to survive particularly harsh conditions. These individuals are then better able to pass these traits onto the next generation, leading to a hardier set of organisms.

Why is this important? Due to climate change and other factors, farmers need resilient crops. Since crops are genetically far from the native crops sown by the first people in North America, it is an ongoing battle. Interestingly, the native areas do not stay exactly the same from year to year. Some years, compass plant is prevalent. Other years we see very few, but the prairie dock is common. Nature cycles plants such that the natural areas self-maintain, provided they are not disturbed. The plants may lie dormant for a season or two, but when the time and conditions are favorable, they reemerge.

Fermilab is continually restoring the prairie, enriching woodlands, forests and waterways. In so doing, the diversity of the Fermilab campus is improving. As plant life is revitalized and enriched, the animals also are coming back as evidenced by the variety of invertebrates and birds onsite. There are many monitoring programs that keep track of onsite species of both plants and animals—including the surveys made by students.

Prior Student Knowledge Expectations:

- General understanding of diverse communities
- Ability to follow directions in a manner appropriate for classroom conduct
- Willingness to accept their demise if their card characteristic is called
- General understanding and acceptance of collaborative behaviors

Possible Preconceptions/Misconceptions:

- Differences within species are uncommon.
- The loss of one species does not really matter.
- Diversity is inherently *messy* and unappealing.
- Native plants are weeds.
- Diversity within the plant communities of an area serves to attract a diverse animal community.

Vocabulary: biodiversity, species, critical attributes, diversity

Materials:

- Diversity Cards

ENGAGE:

Present the class with a clear glass jar containing some ants. Ask, "What are these?" Expect students to identify them as ants. "How many species of ants are there in the world?" Allow responses and follow up by revealing that scientists have named over 14,000 ant species and the number will climb.

Now ask students to glance around the classroom. "What genus and species are all of you?" Homo sapiens. "You are all the exact same species, but do you all look alike? Think alike? Today we will demonstrate why genetic diversity within a species matters."

EXPLORE:

Process:

1. Divide the students into two teams and explain that they are going to be part of a demonstration that illustrates why genetic diversity (diversity within a species) is important. The winning team will be the one with the most people standing after the teacher reads five cards.
2. Carefully explain that the characteristics noted are largely external characteristics, not necessarily human qualities.
3. Read one characteristic off of a card. Anyone with that characteristic must sit down. (*If there is a student who is unable to stand, you might want to change this to give*

everyone a piece of paper to hold up. When the characteristic fits them, then the paper will have to be laid down.)

4. Read five cards. Who is left standing? Why?
5. Offer students another chance. Begin again, but this time everyone may make one change in their appearance. Mix the cards up and do the same thing again.
6. What were the results this time? Why?
7. If too many people are sitting down, use discretion and pick a characteristic that may apply only to one or two people—e.g., shoes with black soles.
8. Discuss how the diversity of the team helped it survive.
9. Are there any two people who are exactly alike in the class? This could continue into a discussion of talents and how everyone has something to contribute.
10. When you do the Quadrat Study: School Lawn, take time to look at more than the plants. What else is there? If they find critters, fungus, etc., that also could be noted on the grid. In the field trip quadrat, invertebrates will be surveyed as well as plants.

EXPLAIN:
Students should understand the difference between ecosystem diversity and genetic diversity within a species.

ELABORATE:
Select five foods you and your family really like. You and your family may have these foods everyday and as much as you would like, but there is a dilemma. You may have these five foods and nothing else regardless of the nutritional value. What effect would this have on you and your family after a week? A year? A lifetime? How does this scenario relate to species genetic diversity?

Some of these foods may lack the proper nutrients for health. One member of the family may be able to physiologically adapt to these conditions while others could languish and perhaps be unable to reproduce or die. The member that survives to be a parent could produce offspring with an even better genetic profile to survive on this diet.

In the Galapagos, Darwin's finches are an example of this situation. Read the ongoing history of this study to fully appreciate genetic diversity.

http://www.livescience.com/32409-whats-so-special-about-darwins-finches.html
http://evolution.about.com/od/Darwin/a/Charles-Darwins-Finches.htm

EVALUATE:
Formative Monitoring: Use Student Reflection questions for discussion throughout the investigation.

Summative Assessment: N/A

Elaborate Further/Reflect/Enrichment: Students may further research the impact of the loss of a species to an ecosystem or how the loss of a species is an indication of the health of an ecosystem. Students may want to highlight keystone species and discuss

the importance of the protection and preservation of a keystone species and how these efforts protect many other species indirectly.

Diversity Cards

Shoes that have laces		Soles of shoes that have a color on them		Wearing something in your hair
Wearing something red		Wearing a ring on your thumb		Wearing a jacket
Not wearing jeans		Wearing stripes		Wearing socks
Wearing a watch		Wearing earring(s)		Shirt with a collar
Wearing short sleeves		Shoes that have buckles on them		Wearing shoes with laces that are not tied
Blue eyes		Unable to curl your tongue		Wearing shorts

Name: _____

Student Reflection: Everyone's Important

1. How was it possible for some people to remain standing throughout the entire game?

2. What patterns did you see as you played the game?

3. Changing a characteristic was easy for you to do. How would it be possible in nature for an animal to change a characteristic?

4. When an ecosystem is systematically destroyed with little concern for natural area land management, organisms can suffer and possibly perish. Provide an example.

5. Did one characteristic wipe out more people on the team than other characteristics? Why? Connect this situation with one in nature.

6. There is an old saying, "Variety is the spice of life." Would you agree? Why or why not?

7. Apply your belief about variety to a Northern Illinois ecosystem.

8. The qualities on the cards are not all human characteristics. Rather, they are garments or jewelry. Which characteristics are truly human? Are these characteristics easy to change? What are some characteristics in the wild that organisms simply cannot change? What happens to these organisms?

Teacher Page

Student Reflection Suggested Responses: Everyone's Important

1. How was it possible for some people to remain standing throughout the entire game?

   Survivors had a variety of characteristics that were not called.

2. What did you do to increase your chances of remaining in the game?

   Change one of the common characteristics.

3. Changing a characteristic was easy for you to do. How would it be possible in nature for an animal to change a characteristic?

   Responses will vary. In nature, organisms capable of relocation do so. Physical changes happen over time. If the organism cannot adapt quickly enough, it will not survive as a species.

4. When an ecosystem is systematically destroyed with little concern for natural area land management, organisms can suffer and possible perish. Provide an example.

   Many students will cite Amazon rainforest. This is true, but there is a more relevant example in Illinois. Many species of prairie plants and animals today are highly endangered or extinct due to the rapid advancement of farming in the mid-1800s.

5. Did one characteristic wipe out more people on the team than other characteristics? Why? Connect this situation with one in nature.

   Responses will vary. Example: An organism not adapted to drought may perish in an extended dry period.

6. There is an old saying, "Variety is the spice of life." Would you agree? Why or why not?

   Responses will vary.

7. Apply your belief about variety to a Northern Illinois ecosystem.

   Responses will vary. Students should be able to relate an example relevant to either plants or animals in the region.

8. The qualities on the cards are not all human characteristics. Rather, they are garments or jewelry. Which characteristics are truly human? Are these characteristics easy to change? What are some characteristics in the wild that organisms simply cannot change? What happens to these organisms?

   Eye color and tongue rolling; eye color can be changed with colored contact lenses, but the true color remains the same. When the lenses are removed, the vulnerable characteristic is still evident. Tongue rolling cannot be changed by any practical means. Organisms with a vulnerable characteristic are greatly disadvantaged for survival.

Pollinators and Consumers – CSI Ecosystem

How do abiotic and biotic factors work together to cycle energy through an ecosystem?

Topic: Adaptations and interrelationships between organisms

Brief Lesson/Lesson Set Description:
Students note the varied invertebrates in and around the quadrat or general area. They study the interrelationships between specific plants and invertebrates, focusing upon the structure/function and adaptations of organisms. (Suggested prerequisites: *Critical Attributes – Prairie Plants and Invertebrates* and *Adaptations*)

Science and Engineering Practice: Obtaining, Evaluating and Communicating Information

Crosscutting Concept: Structure and Function

INVESTIGATION

Objectives: Students will:

- Establish the niche of specific organisms in an ecosystem.
- Observe, collect, and report data pertaining to interrelationships of organisms noted in the ecosystem.
- Explain the nature of adaptations of these organisms.
- Evaluate the effectiveness of the structure to the function of organism attributes.
- Interpret data and utilize it to explain the natural relationships in the ecosystem.

Narrative/Background Information:
A typical native Midwest ecosystem often includes an immense diversity of organisms. Each organism occupies a unique ecological niche. This refers to the role played by an organism in a biological community including its food preferences, requirements for shelter, special behaviors, and the timing of its activities (e.g., nocturnal, crepuscular—active at twilight, or diurnal). The ecological niche of an organism has little to do with where it is found, but much more to do with its function or role (e.g., predator, consumer, decomposer) and how it performs that function.

Pollination, decomposition, and predation are necessary events in an ecosystem. The other residents of the ecosystem continually visit the plants. The most abundant group of organisms, as with virtually every ecosystem on earth, is the invertebrates. Invertebrates, specifically insects, are responsible for most of the pollination and often much of the foliage damage noted. In fact, at the hands (or mouths!) of herbivorous and carnivorous insects, the ecosystem can sometimes appear to us as sites worthy of a crime scene investigation (CSI)!

In order for plant reproduction to take place, pollen must be removed from the stamen's anther on one plant and introduced to the pistil's stigma on another plant, usually of the same species. Sometimes self-pollination occurs, but most plants require pollinators to perform this service. Wind and, to a much lesser degree, water are pollinators, but much pollination is dependent upon insects. Insects are also responsible for what may initially be considered detrimental. In order to maintain a healthy ecosystem, *native* insects do a certain amount of plant damage and some prey upon other insects. These acts are not purely destructive; rather, they are important in the maintenance of the ecosystem.

Because of the diversity of insects, the student will likely concentrate on bumblebees and butterflies as pollinators because they are generally more easily followed, realizing, of course, that many other insects are involved in this process. The observations of the insect consumers (herbivores and carnivores) will be generic. A general description of the consumer will be sufficient (i.e., spider, beetle, larva, etc.). Description of anatomical structure and function will focus on such observations as protective coloration, long tongues for collecting nectar from forbs such as *Monarda fistulosa* (wild bergamot) with deep corollas, or pollen sacs on bumblebee legs to gather pollen.

Students will focus on a wide variety of forbs and should be familiar with the primary ecosystem plants. Prior to taking students to the field, the Fermilab website database and visualization tools for prairie plants will prove helpful. (Woodlands and pond areas to come) http://ed.fnal.gov/data/life_sci/vis_tools/

This exercise can also be accomplished on an open field site near a school building with students observing insects on common flowers such as clover, dandelions, or garden flowers. Encourage students to describe organisms with pictorial as well as textual/verbal details.

The data collection table provided is designed to be a quick, simple way to record invertebrates in the field. Identification by order is sufficient for this exercise. (See Common Insect Orders Guide.) If students have access to digital cameras or cell phones, encourage taking photos for more precise identification.

Prior Student Knowledge Expectations:

- General understanding of what is meant by form/function and adaptations (See *Critical Attributes – Prairie Plants and Invertebrates* and *Adaptations*.)
- Recognition of some plants and invertebrates common to the ecosystem studied
- Ability to use observation skills and collect data within a short time frame
- Willingness to approach invertebrates with confidence
- General understanding and acceptance of collaborative behaviors

Possible Preconceptions/Misconceptions:

Diversity within the invertebrate world is typically underestimated. Encourage students to look closely at the Common Insect Orders Guide for a general grouping, but note also

distinguishing characteristics such as size, color, flight pattern, etc. ALL insects are capable of pollination regardless of niche. Some are more specialized for this task. NOTE: Students may express concern about observing invertebrates, especially insects such as bees and arachnids (spiders). The attitude of the instructors/chaperones is critical. Even stinging organisms are typically far more interested in foraging than bothering humans—provided they are not antagonized. Extra care should be taken and medication readily available if there is a participant with a specific allergy.

Vocabulary: diversity, pollinators, invertebrates, adaptation, abundance, consumer

Materials:

- Fermilab website access (Preparation – Identifying ecosystem plants)
- Field guides
- Common Insect Orders Guide
- Clipboard
- Data sheets
- Pencils with erasers
- Watch with second hand or stopwatch
- Insect medication if allergic to specific insect bites
- Perseverance, energy, and PMA (Positive Mental Attitude)

ENGAGE:
Ask students to envision a natural setting and name a few invertebrates that might inhabit the area. What is that organism's niche? Watch *The Beauty of Pollination*.
http://www.youtube-nocookie.com/embed/xHkq1edcbk4?rel=0

EXPLORE:
Process:
Pre-Lab

1. Prior to field experience, students should design a research question and develop hypotheses for an informal research question such as the following:
    - Will pollinators tend to visit only one kind of flower, or several different species? (Conclusion: If so, what are these relationships and what structural adaptations are evident?)
    - Will a favored forb (showy flower) have specific features that make it more attractive? (Conclusion: If so, what are the structure and function of these characteristics?)
    - Will you see evidence of any animals eating or, in any way, damaging plants in the ecosystem? (Conclusion: If so, what occurred and what adaptations are utilized?)
    - Will you see evidence of any animals eating or, in any way, damaging other animals in the ecosystem? (Conclusion: If so, what occurred and what adaptations are utilized?)
    - *Solicit additional questions from students*. Facilitate adoption of additional questions by confirming that they are researchable. Formulate conclusion prompts accordingly.

2. Ask students to individually contemplate their hypotheses to each question and write them down on Data Sheet 1. (The conclusion segment will be considered after the analysis of field research data.) Explain that different teams will research different questions and debrief findings to the class.
3. As a class, discuss hypotheses. Use newsprint or some other permanent method to record individual thoughts and, where indicated, class consensus.
4. Remind students that at the end of the exercise, they will use their data (and data collected by classmates) to draw conclusions as part of their post-lab debriefing.

Lab Field Experience

1. Assign students to research groups of 3–4 students.
2. Assign (or have students design) a question to investigate from the previously suggested list.
3. Instruct students to design a plan for observation and data acquisition and divide observation and data collecting tasks within their group. (NOTE: It is best to encourage a plan that does not involve movement beyond a relatively small area.) Suggested roles may include:
    - Organizer (project manager, timekeeper, quality control, etc.)
    - Recorder (Record data in an appropriate manner.)
    - Reporter (Present data for class debriefing.)
    - Artist/Interpreter (Draw or otherwise interpret data, assist recorder and reporter.)
4. Visit the ecosystem and collect data.
5. Instruct students to complete Data Sheet 2.

Post-Lab

1. Present the list of hypotheses from pre-lab experience. Re-establish which student research groups will present each set of data and instruct teams to prepare data for debriefing.
2. Compare data collected with the pre-lab hypotheses.
3. Debrief as a class. (Process data collected for hypotheses from pre-lab and establish trends; note observations from other teams, and note sources of error.)
4. Analyze data from all sources and compose conclusions. (NOTE: This step may be class collaboration or an individual effort through which students will compile all data. Ask students to note all similarities and tendencies to construct class conclusion. Include all topics covered in these hypotheses. Consider sources of error.)

ELABORATE:

Invertebrates provide much to an ecosystem. In fact, the ecosystem is dependent on them. How do invertebrates contribute to the following ecosystem services?

- Nutrient cycling** (storage, nutrient cycling, biochemical breakdown)
- Pollination – **MS-LS2-4; MS-LS1-8**
- Biological control (trophic dynamic relationships/keystone species) – **MS-ESS3-3**
- Refugia (habitat for migration/visiting species) – **MS-LS2-1; MS-LS2-2**

- Food production – **MS-LS2-1**

**Concepts beyond middle level

EVALUATE:
Formative Monitoring: Use Student Reflection questions for discussion throughout the investigation.

Summative Assessment: N/A

Elaborate Further/Reflect/Enrichment: Consider the advantages/disadvantages of the lives of pollinators and consumers, select an insect, and write a story about a day in its life. Provide details about the insect's adaptations for survival.

Name: _____

Pollinators and Consumers – Data Sheet 1

Think about the kind of invertebrate life you may see in the ecosystem. What might these spiders, insects or other invertebrates be doing? How might they be affecting the plants and other animals around them? Take time to write a well-constructed hypothesis for each of the questions below. The data evidence will be collected in the field and conclusions will be considered at the end of the lab field experience.

Construct a research question of your own and ask your teacher for approval before you proceed. Follow the protocol noted below for your investigation.

QUESTION:

Hypothesis:

Data Evidence (Brief):

Conclusion:

Other research questions from which to select:

1. Will pollinators tend to visit only one kind of flower, or several different species? (Conclusion: If so, what are these relationships and what structural adaptations are evident? If no correlation is evident, why might this be so?)

Hypothesis:

Data Evidence (Brief):

Conclusion:

2. Will a favored flower have specific features that make it more attractive? (Conclusion: If so, what are the structure and function of these characteristics? If no correlation is evident, why might this be so?)

Hypothesis:

Data Evidence (Brief):

Conclusion:

3. Will you see evidence of any animals eating or, in any way damaging plants in the ecosystem? (Conclusion: If so, what occurred and what adaptations are utilized? If no evidence is apparent, why might this be so?)

Hypothesis:

Data Evidence (Brief):

Conclusion:

4. Will you see evidence of any animals eating or damaging other animals in the ecosystem? (Conclusion: If so, what occurred and what adaptations are utilized? If no evidence is apparent, why might this be so?)

Hypothesis:

Data Evidence (Brief):

Conclusion:

Name: _____

Pollinators and Consumers – Data Sheet 2
Data Evidence

DIRECTIONS: Determine whether your research question refers to pollinators or consumers (herbivores or carnivores) and record data in the appropriate section. Use the table format as a suggested model. Reconstruct on your own paper.

Pollinators

Research Question: _____

_____

Invertebrate	**Abundance** (1–2; 3–10; etc.)	**Forb(s) Visited**	**Adaptations Observed** (Include both plant and animal adaptations.)	**Sketch/Description** (color, patterns, etc.)
1.				
2.				
3.				

Use back of page to add more lines as needed.

Conclusion:

Consumers (Plant Damage)

Research Question: _____

_____

Invertebrate	**Abundance** (1–2; 3–10; etc.)	**Forb(s) Visited**	**Adaptations Observed** (Include both plant and animal adaptations.)	**Sketch/Description** (color, patterns, etc.)
1.				
2.				
3.				

Use back of page to add more lines as needed.

Conclusion:

Consumers (Predation)

Research Question: _____

_____

Invertebrate	**Abundance** (1–2; 3–10; etc.)	**Forb(s) Visited**	**Adaptations Observed** (Include both plant and animal adaptations.)	**Sketch/Description** (color, patterns, etc.)
1.				
2.				
3.				

Use back of page to add more lines as needed.

Conclusion:

Name: _____

Student Reflection: Pollinators and Consumers – CSI Ecosystem

1. Which original hypothesis was best supported? Which were rejected? Are you surprised? Why? Why not?

2. Suggest sources of error in the data collection process.

3. Considering all the invertebrates you noticed, were any NOT pollinators? Support your belief with evidence.

4. Which forb appeared to be most popular the pollinators? Why do you think this is so?

5. Were there any forbs not visited by pollinators at all? How might they be pollinated if not by insects?

6. Which pollinators are also consumers? Name them and indicate your evidence.

7. Explain how some consumers can be both detrimental (harmful) and helpful.

8. Can we survive without pollinators and/or consumers? Why or why not?

9. Decide whether you believe insects are good or bad for the ecosystem. Justify your response with data collected.

10. Considering all the data collected by your classmates, which invertebrate appears to be the most common? Why do you believe this is so? Note the plant(s) this organism visits. How would eradication of this plant or this invertebrate affect the ecosystem in the short and long term?

11. In what way(s) were your observations similar to a crime scene investigation (CSI)? Describe ways your student research teams modeled the strategies of a crime scene investigator.

Teacher Page

Student Reflection Suggested Responses: Pollinators and Consumers - CSI Ecosystem

1. Which original hypothesis was best supported? Which were rejected? Are you surprised? Why? Why not?

   Responses will vary. Expect specificity within the responses. Evidence should be clearly stated.

2. Suggest sources of error in the data collection process.

   Responses will vary. Expect specificity. Errors, human or otherwise, should be clearly reported.

3. Considering all the invertebrates you noticed, were any NOT pollinators? Support your belief with evidence.

   Responses will vary. Check to ensure that the evidence is noted on the data page(s).

4. Which forb appeared to be most popular with the pollinators? Why do you think this is so?

   Responses will vary. Check for logical rationale supported by data evidence.

5. Were there any forbs not visited by pollinators at all? How might they be pollinated if not by insects?

   Responses will vary. Ideas should note a logical rationale.

6. Which pollinators are also consumers? Name them and indicate your evidence.

   Responses will vary. Check to ensure that the evidence is noted on the data page(s).

7. Explain how some consumers can be both detrimental (harmful) and helpful.

   Responses will vary. Explanations should be logical and supported by evidence wherever possible.

8. Can we survive without pollinators and/or consumers? Why or why not?

Responses will vary, but students should be aware that pollination is a critical ecosystem service. Humankind may survive short term without pollination, but the long-term projection of life without pollinators is grim.

9. Decide whether you believe insects are good or bad for the ecosystem. Justify your response with data collected.

   Responses will vary. Check to ensure that the data evidence noted is on the student data sheets.

10. Considering all the data collected by your classmates, which invertebrate appears to be the most common? Why do you believe this is so? Note the plant(s) that this organism visits. How would eradication of this plant or this invertebrate affect the ecosystem in the short and long term?

    Responses will vary. Expect a logical rationale with data evidence.

11. In what way(s) were your observations similar to a crime scene investigation (CSI)? Describe ways your student research teams modeled the strategies of a crime scene investigator.

    Responses will vary. Expect a logical rationale with specific methodologies noted.

Trophic Interactions and Food Webs

How do abiotic and biotic factors work together to cycle energy and resources through an ecosystem?

Topic: Trophic Interactions – Food Chains/Food Webs

Brief Lesson/Lesson Set Description:
This investigation is a complement to *Thinking Environmentally,* which deals with the impact of humans and/or abiotic factors in the environment. It defines the interrelationships in different trophic levels between organisms within the ecosystems on a more global level, specifically Yellowstone National Park. Students will trace the energy transferred from the sun through the trophic levels and appreciate the small percent of energy that finally comes to the apex predator—the wolf. The nutrient cycle will be introduced as well as the impact of introducing and/or removing keystone species from an ecosystem.

Students will create a food web and food chain using organisms indigenous to the Yellowstone ecosystem as presented in the *How Wolves Change Rivers* video and speculate as to the short-term and longer-term effect of removing or introducing a different keystone species. Energy and biomass pyramids as well as trophic cascades are included. This is best used as a post-field trip activity.

Students will jigsaw the following topics:

- Trophic levels
- Food chains and food webs/nutrient cycle
- Trophic cascades
- Biomass Energy Flow – The 10% Rule

Science and Engineering Practice: Constructing Explanations and Designing Solutions

Crosscutting Concept: Energy and Matter in Systems

INVESTIGATION

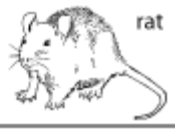
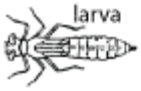
Objectives: Students will:

- Understand that green plants use energy from the sun to produce biomass that serves as a food source for other organisms.
- Design a food chain and food web model to portray the relationships of organisms within a specific ecosystem.
- Recognize that nutrients are recycled throughout the ecosystem.
- Track the transfer of energy as it flows throughout an ecosystem.
- Explain the consequences of the introduction or removal of a key predator.
- Design a visual scenario depicting the result of a trophic cascade, which may have a dramatic effect on an ecosystem.

Narrative/Background Information:
The trophic level of an organism is determined by what it eats—and who eats it. The number of steps an organism is from the start of a food chain is its trophic level.

- Food chains begin with the primary producers at Level 1.
- Plants are eaten by herbivores such as rabbits, deer and cows at trophic Level 2. These organisms eat only vegetation and are called primary consumers.
- Predators that primarily consume herbivores are secondary consumers and occupy Level 3.
- Level 4 organisms, if present in the ecosystem, eat both herbivores and other carnivores and are considered tertiary.
- Levels 5 and 6 (or more, depending on the scenario) include higher carnivores, topped by the apex (quaternary) predator who has no natural predators. NOTE: Food chains rarely extend beyond Level 6 due to the 10% rule, which is discussed later with Biomass Energy Flow.

Sample Food Chains

Trophic Level	Grassland Biome	Pond Biome	Woodlands Biome
Primary Producer	grass	algae	ground coverplants
Primary Consumer	grasshopper	mosquito larva	insect
Secondary Consumer	rat 	dragonfly larva 	bird
Tertiary Consumer	snake	fish	snake
Quaternary Consumer	hawk	raccoon	coyote

Organisms get food based on their roles as producers, consumers or decomposers. Each role is essential for ongoing sustainability.

- <u>Primary producers</u> are autotrophic, meaning that they do not eat other organisms. Rather, they secure their nutrition from their environment. Plant roots

absorb nutrients dissolved in soil water. Algae get nutrients from the body of water that surrounds them. Since these organisms cannot selectively move on their own, they are dependent on their environment for their basic needs, including not only food and moisture, but also pollination or other means of reproduction.

Green plants utilize a process called photosynthesis to make glucose, a simple sugar, which some plants further convert to starch to sustain themselves. Plants get their energy for photosynthesis from the sun. An exception is life that dwells in darkness in the deep-sea hydrothermal zones. These organisms make their food through chemosynthesis. While all levels are important, the role of the producers is most critical. If the plants disappear, the food energy source captured from the sun and transformed into food by the plants disappears as well. For this reason, scientists are concerned about global climate change, pollination, maintaining diversity in native areas, and plant sustainability.

- Consumers are organisms, such as animals that cannot make their own food like plants, and most are ambulatory; they can move from place to place in search of food. The sessile (stationary) animals are positioned in the ecosystem such that food regularly cycles past them. Coral reefs are examples of sessile organisms that receive nutrition, thanks to the ocean current action.

  There may be multiple levels of consumers. For example, grasshoppers eat grass, birds eat grasshoppers, a vulture will eat a bird; a coyote may stalk and eat a feeding vulture, and a cougar might eat the coyote. Animals that eat primary producers, such as a grasshopper eating plants, are herbivores. Animals that consume other animals but few or no plants are carnivores, and animals that eat both plants and animals, like humans, are omnivores.

- Decomposers are not generally included in food chains and webs. Rather, since they decompose (break down) dead organisms and waste so that the nutrients can be released and reused, they are sometimes considered to have their own trophic level. If included, they mark the culmination of the food chain such that primary consumers are the beginning and decomposers are at the end. Without decomposers, our world would not only lose the energy derived from metabolizing the nutrients they release, but we would be mired in waste and dead organisms. Decomposers primarily include bacteria and fungi.

The fungus growing on this dead tree stump is decomposing the stump. It may be many years before the stump is reduced to soil and the nutrients are returned to the ecosystem.

Photo credit: Pat Franzen

Scavengers (usually invertebrates and detritus feeders like vultures) and decomposers (primarily bacteria) are capable of picking a skeleton clean in a short period of time. With the right abiotic conditions, it can take only a matter of weeks or even days.

Photo credit: Pat Franzen

A diagram depicting a complex set of consumer/producer interactions is called a food web. It is not linear like a chain and better represents the multiple interaction possibilities within an ecosystem. Most food chains and webs can be constructed multiple ways. These relationships may begin with different plants, include a wide variety of consumers, and end with one of many possible apex predators. Food chains and food webs depict not only plant/animal relationships, but also the constant flow of energy within an ecosystem. This energy originates with the sun.

Trophic Cascades
The video, *How Wolves Change Rivers*, is an excellent example of a trophic cascade. Trophic cascades are the result of predators reducing the number of prey or in some way changing the prey's behavior. The Yellowstone wolves' return caused the deer and elk to move from the more enclosed valleys and bowls to the open plains where they had less chance of being trapped. The effects were astounding.

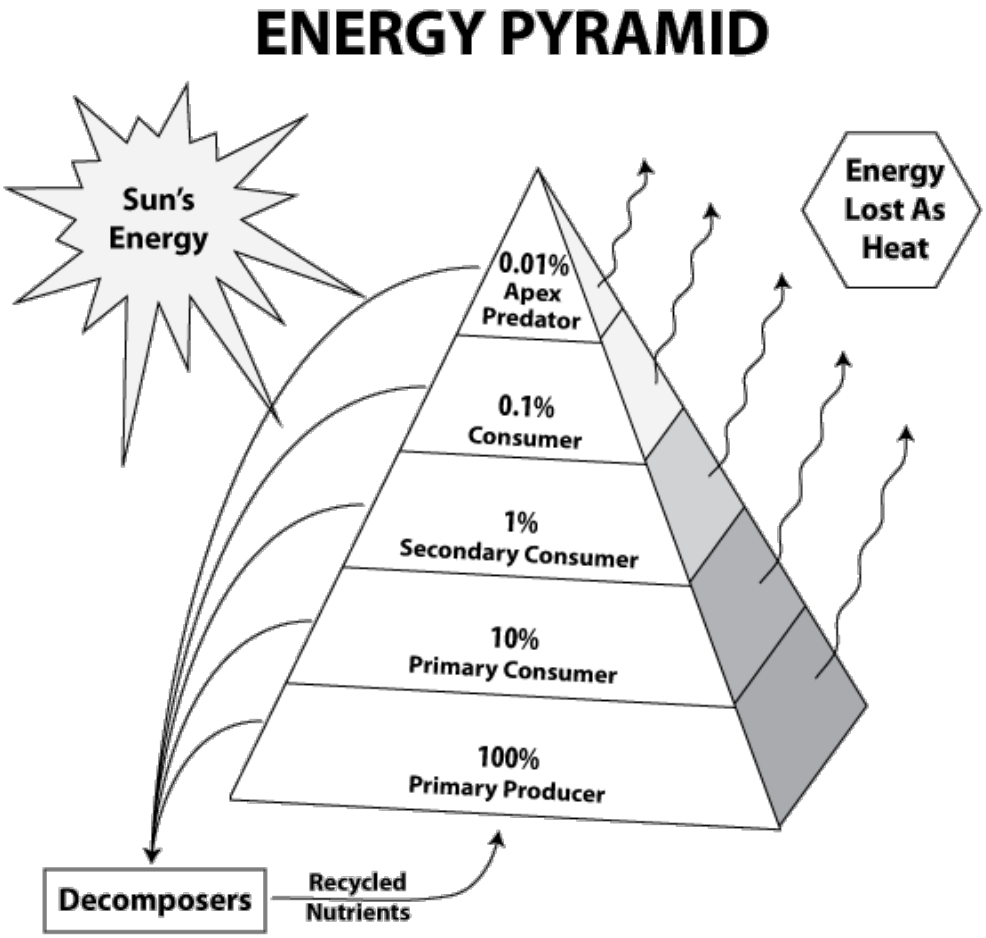
Environmentalist Aldo Leopold (1887–1948) is widely considered the developer of the concept of trophic cascade. He spent many years observing deer grazing on mountainsides after the eradication of wolves from an area. Today, this theory is of primary interest to ecologists who study food webs often in areas that they believe to be overhunted or overfished. Fermilab ecologists constantly work to better understand all that live in the site's many ecosystems. This data informs them of when the deer population is getting too large and whether the Canada geese are negatively impacting the areas.

The *How Wolves Change Rivers* video depicts a top-down cascade. Bottom-up cascades can also occur when a primary producer or primary consumer is removed or reintroduced. Any organism capable of triggering a trophic cascade is considered to be a keystone species.

Biomass Energy Flow – The 10% Rule
Trophic levels relate to one another because energy is transferred from level to level. Most diagrams are not to scale because in nature only about 10% of the transferred energy converts to biomass—natural energy for the next level. For this reason, the producer level biomass at the bottom of the pyramid is much larger than the apex predator at the top. Ecosystem biomass and energy pyramids are essentially the same. The number and collective mass of organisms at each level is summarily reduced as we move up the levels.

When we are hungry, we eat. The food we eat is converted to energy so our bodies can function. The calories we intake is commensurate to the amount of energy we receive. If we do not burn all the calories we consume, our bodies store it as fat. A significant amount of energy is lost as heat as organisms perform functions and regulate their body temperatures. Thus, there is less available biomass and fewer organisms can be supported as we move up the levels. The law of conservation of energy is upheld as much of the energy/calories consumed is released as heat.

The ecological efficiency is the measure of the energy or biomass is transferred from one trophic level to the next. Since consumers at each level convert on average only about 10% of the chemical energy in their food to their own organic tissue, food chains rarely extend for more than five or six levels. At the lowest trophic level (the bottom of the food chain), plants convert about 1% of the sunlight they receive into chemical energy. It follows from this that the total energy originally present in sunlight absorbed by the green plants that is finally embodied in a fourth-level consumer is only about 0.001%.



Example of energy pyramid with organisms living in Yellowstone.
http://www.yourarticlelibrary.com/ecology/3-major-types-of-ecological-pyramids-pyramid-of-number-biomass-and-energy/9855/

Prior Student Knowledge Expectations:

- Basic vocabulary
- General understanding of organisms common within a specific ecosystem
- Ability to use reference materials and personal observation to apply to an original design
- General understanding and acceptance of collaborative behaviors

Possible Preconceptions/Misconceptions:

- The belief that the largest organism in an ecosystem constitutes the greatest biomass and/or has the most impact
- The role of the sun as the initial energy source is often overlooked.
- The impact of the cattle/sheep grazing industry is often underestimated.
- The effects of losing/regaining an apex predator can be devastating (Wolf video). (Some students think primarily of the cute bunnies and deer that lose their predator.)

- The role of keystone species may be misunderstood. It is not always the largest or the top-level organism.
- Humans are NOT at the top of the food chain.

Vocabulary: food web, food chain, consumer, producer, decomposer, herbivore, carnivore, omnivore

Materials:
- Access to *How Wolves Change Rivers* video http://www.filmsforaction.org/watch/how-wolves-change-rivers/
- Research opportunities to gather information about Yellowstone National Park
- Student data sheets
- Writing instruments/colored pencils, if desired
- Access to the *Hawk and Squirrel* video https://www.youtube.com/v/XBEyCr5AoIs

ENGAGE:
Ask students to recall the wolf video. What organisms did they observe? Record responses so all can see. Replay the *How Wolf Change Rivers* video asking students to add to the class list if needed and specifically note the *changes* in the ecosystem after the wolves return after a 70-year absence. Why do you think the wolf was removed from the ecosystem in the first place? Why was this a good/bad idea?

EXPLORE:
Students will create a food web and food chain using organisms indigenous to the Yellowstone ecosystem and speculate as to the short-term and long-term effect of removing or introducing a different keystone species. Energy and biomass pyramids as well as trophic cascades are included.

Process:
1. Ask students to recall the organisms portrayed in the *How Wolves Change Rivers* video and record responses for all to see.
2. Represent *How Wolves Change Rivers* video and, as a class, engage in discussion.
3. In student research groups of four, ask students to count 1, 2, 3, 4. Instruct students to move to their temporary new group by number and research the following:

    1. Trophic levels
    2. Food chains and food webs/nutrient cycle
    3. Trophic cascades
    4. Biomass Energy Flow – The 10% Rule

    If the class is large, two or more groups can research the same topic.
4. As experts on their topics, instruct students to return to their original teams and debrief. Each team should now have “expert” information about each topic.
5. Research teams will use resources to determine at least 12 organisms indigenous (native) to Yellowstone Park, including plants and insects. Encourage

different ecosystems within Yellowstone. Write the name of each organism on Student Data Sheet 1 and complete the trophic pyramid.

6. Each team then will follow instructions and use their selected organisms to create a food chain (Student Data Sheet 2) and a food web (Student Data Sheet 3).
7. Compare the webs with those of other groups. Are they identical? In what ways are they similar or different? Is that OK? Is there anything that needs to change?
8. Challenge the students to determine a keystone species for their webs, one that will severely disrupt the present conditions if introduced or removed from their web and pyramid. Discuss these predictions.
9. Present the *Hawk and Squirrel* video, https://www.youtube.com/v/XBEyCr5AoIs, 3:31 minutes. Discuss. How many students cheered for the squirrel? Hawk? Why?
10. Continue with Student Reflection questions.

EXPLAIN:
Students describe and explain their Yellowstone scenario predictions in terms of changes after the keystone species they selected came back or are removed.

ELABORATE:
Consider the following ecosystem services as they relate to trophic levels. In what ways does the *How Wolves Change Rivers* video relate to these topics? Which relationship/connection is the most profound? Why?

Ecosystem Services:
The important benefits for human beings that arise from healthily functioning ecosystems (See *Resources:* Costanza, 2014.)

- Gas regulation (Production of oxygen) – **MS-LS1-6; MS-LS2-3; MS-ESS2-4**
- Climate regulation – **MS-LS1-5; MS-PS3-4**
- Disturbance regulation (storm protection/flood control) – **MS-LS2-4; MS-ESS3-3**
- Water regulation – **MS-ESS2-4**
- Erosion control/sediment retention – **MS-LS2-4; MS-ESS3-3**
- Soil formation – **MS-LS2-3; MS-ESS2-4**
- Nutrient cycling** (storage, nutrient cycling, biochemical breakdown) – **MS-LS2-3**
- Waste treatment** (recovery of mobile nutrients and removal of xenic/toxic substances)
- Pollination – **MS-LS2-4; MS-LS1-8**
- Biological control (trophic dynamic relationships/keystone species) – **MS-ESS3-3**
- Refugia (habitat for migration/visiting species) – **MS-LS2-1; MS-LS2-2**
- Food production – **MS-LS2-1**
- Raw materials (biofuels) – **MS-LS1-6; MS-LS2-3; MS-ESS2-4**
- Genetic resources**
- Recreation*
- Culture*

*N/A within NGSS context

**Concepts beyond middle level

EVALUATE:
Formative Monitoring: Use Student Reflection questions for discussion throughout the investigation.

Summative Assessment: Students can extend their work on a web. Use the model to identify potential effects of the elimination of a species of the addition of a species.

Elaborate Further/Reflect/Enrichment: Students can relate their learning of food webs/energy webs to ecosystem services through describing how the connections in the web relate to an ecosystem service. For example, students can describe how parts of the food web contribute to the creation of the humus layer in soil and how it is a renewable resource.

Name_____

Student Data Sheet 1

I studied this ecosystem. _____

List of Yellowstone organisms including plants, primary consumers, tertiary consumers, and apex predators

Construct your energy pyramid to reflect the proper placement of these organisms. (No more than 5–6 levels)

Organism list:

1.

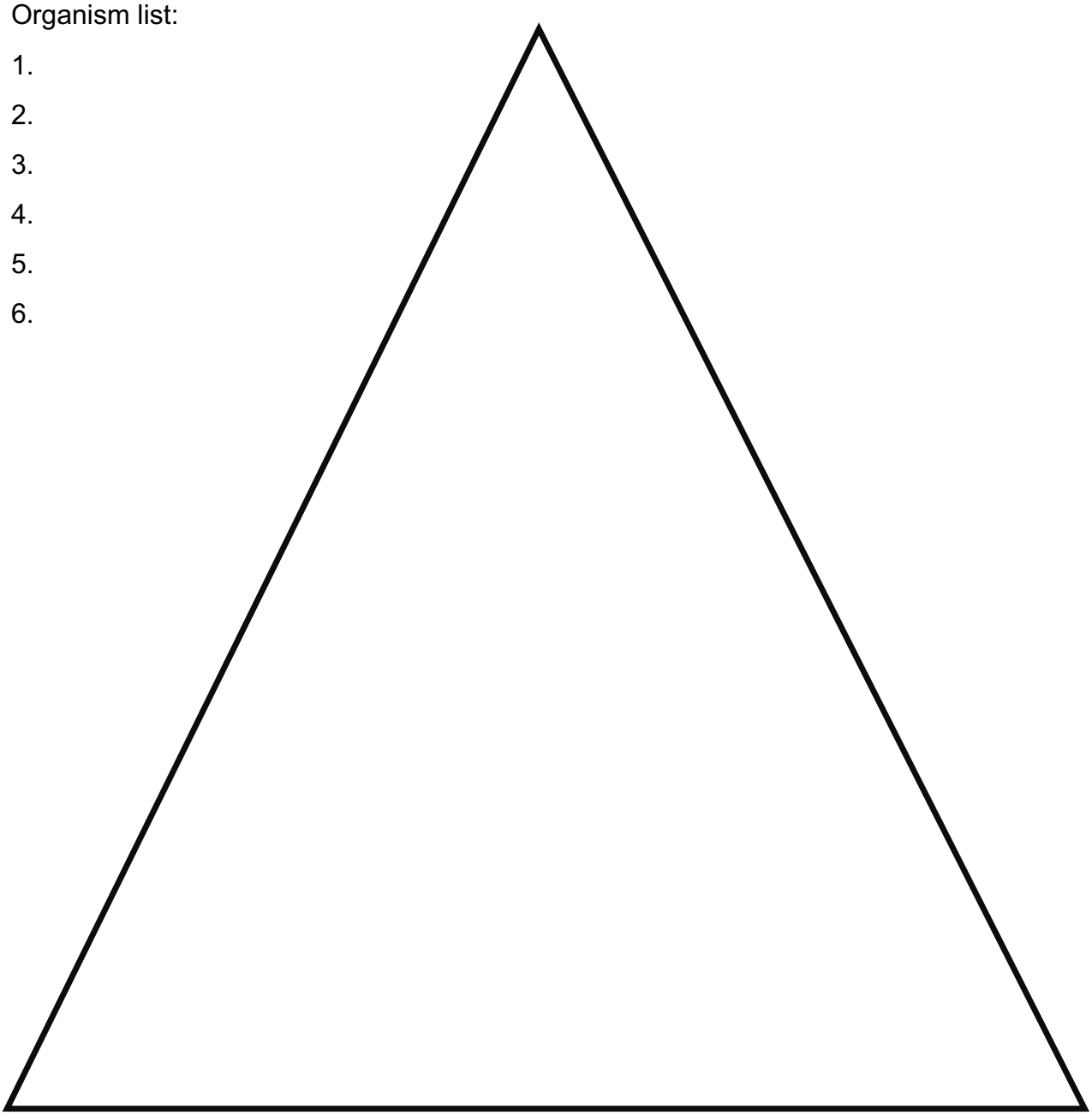
2.

3.

4.

5.

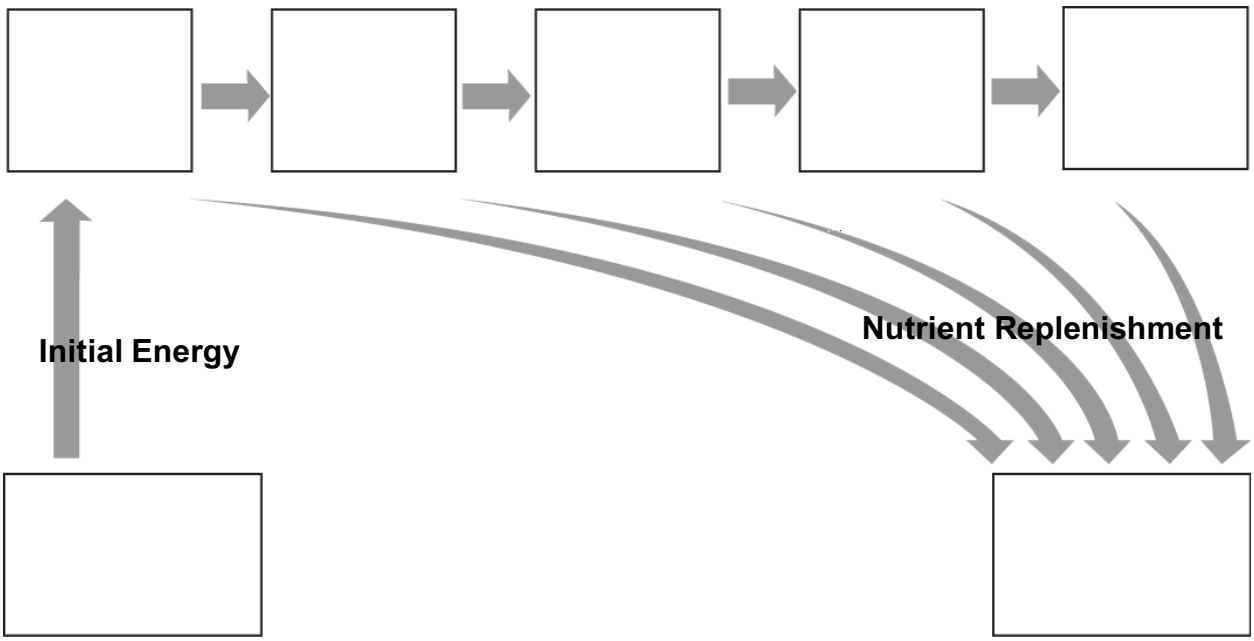
6.



Name_____

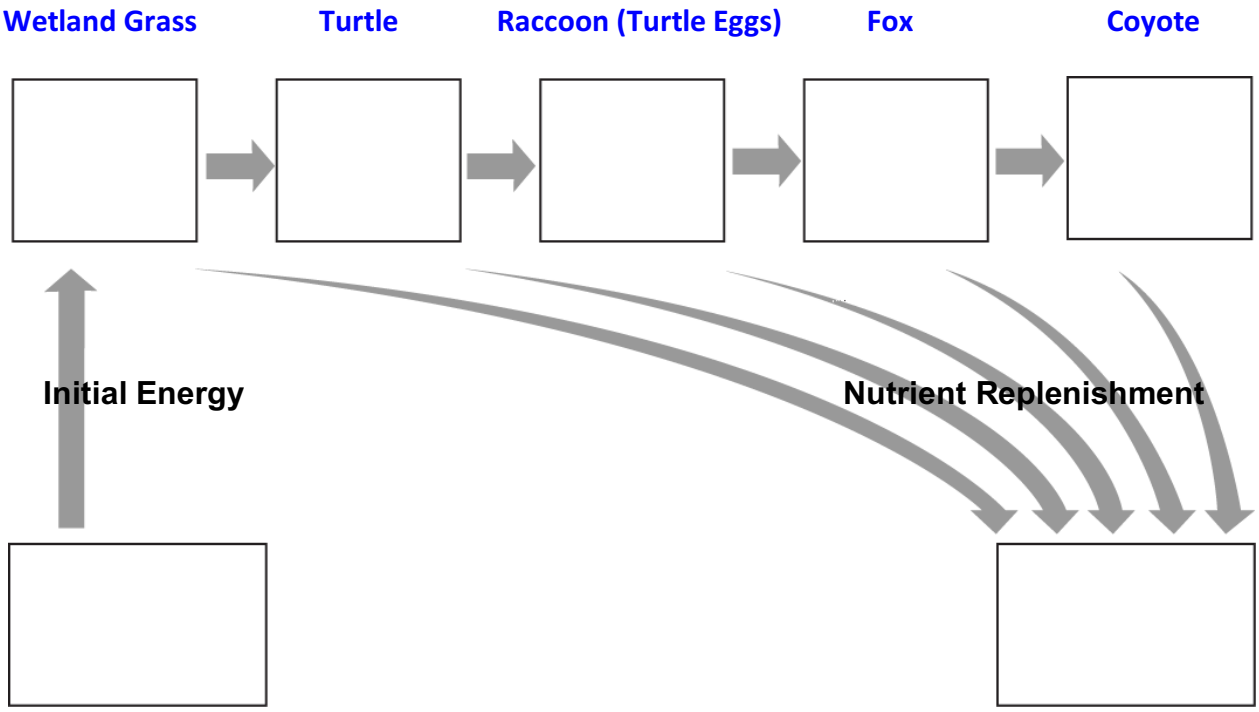
Student Data Sheet 2

Considering the organisms on your list, construct a food chain with at least four organisms. Label the organisms within the boxes. At the beginning and at the end, beyond the boxes, note the initial organic energy source and the final step in nutrient replenishment.



Teacher Page: Student Data Sheet 2 Possible Answers

Considering the organisms on your list, construct a food chain with at least 4 organisms. Label the organisms within the boxes. At the beginning and at the end, beyond the boxes, note the initial organic energy source and the final step in nutrient replenishment.



Name_____

Student Data Sheet 3

Again using your organism list, create a food web below using all of the organisms on the list. You may write the names rather than draw. Suggestion: Write the names first on slips of paper and position them before you begin the web.

Respond to the questions on the next page.

Student Data Sheet 3 (continued)

Compare your web with others in your class. How are they similar? Different?

_____

_____

_____

_____

Identify the keystone species. Predict what you think would happen in one month.

_____

_____

_____

_____

In one year…

_____

_____

_____

_____

In 10 years…

_____

_____

_____

_____

What do you conclude as a result of this activity?

_____

_____

_____

_____

Name: _____

Student Reflection: Trophic interactions and Food Webs

1. *The sun is our life source.* Why is this statement true?

2. As humans, we are naturally omnivores. We know that because of our tooth structure. We have flat, grinding molars for chewing plants and longer canine teeth plus incisors (front teeth) for biting and gnawing meat. Where are humans on your food web? Defend your response.

3. Roadkill. YECCH! Have you ever examined roadkill? It smells nasty. It is probably covered with invertebrates like worms, larvae and insects—and hordes of microorganisms that we cannot even see. Perhaps a scavenger bird is pecking on some flesh—that is if the raccoons have not already gotten to fresh roadkill. Why is this scene actually a good story? For everyone except the roadkill, that is…

4. What part of Yellowstone Park did your food chain and web design represent? Just like Fermilab and perhaps even your own neighborhood, Yellowstone holds many diverse ecosystems. Think of another type of Yellowstone ecosystem. How would your designs change?

5. Considering your food chain, sketch a trophic diagram and explain how energy is transferred from level to level. How much original energy is available for the apex predators? Now think about the hawk and squirrel video. With the trophic levels in mind, which animal do you think has a tougher time finding food? Explain.

6. Explain the consequences of the introduction or removal of a key predator from your scenario.

7. John Muir once said, "When we try to pick out anything by itself, we find it hitched to everything else in the universe." What does this statement mean?

8. Aldo Leopold once remarked, “Harmony with land is like harmony with a friend; you cannot cherish his right hand and chop off his left.” How does this statement relate to trophic levels?

Teacher Page

Student Reflection Suggested Responses: Trophic interactions and Food Webs

1. *The sun is our life source.* Why is this statement true?

   The sun is the source of energy for living organisms.

2. As humans, we are naturally omnivores. We know that because of our tooth structure. We have flat, grinding molars for chewing plants and longer canine teeth plus incisors (front teeth) for biting and gnawing meat. Where are humans on your food web? Defend your response.

   Rationales may vary. Ensure that students understand that although humans have great power and influence over other organisms, we are not at the top of the food chain.

3. Roadkill. YECCH! Have you ever examined roadkill? It smells nasty. It is probably covered with invertebrates like worms, larvae and insects—and hordes of microorganisms that we cannot even see. Perhaps a scavenger bird is pecking on some flesh—that is if the raccoons have not already gotten to fresh roadkill. Why is this scene actually a good story? For everyone except the roadkill, that is…

   Scavengers are key to putting nutrients back into the ecosystem. They break down organic matter such that fungi, microorganisms and other decomposers can complete the work.

4. What part of Yellowstone Park did your food chain and web design represent? Just like Fermilab and perhaps even your own neighborhood, Yellowstone holds many diverse ecosystems. Think of another type of Yellowstone ecosystem. How would your designs change?

   Responses will vary. Ensure that students recognize the effect abiotic factors such as moisture, temperature, sun exposure, etc., have on the process.

5. Considering your food chain, sketch a trophic diagram and explain how energy is transferred from level to level. How much original energy is available for the apex predators? Now think about the hawk and squirrel video. With the trophic levels in mind, which animal do you think has a tougher time finding food? Explain.

   Responses will vary. Ensure that the student recognizes the needs of both animals.

6. Explain the consequences of the introduction or removal of an apex predator from your scenario.

Responses will vary based on the situation. Students should understand that without an apex predator, animals down the chain can experience a population explosion and deplete resources.

7. John Muir once said, "When we try to pick out anything by itself, we find it hitched to everything else in the universe." What does this statement mean?

   Responses will vary. Expect a degree of sophistication that reflects an understanding of food webs and chains.

8. Aldo Leopold once remarked, “Harmony with land is like harmony with a friend; you cannot cherish his right hand and chop off his left.” How does this statement relate to trophic levels?

   Responses will vary. Expect a degree of sophistication that reflects an understanding of food webs and chains as well as a need to promote and protect natural cycles.

Photosynthesis

How do abiotic and biotic factors work together to cycle energy and resources through an ecosystem?

Topic: Photosynthesis and its role in interactions and relationships of all living organisms

Brief Lesson/Lesson Set Description:
Students explore photosynthesis and the role of the chemical reaction in an ecosystem food web as they engage in a photosynthesis simulation and apply principles learned to an ecosystem field study. After completing the simulation, students may apply their understanding within an ecosystem by using light intensity meters and careful observation to predict the rate of photosynthesis under specific conditions.

Science and Engineering Practices: Planning and Conducting Investigations; Developing and Using Models

Crosscutting Concepts: Systems and System Models; Energy and Matter: Flows, Cycles, and Conservation

INVESTIGATION

Objectives: Students will:

- Explore the process of photosynthesis using a manipulative simulation to demonstrate the effect of light intensity on the process.
- Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms.
- Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems (when coupled with *Trophic Interactions and Food Webs*).
- Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem (when coupled with *Trophic Interactions and Food Webs*).

Narrative/Background Information:
All living things need certain elements for survival: air, water, food, sunlight and a habitat temperature to which they are adapted. Plants do not have the option of relocating to find these elements. Fortunately, plants tend to grow in places to which they are best adapted. They have all of these elements for survival available to them—except food. Since they are not mobile, green plants make their own food through a process called photosynthesis.

The definition of photosynthesis is revealed in the name itself: photo = light; synthesis = to make. Photosynthesis is the process plants use to change carbon dioxide (a waste

product of animals) and water (absorbed through roots or root-like structures) into simple sugar (glucose) using sunlight as the energy source. Glucose is food made by the plants, and oxygen, needed by animals, is given off as a waste product. Through photosynthesis, light energy is converted into chemical energy.

The chemical formula $6CO_2$ (carbon dioxide) + $6H_2O$ (water) → $C_6H_{12}O_6$ (glucose) + $6O_2$ (oxygen) requires sunlight (energy) and a chemical within the leaves known as chlorophyll (catalyst) to work. Photosynthesis is critical for sustained life on Earth. Carbon dioxide, a waste product of animals, is essential for plants to make their food. Conversely, oxygen, a waste product of plants, is critical to animal respiration. Additionally, plants typically produce more food than they need for survival. Animals, specifically herbivores and omnivores, consume this food. Carnivores consume herbivores and omnivores, effectively transferring energy up the food chain. (See *Trophic Interactions and Food Webs.*)

Prior Student Knowledge Expectations:

- Completion of Set 3 *Trophic Interactions and Food Webs* investigation
- General understanding of trophic levels and the energy pyramid, nutrient cycling, concept of molecular movement
- Ability to use reasoning to transfer the concepts of the simulation to a real-world setting
- Willingness to think tangentially to apply concepts and project understandings into future predictions
- General understanding and acceptance of collaborative behaviors

Possible Preconceptions/Misconceptions:

- In the middle grades, the concept of molecular movement and reactions is just beginning to emerge. If not previously studied, take time to introduce this concept.
- Students likely know that plants and animals have a critical relationship as they utilize each other's gaseous waste products (oxygen and carbon dioxide), but they may not realize that without each other, they face certain death.
- Students recognize that plants are a food source and that food helps other organisms grow, but they may not conceptualize the feat of producing food within themselves for the plant itself as well as for other organisms.

Vocabulary: Basic vocabulary to describe photosynthesis (glucose, chloroplast, chlorophyll, oxygen, carbon dioxide, water vapor), trophic interactions, respiration, sustainability)

Materials:

- Access to https://authoring.concord.org/activities/1008/single_page/349c2d2d-a8a4-4142-9680-552576c24a09; The Concord Consortium developed the simulation.
- Light intensity meters (one per team)
- Student data sheet

ENGAGE:
Ask: *What did you eat for breakfast this morning?* Record 8–10 responses for all to see. Briefly analyze the list to note if the items were from plant or animal sources. Look more closely at the animal sources (eggs, milk, bacon, etc.). What did the animal that was the source of these foods eat to be able to produce food? Once students are satisfied that all natural food originates with plants, introduce the process of photosynthesis.

EXPLORE:
Process:
In this investigation, students work individually on the simulation at first. They then collaborate with their predetermined student research team on the simulation manipulation and the field experience.

1. Complete *Trophic Interactions* and refer to it throughout the *Photosynthesis* investigation.
2. Engage students individually in the photosynthesis simulation, allowing time for them to explore and complete the online responses.
3. When they are done, encourage them to share their findings with others in their research team and explore in depth one or more scenarios within the simulation. Instruct the teams to prepare a brief summary of their findings.
4. Share findings with the class. Which conditions did each group investigate further? Are there commonalities? Incongruities? What basic rules of photosynthesis did they discover?
5. Instruct students to speculate about their findings when they test light intensity in the field. How might they tell by observation if plants are photosynthesizing? (See student data sheet.)
6. After the field investigation, review findings and share results and observations.
7. Suggest ways to more accurately monitor photosynthesis in the field and in the lab.
8. Instruct students to conceptualize their understandings about photosynthesis by creating a visualization on newsprint or electronically. Share this visualization with the class.

Probing or clarifying questions: See simulation, process steps and student data sheet.

EXPLAIN:
Students complete the simulation and utilize new conceptual understanding to a real world field experience. Though they will not find empirical evidence of the varying degree of photosynthetic activity, they should notice differences in the shades of green and relative size within the same species in plants when they observe top leaves compared to understory leaves or plants growing in sun vs. those growing in partially shaded communities. (Use docents for clarification, as there are anomalies such as some plant species have large basal leaves.) Note carefully the interpretations rendered in the visualization as misconceptions may be revealed.

ELABORATE:
Ecosystem Services:
Investigate ways that photosynthesis contributes to these ecosystem services.

- Gas regulation (Production of oxygen) – **MS-LS1-6; MS-LS2-3; MS-ESS2-4**
- Climate regulation – **MS-LS1-5; MS-PS3-4**
- Disturbance regulation (storm protection/flood control) – **MS-LS2-4; MS-ESS3-3**
- Water regulation – **MS-ESS2-4**
- Erosion control/sediment retention – **MS-LS2-4; MS-ESS3-3**
- Soil formation – **MS-LS2-3; MS-ESS2-4**
- Nutrient cycling** (storage, nutrient cycling, biochemical breakdown)
- Waste treatment (recovery of mobile nutrients and removal of xenic/toxic substances)
- Pollination – **MS-LS2-4; MS-LS1-8**
- Biological control (trophic dynamic relationships/keystone species) – **MS-ESS3-3**
- Refugia (habitat for migration/visiting species) – **MS-LS2-1; MS-LS2-2**
- Food production – **MS-LS2-1**
- Raw materials (biofuels) – **MS-LS1-6; MS-LS2-3; MS-ESS2-4**

**Concepts beyond middle level

Web Links:
Photosynthesis for Kids: http://www.coolkidfacts.com/photosynthesis-for-kids/
BBC Gardening - Photosynthesis for Kids:
http://www.bbc.co.uk/gardening/gardening_with_children/didyouknow_photosynthesis.shtml

EVALUATE:
NOTE: Assessment rubrics (located in *Introduction* section):
Investigation Rubric
Participation Rubric
Performance Rubric

Formative Monitoring: Content questions embedded within the simulation, process and student data sheet

Summative Assessment: Students create a visualization of the role photosynthesis plays in relationships and interactions within an ecosystem. What further questions do students generate?

Elaborate Further/Reflect/Enrichment: Consider a classroom lab experience.
Activity Idea 1
Carolina Biological Supply activity, "Hands-On with Photosynthesis and Cellular Respiration"
http://www.carolina.com/teacher-resources/Interactive/photosynthesis-cellular-respiration/tr10764.tr?s_cid=em_ccphoto_201511&utm_source=bronto&utm_medium=e

mail&utm_term=Try+the+Activity&utm_content=11/23/2015&utm_campaign=2015+-+Content+Connection+Photosynthesis+Nov+Wk1

Activity Idea 2

Science and Plants for Schools activity, "Bubbling *Cabomba* Pondweed"
http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&ved=0ahUKEwiZtYfRv-nNAhVsxoMKHWXUCXsQFgglMAE&url=http%3A%2F%2Fwww.saps.org.uk%2Fattachments%2Farticle%2F190%2FSAPS%2520-%2520Bubbling%2520Cabomba%2520pondweed%2520-%2520student%2520sheet.doc&usg=AFQjCNGDN3C3PXjyFea8i2eLjc36moNc1A&sig2=ln-R8-4hhdG4XMOZmXEyIA&cad=rja

Science and Plants for Schools, "Bubbling *Cabomba* Pondweed – Technical Notes"
https://www.google.com/search?q=Bubbling+Cabomba+Pond&ie=utf-8&oe=utf-8&aq=t&rls=org.mozilla:en-US:official&client=firefox-a#

Name: _____

Photosynthesis Simulation Data Sheet

Simulation: After you complete the simulation on your own, meet with your student research team to discuss your findings.

1. Which conditions do you want to investigate further as a team?

2. Are there commonalities that you noted as you manipulated the factors? Incongruities?

3. What basic rules of photosynthesis did you discover?

4. If you were to test light intensity in the field, how might you tell by observation if plants are photosynthesizing? List criteria you believe to be evidence of photosynthesis rates.

5. Suggest ways to more accurately monitor photosynthesis in the field and in the lab. (Respond after the field investigation.)

6. On the next page, design a data collection chart to record your light intensity data. Remember to include your methodology (rules for your investigation so another team can replicate it in the same manner), the criteria that you select to observe (species, depth of color of leaves, whether it grows in sun or partial shade, placement of leaves on the trunk or stem, etc.), your prediction of what you will actually observe and the actual observations.

Data Chart: This is a data chart of your own design. Include criteria noted in the description of the task in #6. Your work will be evaluated with a rubric presented by your teacher.

Teacher Page

Student Suggested Responses: Photosynthesis Simulation Data Sheet

Simulation: After you complete the simulation on your own, meet with your student research team to discuss your findings.

1. Which conditions do you want to investigate further as a team?

   Responses will vary. Make certain that students select conditions relevant to the simulation.

2. Are there commonalities that you noted as you manipulated the factors? Incongruities?

   Responses will vary. Make certain that students report commonalities and incongruities relevant to the simulation.

3. What basic rules of photosynthesis did you discover?

   The basic product of input and output of the photosynthesis process, factors that regulate the process, factors critical to the process (sunlight and chlorophyll), results of manipulation of the factors, etc.

4. If you were to test light intensity in the field, how might you tell by observation if plants are photosynthesizing? List criteria you believe to be evidence of photosynthesis rates.

   Responses will vary. Make certain that students note observable factors such as shades of green and/or relative size of leaves/plant. They will not be able to see molecular flow.

5. Suggest ways to more accurately monitor photosynthesis in the field and in the lab. (Respond after the field investigation.)

   Responses will vary. Make certain that students are suggesting practical solutions - but encourage students to think out of the box as long as they are within the realm of reason.

6. On the next page, design a data collection chart to record your light intensity data. Remember to include your methodology (rules for your investigation so another team can replicate it in the same manner), the criteria that you select to observe (species, depth of color of leaves, whether it grows in sun or partial shade, placement of leaves on the trunk or stem, etc.), your prediction of what you will actually observe and the actual observations.

Data Chart: This is a data chart of your own design. Include criteria noted in the description of the task in #6. Your work will be evaluated with a rubric presented by your teacher.

This is a data chart of the students' own design. They are to include criteria noted in the description of the task in #6. The work will be evaluated with a rubric provided to the students in advance. A model rubric that you may manipulate to best meet your assessment goals is found in the Introduction section.

Name: _____

Student Reflection: Trophic Interactions and Photosynthesis

1. It has been said that photosynthesis is the most important process on earth. Do you agree? Support your response, yes or no, with sound scientific statements based on your understandings of photosynthesis and other trophic relationships and interactions.

2. Photosynthesis is dependent on the sun's energy to produce food for the plant. What other abiotic conditions are necessary for green plants to survive? Explain why these factors are needed.

3. Imagine that the sun began to produce less and less energy. Do you believe that human technology could create a replacement energy source that would sustain life on earth? Support your response with sound scientific statements.

Based on your understanding of photosynthesis' role in relationships and interactions, use newsprint or computer project design program to create a visualization of this critical role. Make note of everything needed and the connections between other organisms and abiotic components.

Teacher Page

Student Reflection Suggested Responses: Trophic Interactions and Photosynthesis

1. It has been said that photosynthesis is the most important process on earth. Do you agree? Support your response, yes or no, with sound scientific statements based on your understandings of photosynthesis and other trophic relationships and interactions.

   Responses will vary. Make certain that students relate to concepts learned in the Photosynthesis and Trophic Interactions investigations.

2. Photosynthesis is dependent on the sun's energy to produce food for the plant. What other abiotic conditions are necessary for green plants to survive? Explain why these factors are needed.

   Responses will vary. Make certain that students relate to concepts learned in the Photosynthesis and Trophic Interactions investigations.

3. Imagine that the sun began to produce less and less energy. Do you believe that human technology could create a replacement energy source that would sustain life on earth? Support your response with sound scientific statements.

   Responses will vary. Make certain that students relate to concepts learned in the Photosynthesis and Trophic Interactions investigations.

Based on your understanding of photosynthesis' role in relationships and interactions, use newsprint or computer project design program to create a visualization of this critical role. Make note of everything needed and the connections between other organisms and abiotic components.

Life on a Log – Soil Structure

How do abiotic and biotic factors work together to cycle energy and resources through an ecosystem?

Topic: Investigating microhabitats within a larger ecosystem

Brief Lesson/Lesson Set Description:
Students will become familiar with the diversity of organisms utilizing fallen timber as a habitat and contributing to the decomposition of the wood and its transformation into organic soil. Their observations will contribute to the Fermilab database of site organisms (TBA). Students will also examine different types of soil from a variety of areas, observe differences and provide predictions based on evidence as to the types of plants best suited for that soil type.

This activity is best conducted in conjunction with *Trophic Interactions and Food Webs*.

INVESTIGATION

Objectives:
- Observe, identify and count the different types of organisms existing on, in and below a rotting log.
- Analyze the habitat selected by these organisms and relate this information to the organism's position on the food web.
- Determine environmental factors necessary for the success of these organisms.
- Speculate as to how the ecosystem would change if these organisms were deprived of one or more of their biotic or abiotic resources.
- Note adaptations of organisms living on or under the log and suggest how these structures contribute to their success.
- Compare different soil types and predict which type will best support plant life.

Science and Engineering Practice: Planning and Carrying Out Investigation

Crosscutting Concept: Energy and Matter in Systems

Narrative/Background Information:
In a natural setting, ground litter (including leaves, twigs, animal excrements and remains, as well as fallen timber) contributes to the ongoing organic recycling necessary to replace nutrients and minerals into the soil. The breakdown of this material is the job of countless microorganisms known as decomposers such as various bacteria, and many macro-organisms—primarily fungi and invertebrates. Through the life functions of these organisms, vital nutrients and minerals are reduced to forms that can be absorbed by the roots of other plants. These plants then become the producers for consumers (herbivores and omnivores) who will continue the cycle. Soil also contains minerals from the rocks below and nearby. Wind and water can carry rock particulates far from their origin. Soil in a specific area depends not only on what grows there now, but what

preceded that growth. Climate, wind, water and especially human activities such as construction, grazing and farming contribute to the condition of the soil.

Soil is a valuable resource. In Illinois and other farming states, it is arguable one of our most precious resources—if not the most valuable. Naturally formed soils in Northern Illinois often have similar structures. This can be seen in an excavation that is more than two meters deep or cut for a roadway extending through a hillside. Usually, the relatively thin, dark layer of topsoil lies above a lighter-colored subsoil. Below the two upper layers is a foundation of bedrock (dolomite or limestone in our area).

The layer of topsoil in the plains originated with glacial loess that was deposited as the glaciers retreated. On this layer of debris, the prairie took hold. With its enormous biomass and cycles of lightning strike burns, nutrients were continually returning to the soil, eventually building the rich farmland we greatly value. For many generations the prairie continued its soil building and replenishment of the soil.

Over the years, the layer of topsoil, generally highly organic (originated from once-living organisms), has diminished. In most plains areas, what once was ½ meter or more of topsoil is now a mere few centimeters. The greatest decline came after the mid-1800s and the advent of the steel plow. As the prairie became farmland, the rich topsoil became depleted, leading to wind and water erosion. Today's modern agricultural methods have significantly improved the soil, but nothing except the prairie is likely to return the soil to its original state.

Research has shown that the restored prairie has improved the soil quality at Fermilab. Prairies increase the basic unit of soil called soil aggregates. Soil aggregates stabilize the soil, resist soil breakdown and erosion, and stimulate plant growth.

In the woodlands, the soil structure has not changed as quickly. Woodland areas like the Big Woods is essentially the same as it was when settlers first arrived in the area and began planting trees. For one thing, fire was rare. Soil here is created primarily by the decomposition of organic materials that fall to the forest floor. There are a few native forests on the Fermilab site, one of which is the Lederman Woods adjacent to the Lederman Science Education Center. Here we find old growth forest with some oaks estimated at 200 years old.

To learn more about the various natural areas on the Fermilab campus, refer to the *Fermilab Site Map* and *Habitat Communities of the Fermilab Site*, by Julie Jastrow. (Both found in *Resources*)

Prior Student Knowledge Expectations:

- General understanding of trophic levels, food chains and food webs
- Ability to use reference and observation skills to count and identify organisms
- Willingness to get messy!
- General understanding and acceptance of collaborative behaviors

Possible Preconceptions/Misconceptions:
Some students do not realize that:

- Soil is made up of primarily only three general ingredients: minerals from the geological structures of the area, living organisms that reside in the soil, and organic matter created by decomposed organisms.
- The organic elements in the soil that are either in the process of decomposition or already set to be absorbed as minerals and nutrients for plants determine the richness of the soil.
- Soil is created as part of a natural cycle; it was not always *just here*. What is now under that log could one day become part of another living organism.
- The soil found under a rotting log was largely once part of that log—and prior, a living tree.
- Soil structure is ever-changing depending on biotic and abiotic factors.
- Soil from areas that have been disturbed within the few decades may be strikingly similar. For example, it takes about a century to bring prairie soil back to close to its state prior to modern day farming.
- Soil and dirt are two different things.

Vocabulary: microhabitat, habitat, ecosystem, environment, producer, consumer, decomposer, herbivore, carnivore, scavenger

Materials:

- Hand lens
- Notebook
- Digging blade or knife
- Ruler
- Collecting containers (bags, jars, etc.)
- Forceps
- Student data sheet
- Soil Flow Chart

ENGAGE:
What is Soil? YouTube video, by European Environment Agency
Soil is connected to almost all aspects of our lives, yet we often take it for granted. To mark the International Day of Soil on December 5, 2015, the EEA produced this video (2:13 minutes):
https://www.youtube.com/watch?v=I6HGPoQ3dZY

EXPLORE:
Lesson Description: On the field trip or schoolyard site, students will examine the soil under a fallen and rotting log. Invertebrates observed will be identified (or drawn and described for later identification) and counted. If on the Fermilab site, these data will contribute to the Fermilab site database. Adaptations for success in their niche will be noted. Students will examine different soils and recognize differences from area to area.

Process:

Log Activity – Field Trip

1. Provide each student research team with student data sheet. NOTE: Multiple pages of the student data sheet for each team may be needed.
2. Review the differences between herbivores, omnivores, and carnivores. Ask students to provide examples of each. Invite them to suggest characteristics of each type that might help in the identification process.
3. Review food chains, food webs and trophic levels, emphasizing the roles of the decomposers at the end of the food chain.
4. Select a woodland site with a fallen, rotting log or include in Fermilab field trip.
5. Carefully observe the bark. Note color and texture variations. Check for the presence of fungi, lichens, and mosses. Note the current abiotic factors, including relative amount of sunshine and dampness present in the area of the log.
6. Carefully lift a section of bark from the log; try to find a small piece that is easily separated. You may find a wide variety of invertebrates such as beetles, ants, termites, pill bugs, centipedes and a diverse collection of larvae. If fungi are present, webs of yellow and white threads may be seen. These threads are the feeding sources for the fungi. Certain types of bacteria that you cannot see even with your hand lens live along these threads and do the actual decomposing.
7. Carefully observe any visible invertebrate life, including beetle trails and shed exoskeletons. Notice any adaptations that help it live in this environment such as exoskeleton, mouthparts, legs and eyes. (Be sure to put organisms and bark back as you found them.)
8. If the log can be easily lifted and replaced, study the underside. Be sure to observe both the log and the ground under the log.
9. Make comments as indicated on the *Life in a Log* Student Data Sheet.
10. Using these data, as a class construct a food web for the organisms.
11. Secure soil samples from three different ecosystems for the Soil Structure activity.

Soil Structure Activity

1. Fill a jar three-fourths of its height with water. A large baby food jar is perfect, but larger clear glass jars are fine. Add a selected soil sample to raise the level so that the jar is about full. Save some soil for future investigation if the sedimentary layers are thin to collect for the soil test. Tightly screw on the cap and shake vigorously. Allow the jar to stand quietly until all the soil solids have settled. This action may take a day or two.

Separation of layers of materials makes up a sample of soil. Other soils will show other layers and different thicknesses of the layers. The layers separate in this manner because of the density and size of the particles. Clay, for example, has extremely small particles that tend to suspend in water.

2. Measure the depth of the different layers, in centimeters, and record, noting that good topsoil consists of particles of fine sand, some clay, and lots of humus.
3. Using the saved portion of soil, follow the Soil Flow Chart to determine which soil components are present: humus (loam), sand, and/or clay.
4. Debrief using the student formative assessment questions.

EXPLAIN:
Students will compare soil types and describe differences, mindful that soil from areas that have been disturbed within the last century may be very similar.

ELABORATE:
Collect some soil samples from under and around a decaying log and put it into a Berlese apparatus. (See Sampling Terrestrial Invertebrates in the *Resources* section.) Look carefully at the invertebrates collected and identify adaptations that promote the success of the organisms. Research organisms found and create a food web that includes vegetation and microorganisms. (See *Trophic Interactions and Food Webs.*)

EVALUATE:
Formative Monitoring: Use Student Reflection questions for discussion throughout the investigation.

Summative Assessment: N/A

Elaborate Further/Reflect/Enrichment: Many ecosystem services are represented in these activities as represented in the selected list below. How does decomposition and soil structure relate to the following ecosystem services?

What further questions do you have? Suggest one researchable question to share.

Ecosystem Services: The important benefits for human beings that arise from healthily functioning ecosystems (Costanza, 2014)

- Gas regulation (production of oxygen) – **MS-LS1-6; MS-LS2-3; MS-ESS2-4**
- Climate regulation – **MS-LS1-5; MS-PS3-4**
- Disturbance regulation (storm protection/flood control) – **MS-LS2-4; MS-ESS3-3**
- Water regulation – **MS-ESS2-4**
- Erosion control/sediment retention – **MS-LS2-4; MS-ESS3-3**
- Soil formation – **MS-LS2-3; MS-ESS2-4**
- Nutrient cycling** (storage, nutrient cycling, biochemical breakdown) – **MS-LS2-3**
- Biological control (trophic dynamic relationships/keystone species) – **MS-ESS3-3**
- Refugia (habitat for migration/visiting species) – **MS-LS2-1; MS-LS2-2**
- Food production – **MS-LS2-1**
- Raw materials (biofuels) – **MS-LS1-6; MS-LS2-3; MS-ESS2-4**

**Concepts beyond middle level

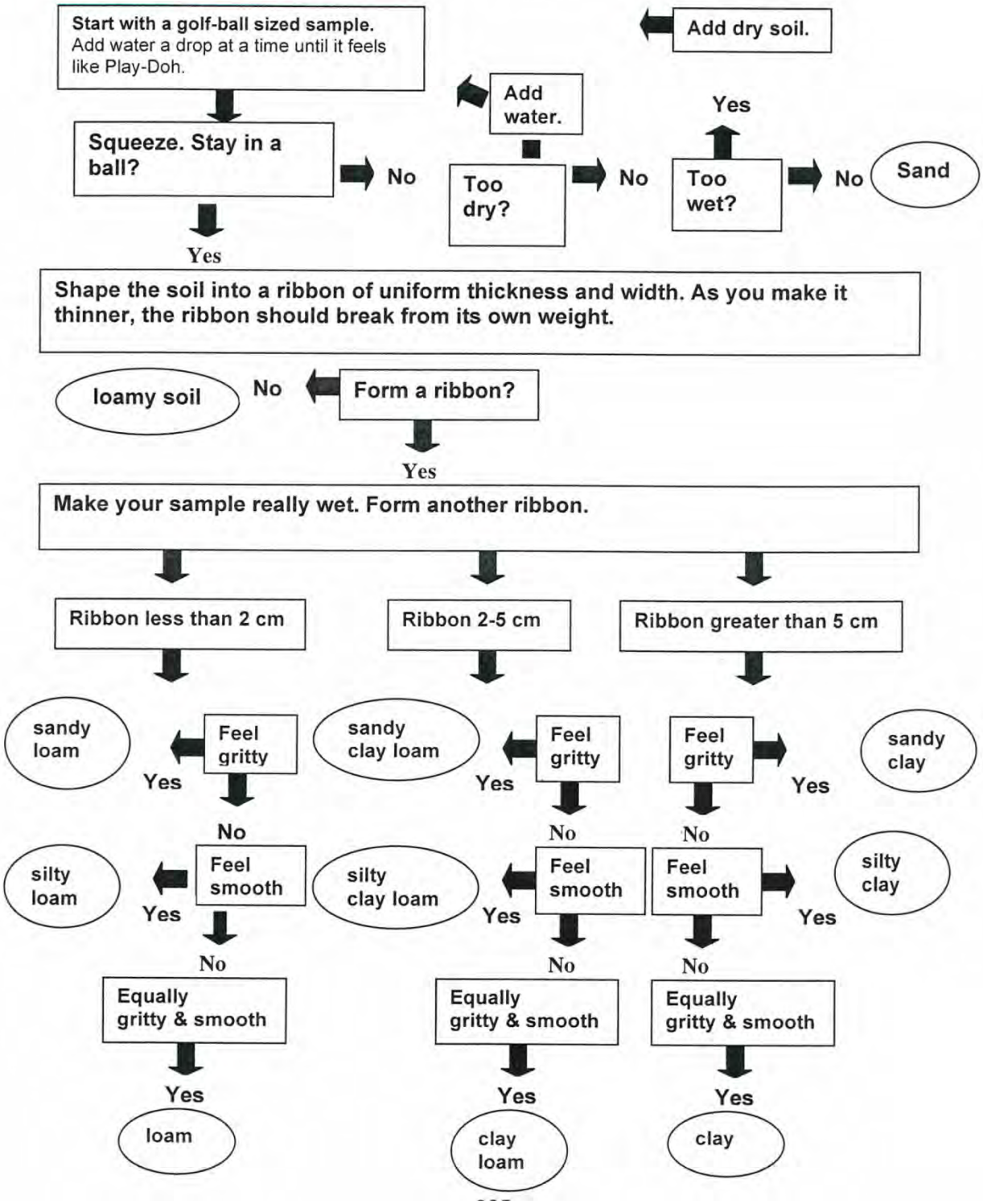
Name: _____

Life in a Log Student Data Sheet

Using the Wanted Posters, attempt to identify the organisms you observed. As a class, construct a food web using the organisms found on, in, and under the rotting log. Multiple data sheets may be needed.

Location on Log	Organism	Description	Drawing	Adaptations
Top Surface				
Under the Bark				
Under the Log (log)				
Under the Log (soil)				

Estimating Soil Texture



Name: _____

Student Reflection: Life in a Log – Soil Structure

Life in a Log

1. How many different organisms did you find? Which were most common? Least common? Why do you think this is so?

2. What are some of the differences between the organisms found in, on and under the log? Why do you think this is so?

3. How can you tell if the organisms are carnivores, herbivores or scavengers?

4. An oak log needs at least 8 to 10 years to completely decompose. How long do you think the log you are observing has been disintegrating? Justify your response.

5. As you observed the underside of the log, did you see any indication that the soil was becoming enriched? Describe what you observed.

Soil Formation

6. How do you think new soil forms?

7. Compare different soil types and predict which type will best support plant life. Defend your prediction. What do you believe is the composition of your samples? (Loam, sand or clay?) Complete Student Reflection sheet and confirm or reject your prediction.

8. Take a small amount of material from each soil layer in your jar. Rub it between your fingers and follow the Soil Flow Chart to identify the soil type. How are the textures different?

9. Which layer would hold water best? How do you know?

10. Is there any other type of soil that would hold water even better?

Communication in science is an important skill. Verbal and written communication skills are imperative for success.

Use your imagination to either:

A. Gather with other students and position yourselves in a line along the log. Beginning on one end of the log, each person tells a part of a story about a selected organism on the log. It may be a spider, ant, or pill bug—anything. Time each person and allow one minute per individual. The person at the end of the log ends the story.

B. After the field trip, write a story of your own about the invertebrate activities that just might take place on the log. Include factual descriptive details, but make the story entertaining, too!

Teacher Page

Student Reflection Suggested Responses: Life in a Log – Soil Structure

Life in a Log

1. How many different organisms did you find? Which were most common? Least common? Why do you think this is so?

   Responses will vary. The more complex carnivorous organisms are generally less common. The tiny, herbivorous creatures are often present in profusion. One reason for this observation is that it takes many herbivores to support one carnivore. (Refer to Trophic Interactions activity.)

2. What are some of the differences between the organisms found in and on the log? Why do you think this is so?

   Responses will vary. Expect students to note specific adaptations and consider the structure and function of each.

3. How can you tell if the organisms are carnivores, herbivores or scavengers?

   Responses will vary. Generally, students will note structural adaptations to the mouthparts—or observe the actual demise of an organism.

4. An oak log needs at least 8 to 10 years to completely decompose. How long do you think the log you are observing has been disintegrating? Justify your response.

   Responses will vary. Expect justification of the speculation.

5. As you observed the underside of the log, did you see any indication that the soil was becoming enriched? Describe what you observed.

   Responses will vary. Students should note that there was little difference between the texture of the most decomposed bark and the soil just below it. Logic says that the bark/log is becoming soil.

Soil Formation

6. How do you think new soil forms?

   In addition to the above observation, students should recognize the effects of wind, water, and other factors in soil formation.

7. Compare different soil types and predict which type will best support plant life. Defend your prediction. What do you believe is the composition of your samples? (Loam, sand or clay?) Complete Student Reflection sheet and confirm or reject your prediction.

   Responses will vary. A combination of humus (loam), sand, and clay is preferred. However, certain plants like specific ratios of these soil types. Students may wish to investigate the specific soil requirements of certain plants. Humus is the only organic component of soil. Both clay and sand are inorganic and lack the nutrients to easily sustain life.

8. Take a small amount of material from each soil layer in your jar. Rub it between your fingers and follow the Soil Flow Chart to identify the soil type. How are the textures different?

   Responses will vary depending on the soil structure. [NOTE: If the layers are narrow, it may be necessary to analyze the saved, non-separated soil sample.]

9. Which layer would hold water best? How do you know?

   Responses will vary depending on the sample. Generally, sand has poor water-holding capacity.

10. Is there any other type of soil that would hold water even better?

    Clay is an excellent water seal. In fact, it is used as the bottom of many ponds. Unfortunately, clay and sand are inorganic and do not have the nutrients needed to support life.

Communication in science is an important skill. Verbal and written communication skills are imperative for success.

Use your imagination to either:

A. Gather with other students and position yourselves in a line along the log. Beginning on one end of the log, each person tells a part of a story about a selected organism on the log. It may be a spider, ant, or pill bug—anything. Time each person and allow one minute per individual. The person at the end of the log ends the story.

B. After the field trip, write a story of your own about the invertebrate activities that just might take place on the log. Include factual descriptive details, but make the story entertaining, too!

Fire Ecology

How do abiotic and biotic factors work together to cycle energy and resources throughout an ecosystem?

Topic: The relationship between fire and the health of an ecosystem like the prairie is beneficial and essential.

Brief Lesson/Lesson Set Description:
Students will research historical information about prescribed burns by Native Americans as a land management method as well as early environmentalist researchers such as Aldo Leopold. Students will access information about prescribed burn events on the Fermilab campus via the Fermilab website and compare site burn years with plant data to look for trends and explore the effects of prairie (and forest) fire as a land management tool to encourage ongoing success of wildlife species and their habitat.

Science and Engineering Practice: Constructing Explanations and Designing Solutions

Crosscutting Concept: Stability and Change

Objectives: Students will:

- Identify, describe, discuss, and evaluate some possible positive and negative effects on wildlife that result from prairie (and forest) fires.
- Debate the need for land management.
- Recognize the land management practices of Native Americans.
- Design a practical land management scenario for a local site utilizing fire as a management tool.

Narrative/Background Information:
In managing public lands, government agencies for many years have been making a slow movement to change the public's attitudes toward fires in the natural setting. Whereas all fires were once suppressed or vigorously fought, some now are allowed to burn as part of a natural cycle within the forest, savannah, and prairie ecosystems. In fact, there has been a movement to "prescribe" fires under some conditions. In some places, fires are intentionally set to replicate natural cycles that contribute to maintaining healthy ecosystems.

Such "prescribed burns" are planned and tended by qualified individuals. Such fires are designed to reduce the fuel load in a given area. Reducing the fuel load can prevent fires from getting so hot that they eliminate virtually all life forms and even scorch the soil, sterilizing it. Fires every one to three years in the prairie can maintain the grassland by preventing trees and shrubs from taking over. In the forest, fires every five to ten years can clear away the heavy underbrush without harming the larger trees. A major

fire such as the Yellowstone fire of 1988, with an old accumulation of brush and maturing timber, can cause intensively hot and destructive fires.

It is still correct, of course, that humans should take precautions in camping situations. “Smokey the Bear” and his “Only you can prevent forest fires,” is still a warning against carelessness in causing fires through error and accidents.

It is also still correct that fires can have negative as well as positive effects. Forest products companies would rather harvest trees than see them burn. If a fire is too large and too fast, wildlife cannot easily move to safety. Loss of vegetation can have a variety of effects, including impact on wildlife and increase in silting and sedimentation in the surrounding waters.

There are many benefits of fire, particularly in the case of those smaller burns that do not get exceedingly hot. For example, prairie and forest burns can:

- Maintain and enhance fire—dependent habitats such as prairies, savannahs, and jack pine forests.
- Increase soil productivity by more quickly releasing and recycling nutrients tied up in litter and undergrowth.
- Prepare soil for germination of some seeds.
- Activate heat-dependent seed varieties, such as lodgepole pines.
- Contribute to an “edge effect,” providing a greater variety of food and shelter sources for wildlife.
- Open up the habitat, generating new growth, diversity and abundance of food plants for some of the herbivores.

Wildfires were common in history. Lightning strikes regularly ignited vast areas of prairie and forestland. Interestingly, after a prairie fire, the grasses came back in profusion—bringing the bison herds with it. Native Americans soon learned how to ignite prairie to bring the herds back year after year. These wildfires typically swept across the plains slowly enough for large animals to get out of the way, but fast enough that ground-dwelling animals could duck into their burrows and be largely insulated from the flames. In the devastating fires at Yellowstone National Park in 1988, very few large animals succumbed, contrary to media reports and speculation at the time. Surveys indicated that only about 345 elk (of an estimated 40,000–50,000), 36 deer, 12 moose, 6 black bears, and 9 bison had perished, mostly animals trapped in box canyons or other geological barrier.

Aldo Leopold (1887–1948) was a renowned conservationist who looked at land management through the eyes of respect for the power of the land. A study of land conservation is not complete without mention of this remarkable man; particularly his work in the area of wildlife conservation.

He authored *A Sand Country Almanac,* which was published posthumously in 1949 and sold over 2 million copies. His credits as an author, scientist, ecologist, forester,

conservationist and environmentalist are revered yet today, primarily for his ecocentric ideas for natural ecosystem land management. Fire was an integral part of his philosophy.

Contemporary environmentalist Mike Dombeck, Chief Emeritus U.S. Forest Service, Professor of Global Environmental Management UW-Stevens Point, UW System Fellow of Global Conservation, remarked about Leopold's work, *"As a society, we are just now beginning to realize the depth of Leopold's work and thinking."*

Scientists learned much about fire ecology as the result of the devastating forest fire that swept through Yellowstone National Park in 1988. At that time, the fire created much angst among the public who cried, "Don't let the fires burn!" Dr. Don Despain was a research biologist at Yellowstone at that time and vehemently promoted the "let it burn" philosophy. Only when the fires threatened important buildings did it become imperative to take fire abatement measures. Snows that winter finally stopped the fires naturally.

Dr. Despain was instrumental in generating the fire management plans used by the park since 1972. He created a vegetation site plan, noting the relative ages of the different forested areas. It was clear that as the fires moved, they took down the primarily old vegetation and seemed to bypass or jump over younger forests. Prior to 1972, fires were suppressed, creating a condition with many old forests with dry and dying trees. This fire management plan is still in effect throughout the U.S. Forest Service.

After the fire, the burned forest, even the severely charred portions, began anew. Beneath the fireweed, which flourished almost immediately, were tiny trees, protected by the first wave of new plants. The terrible Yellowstone fires became one of ecology's best success stories.

This tree is an example of old forest growth. Weakened by termites and disease, it is likely to fall. It is this type of forest that would benefit from a forest fire. In a short period of time, nutrients would be released into the soil and the cycle of new growth would be hastened.

Photo credit: Pat Franzen

Possible Preconceptions/Misconceptions:

- Fire is bad and should always be extinguished. In fact, fire releases nutrients back into the soil and allows for new growth to begin again.
- In a prescribed burn, animals are at risk. In nature, most animals are able to flee or retreat to underground habitats. In the case of the expansive Yellowstone fire in 1988, only a small number of animals perished due to entrapment in a box canyon.
- Wildfire is often a rapid burn, consuming material quickly. Thus, soil organisms are not at as much risk from the heat as the fire passes quickly.
- Fires permanently damage ecosystems. In reality, natural or prescribed burns are often beneficial.

Vocabulary: Dependent on student work

Materials:

- Student Pages 1 and 2
- Access to online research options
- Resource/reference suggestions, including the Fermilab website prescribed burn database (TBA)
- Paper or journal
- Pen or pencil

ENGAGE:

Show the first 2:30 minutes of *Prairie Fire!!!* This segment depicts only the back burn, a safety corridor to keep the main fire from spreading to unintended areas. Ask students to consider this measure of a controlled burn. Why is creating a firebreak critical if a natural break, such as a road or bare area, does not exist?

Continue with the video through 8:00 minutes to view the main burn with 40- to 50-foot-high flames. Impressive!
https://www.youtube.com/watch?v=PXXINFdkPoY

NOTE: The entire video is 8:26 minutes, but the content ends at 8:00 minutes.

EXPLORE:

Process:

1. Show the *Prairie Fire!!* video.
2. Stop the video to engage the class in discussion as desired. About 2:30 minutes is a good time to emphasize the need for firebreaks.
3. Briefly discuss the concept of fire. Allow students to suggest responses. What does fire need? (Heat, fuel, oxygen) What is some positive work that fire does? (Reduces fuel to ash, and in so doing, releases nutrients back into the soil) What are some of the negatives of fire? (Collateral damage to property and lives) How might this damage be abated? (Responses will vary, but taking steps in controlling the burn is critical.)

4. Separate students into research teams of 3–4 students. Distribute Student Page 1 and ask teams to select a topic that interests them. Take note of topics selected and assign one more topic per group so that all topics are researched within the class.
5. Utilizing classroom and online resources, instruct students to prepare a presentation that will be presented to the class. (Teams researching the same topic are encouraged to collaborate. All teams will submit their presentations, but only one representative team needs to give the classroom presentation.)
6. After all topics have been presented to the class, challenge the teams to consider one parcel in nature for which they will develop a land management plan.
7. Distribute Student Page 2. Encourage students to work collaboratively.
8. Allow students the opportunity to share their plans and post their food webs. (Drawings may be scanned and posted electronically or simply attached to a display board.

EXPLAIN:
Student presentations will determine the level of understanding and perpetuate new questions.

ELABORATE:
Not all ecosystems react the same to fire. Students can investigate what fire does to different ecosystems and participate in a class discussion to share their results. Students should focus on the benefits to fire and what obstacles the ecosystem must overcome as regeneration occurs. Time of regeneration should be a focus as well as milestones scientists would look for as they study restoration.

EVALUATE:
Formative Monitoring: Use Student Reflection questions for discussion throughout the investigation.

Summative Assessment: N/A

Elaborate Further/Reflect/Enrichment:
- Consider the areas of Southern California, Colorado and Washington State, all of which have suffered catastrophic wildfires over the last decade. Discuss other impacts from wild and controlled burns. What is the public attitude toward fires in forest and grassland areas in these areas? What are the broad range of consequences of fires and lack of fires, on local economy, on aesthetic value, ecological value and agricultural value? What are the trade-offs in allowing and preventing fires?
- Design a set of recommendations for conditions under which fires should be allowed in these or your area. Check your recommendations against present guidelines used by the U.S. Forest Service and state wildlife agency.
- Find out the history of fire management in the U.S. Contrast policies of Native American Indian people and federal agencies.
- Study the Yellowstone fire of 1988.
- Consider the ecosystem services provided by controlled burns.

Resources:

- *From Beneath the Ashes* (Argonne National Lab: The New Explorers Series), 28 minutes (download required)
- *Yellowstone's Burning Question* (Nova), 60 minutes (download required)

Student Page 1

Name: _____

Student Reflection: Fire Ecology

In teams of 3–4, select one of these topics to research. Your teacher will assign one more. As a class, debrief topics and formulate opinions regarding burning as a form of land management.

1. Historical information about prescribed burns by Native Americans as a land management method to help ensure that the bison herds would return to their hunting area. Concentrate on *.gov* and/or *.edu* sites for most accurate information. Example: http://www.geo.arizona.edu/palynology/geos462/wildlandfire.html
    - **Keyword search suggestion:** *Native American controlled burns/Native American use of fire*

2. Early environmentalist researchers who promoted the concept of burning natural areas to enhance native species abundance and diversity. Dr. Aldo Leopold and Dr. Don Despain are examples.

3. Opposition to prescribed (controlled) burns; information about burn protests and reasons for concern are available online. Look for specific circumstances and situations where burning is of concern. This is an example: http://appvoices.org/2013/02/13/the-heated-issue-of-prescribed-burns/
    - **Keyword search suggestion**: *controlled burn opposition*

4. Access information about prescribed burn events on the Fermilab campus via the Fermilab website and compare site burn years with plant data to look for trends.
    - Burn data: TBA
    - Plant Data: http://eddata.fnal.gov/lasso/quadrats/dataset-sum.lasso

After your class has debriefed these topics, you will be ready to formulate your land management plan. (See Student Page 2.)

Student Page 2

Name: _____

Prescribed Burn Land Management Plan

Area to be managed: _____

Permission granted by: _____

Describe the area by its ecosystem (wetland, prairie, woodland, forest, old field succession, vacant urban lot, etc.), native species present, non-native species present, size, shady or sunny, etc.:

_____

_____

_____

_____

_____

_____

Considerations such as proximity to buildings or work areas, natural firebreaks, access to emergency water supply, etc.:

_____

_____

_____

_____

_____

_____

Reason for the burn (Be very specific.):

_____

_____

_____

_____

Describe how you will undertake this effort using a step-by-step format. Research what is needed to perform a safe, prescribed burn before you begin.

Using the organisms previously listed (native and non-native), develop a food web for the property, as it currently supports. Use the space below for your labeled sketch.

Using the organisms previously listed (native and non-native), develop a food web for the property, as it may appear ten years after the burn. Use the space below for your labeled sketch.

About his environmental beliefs, Aldo Leopold once said, *"A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community."*

How will your plan support Dr. Leopold's statement?

_____

_____

_____

_____

_____

_____

Home on the Range

How do abiotic and biotic factors work together to cycle energy and resources through an ecosystem?

Topic: Exploration of the proximity and relative size of mound-building ant mounds

Brief Lesson/Lesson Set Description:
Students recognize the ecological importance of animal range patterns and apply this understanding to real-world issues. Considering a photograph of ant mounds on a Fermilab prairie parcel, students note the relative proximity of one anthill to another and determine if there is a correlation between diameter and/or height of a mound and its proximity to adjacent mounds.

Science and Engineering Practices: Using Mathematics and Computational Thinking; Engaging in Argument from Evidence

Crosscutting Concept: Patterns, Cause and Effect

INVESTIGATION

Objectives: Students will:

- Understand the concept of animal ranges including factors that affect ranges.
- Apply animal range understandings to practical, real-world ecological issues.
- Construct a model depicting the range of specific organisms and consider ramifications of overcrowding.

Narrative/Background Information:
The term “range” has a number of meanings pertaining to nature. Webster defines it as an open region over which animals (as livestock) may roam and feed or the region wherein an organism or ecological community naturally lives or occurs. Rangeland is not only found in North America. The term applies to any extensive area of land occupied by native herbaceous or shrubby vegetation and grazed by domestic or wild herbivores. Rangeland around the world includes tallgrass prairies, steppes (shortgrass prairies), desert scrublands, shrub woodlands, savannas, chaparrals, and tundra. Some temperate and tropical forests are used for grazing as well, but technically are not rangeland because they are not predominantly grassy.

Range, when applied to a population, can be an expansive area. For example, the range of the housefly as a species is enormous! The range of an individual organism is generally much smaller. Catfish, for instance, tend to be territorial. An individual usually stays in the same general area their entire lives, but the species is found throughout a vast area.

Before the advent of the steel plow, two things sustained the prairie. Wildfires from time to time destroyed the surface dry grass and encouraged reseeding. Also, large herds of animals such as bison and pronghorn antelope dispersed grass seeds in their waste and trampled them into the soil, promoting germination.

At one time, an estimated 60 million bison roamed the Great Plains. Today, only a fraction of this number remains. (See Bison materials in *Resources*.) Virtually all of these remaining animals are maintained on ranches, farms and zoos. Only two wild herds exist: one in Yellowstone National Park and the other in Canada. Prairie dogs and prairie chickens were also common. Today, they are rarely seen. The grassy ecosystem that so richly supported these herbivore (plant-eater) animals has vanished. As the prairie land declined, the ranges of many once populous animals began to shrink, as did their numbers.

It took the farmers awhile to discover the rich prairie soil that is so conducive to growing corn, wheat, and other crops. With the advent of the steel plow, grasslands became farmlands. Towns and cities followed. The once common wildfires started by lightning and/or Native Americans who knew burning enriched the soil and brought back the prairie, and thus the bison, in profusion, were kept in check. In short, animals were pushed out of their prairie homes. As natural areas disappeared, animal ranges became smaller and smaller. Because some animals require vast expanses of land to thrive, many species all but vanished from the Midwest.

It is reported that bison herds ranged hundreds of miles in search of fresh grazing land. Prairie dog villages covered tens of thousands of miles in the Midwest to Western prairies. Bobcats ranged throughout this vast area, with individual ranges of 50–100 miles!

Even the tiny ant has a range to consider. Species of mound-building ants of the North American prairie once created anthills that dotted the land from Indiana to the foothills of the Rockies. While the range of these species was enormous, the range of an individual colony is relatively small. It is unclear whether an ant cohabitates hills with individuals from other colonies, but strong evidence shows that each colony is independent. Since they are social organisms with a well-defined caste system consisting of queens, males, and workers (including soldiers), this is possible, particularly within the same species. Collectively, ants are considered superorganisms. Now, except for protected areas, these colonies of ants that once helped aerate the soil and perform many functions important to the prairie are greatly diminished.

The eradication of natural ecosystems around the world is a common problem. Prairies and grasslands make way for farms, villages, cities, and other infrastructure. Sometimes, native animals that once held an important niche in their natural community are deemed a nuisance. For example, some American ranchers complain that golden eagles, wolves, and coyotes prey on their livestock, particularly lambs and other young livestock. It is probable that the predators only select lambs that are sick, dying, or already dead. Nonetheless, these hunters are often killed or relocated, effectively upsetting the natural order. As a result of limiting the range of predators, first-level consumers such as mice, voles, and rabbits become numerous. The problem escalates on another level, as the animals compete for food needed by the domestic grazing herds. (See video *How Wolves Change Rivers*.)

Engage students in relevant questions such as: How do animals, including people, resolve their conflicts within the natural world? What factors must they consider? Are there

situations in your community or in the world where opposing groups have found a workable solution?

Prior Student Knowledge Expectations:
General understanding of perspective, recognizing that a two-dimensional photograph has limitations when trying to estimate size and distance

- Ability to take these perception limitations into consideration while completing the investigation
- Willingness to make suggestions even though there is a likelihood that the estimations are less than perfect
- General understanding and acceptance of collaborative behaviors

Possible Preconceptions/Misconceptions:

- Ants are not the most populous invertebrate; while ants are common, there are far more springtail in a cubic meter of soil.
- Ants do not randomly go about their day. Rather, they are a part of a highly evolved social structure with each individual responsible for its own part of life in and outside the mound. In some ant species, the population is considered a single organism known as a superorganism.
- Ants bite. It's not wise to stand on an ant mound!
- Ants are individuals, but not entirely. Collectively, ants are considered superorganisms, functioning as though they are single organisms.

Vocabulary: range, species, population, community, superorganism

Materials: (per two students)

- Student data sheet: *Home on the Range – Mound-Building Ants*
- Ruler (one per partnership)
- Compass
- Calculator
- Colored pencils

ENGAGE:
Ask: *What is a superorganism?* Expect responses like a fierce lion or even a dinosaur. Superman or Batman may emerge. Play along with the responses for a brief time, collecting responses for students to see.

Play the first 1:14 minutes of this excellent 44-minute video, *Wild City of Ants*, a National Geographic video. NOTE: The entire video is excellent!
https://www.youtube.com/watch?v=4hsmSoUlhgc

EXPLORE
Process:

1. Read the background information and differentiate between range of a species and that of an individual animal.
2. Brainstorm with students about ranges in general. How far do they think specific animals range? Is there a specific formula to determine the range of a particular

species? (Some bottlenose dolphin populations, for example, may range hundreds of miles in a year. Other populations, such as the one in Sarasota Bay, Florida, stay within a relatively small area.)

3. Consider range limitations. What can limit the range of a deer or a rabbit? (Urban sprawl, fences, highways, food sources, etc.)
4. Pair students so that each has a partner. Arrange pairs of students in groups of four if possible.
5. Present "Home on the Range – Mound-Building Ants" student data sheet. Instruct students to work with a partner to estimate the number of anthills found in the photograph. *Tell them to count only those anthills on or below the line.* Allow partners to share their data with another partner set. Do they agree? Encourage students to come to a consensus and place a dot in the center of each anthill. Do NOT stress over the "right number" (*approximately 30 anthills)*.
6. On the grid below the image, students will place a dot corresponding to that on the image. Using the compass and colored pencils, draw a circle around each anthill so that it comes to approximately halfway between hills on all sides. (NOTE: This is not perfect! Students should notice a pattern in the placement of the anthills.)
7. Complete "Home on the Range – Mound-Building Ants" student data sheet.
8. Complete "Student Reflection: Home on the Range" within the established partnership, group of four, or as a class.
9. Allow students the opportunity to communicate their data beyond the partnership. (Class discussion, designated report, etc.)

EXPLAIN:
Following the investigation, engage students in a class discussion about range. Using what they have learned about mound-building ants and bison, ask them to draw a model of a 2,000 x 2,000 square meter plot. Estimate how many bison and ants could comfortably inhabit that area. Prepare to defend the speculation and extrapolate to consider issues if there were too many ants or too many bison.

4,000,000 square meters is approximately 988 acres. A free-range cow and calf need about 20 acres. Thus, only about 100 bison mamas and calves would comfortably live on this plot. Approximately 480,000,000 ants could be sustained if we use our student data sheet estimate of about 300,000 ants per 50 x 50 square meter plot.

ELABORATE:
Show the entire 44-minute National Geographic video, *Wild City of Ants.*
https://www.youtube.com/watch?v=4hsmSoUlhgc

Challenge students to isolate all the different tasks of individual ants within a colony and speculate about the relative number of ants that perform specific functions. For example, does a colony need more nursery workers or warriors? Why do they believe their speculation to be true? How might they find out whether they are correct?

EVALUATE:
Formative Monitoring: Guide the investigation with ongoing questions from the student sheets.

Summative Assessment: Select an assessment(s) rubric. Adapt *Participation, Investigation,* and/or *Product Rubric* or *Checklist* as desired. (See *Introduction* section.) Communicate rubric criteria to students prior to the activity to help ensure success.

Elaborate Further/Reflect/Enrichment: Continue web research on mound-building ants and note how they provide tremendous ecosystem services.

Name: _____

Home on the Range – Building Ants!

Study this photograph. On the grid below, plot the anthills by making a pencil mark. Imagine that the area is 50 meters by 50 meters. (Do not consider perspective because you are just looking for an estimate.) After you draw the anthills, use a compass to draw a circle around each anthill. Share your grid with a partner. How do they compare?

Name: _____

Home on the Range – Mound-Building Ants!

1. How many anthills did you find? _____ How does this number compare with that of your classmates?

2. Why were the numbers different?

3. How do you think field researchers count specimens? What difficulties might they have when trying to count animal populations?

4. Research tells us that there can be thousands of ants in a single anthill colony. If there were 10,000 ants in each colony, how many ants are in this 50-meter x 50-meter plot? Show your calculations!

5. Why do you suppose there are so many anthills in this place? Of what benefit are ants to the prairie? To other ecosystems?

6. If Fermilab were to put bison on this plot, how many animals might live comfortably? Explain.

7. What other animals might share this plot with the ants? List at least five.

8. Select two of the animals you listed and describe their relationship with the ants. (Predator, prey, does not interact, etc.)

Teacher Page

Suggested Responses: Home on the Range – Mound-Building Ants!

1. How many anthills did you find?

   About 30

   How does this number compare with that of your classmates?

   Responses will vary. Encourage students to come to consensus, recognizing that perspective is a problem. It is hard to see the anthills in the distance. Without complicating the issue, remind students that this is one reason that certain aspects of field science MUST be performed in the field.

2. Why were the numbers different?

   Responses will vary. Without actually being on the prairie to count, some bare ground might be confused and called an anthill. Perspective also complicates the count, as distant anthills are hard to identify.

3. How do you think field researchers count specimens? What difficulties might they have when trying to count animal populations?

   Field researchers may use transect lines and follow a straight course through an area. Quadrat studies compare numerous square meter plots over time. Many other means are employed by researchers to study natural areas. The most important part of any observation, however, is firsthand. Effective field observation takes place in the field.

4. Research tells us that there can be thousands of ants in a single anthill colony. If there were 10,000 ants in each colony, how many ants are in this 50-meter x 50-meter plot? Show your calculations!

   Approximately 300,000 ants may exist in the plot. (30 x 10,000)

5. Why do you suppose there are so many anthills in this place? Of what benefit are ants to the prairie? To other ecosystems?

   Ants are efficient creatures. They require relatively little space because of their tiny size. Their colonies are built up and down, sometimes extending a meter or more below the surface of the soil. Some benefits of ants include the following:

   Ants help keep the prairie clean by consuming remnants of dead organisms. Thus, they enrich the soil by replacing some valuable nutrients.

Ants aerate the soil, allowing more efficient gas exchange through prairie root systems.

Ants also are a food source for other organisms.

6. If Fermilab were to put bison on this plot, how many animals might live comfortably? Explain.

   Because of their size, it takes about 20 acres to satisfy the needs of a free range cow and one calf for a year. This plot is too small!

7. What other animals might share this plot with the ants? List at least five.

   Responses will vary. Students may include rodents, insects, raccoon, deer, opossum, coyote, birds, reptiles, etc.

8. Select two of the animals you listed and describe their relationship with the ants. (Predator, prey, does not interact, etc.)

   Responses will vary. Examples: Reptiles and birds prey on ants. While there is no direct interaction between deer and ants, the contributions of the ants to the prairie soil help keep the prairie healthy, which benefits the deer. Encourage such connections!

Name: _____

Student Reflection: Home on the Range

1. Describe your personal home range. How far do you roam on your own?

   What or who sets the limits of your home range?

   If these limits were not in place, how far would you roam from your home on your own? Explain how you would travel. (Remember, you cannot drive yet.)

2. Consider the bison of North America. How far did the bison once roam? What is its range today?

   What changed the limits of the bison's home range?

   Describe the environmental differences in the bison's range now compared to the early 1800s when vast herds of bison roamed the range. In what ways did the bison's range change and why?

3. Take another look at the distance between anthills in your exploration. What do you think is the range of an individual ant?

4. How does this differ from the range of mound-building ants as a population?

5. How does this compare to human ranges? Bison?

6. Describe limiting factors common to all populations. (Advanced)

You are a Native American living in the 1800s. When you were born, your tribe followed the bison herds. The hunters knew where to find these enormous animals grazing on the vast prairie. They even set fires to ensure rich prairie grass growth the following year. They knew that the bison would return to graze on the thick grass. The adults also knew how to use bison hide for shelter and clothing. The horns were used as cups, horns, and decoration. The meat was dried for food. Even the shaggy hair was woven into fabric. You learned at a very early age not to take more than you could use. Life is precious. Enough bison must remain to reproduce and grow the herd.

While you were still young, your world began to change. Settlers were moving into the prairie. Farms and villages were built. The bison were driven further and further away. Your people followed the herd. You traveled greater distances than ever before, leaving what was familiar for new terrain.

Write a poem, essay, or short story describing your feelings.

Teacher Page

Student Reflection Suggested Responses: Home on the Range

1. Describe your personal home range. How far do you roam on your own?

   Responses will vary. Most students have limits. These limits may vary depending on individual family policy.

   What or who sets the limits of your home range?

   Responses will vary. Generally parents or guardians set limits. Schools also set limits. Encourage students to think about places they are NOT allowed to go.

   If these limits were not in place, how far would you roam from your home on your own? Explain how you would travel. (Remember, you cannot drive yet.)

   Responses will vary. Remind students to be realistic in their responses.

2. Consider the bison of North America. How far did the bison once roam? What is its range today?

   The American bison once had a range of tens of thousands of miles.

   What changed the limits of the bison's home range?

   Human interactions with the environment changed the ecosystem. Encourage students to identify some of these changes. (See Background Information.)

   Describe the environmental differences in the bison's range now compared to the early 1800s when vast herds of bison roamed the range. In what ways did the bison's range change and why?

   Responses will vary.

3. Take another look at the distance between anthills in your exploration. What do you think is the range of an individual ant?

   Most anthills are within 10 meters of one another. Some ants may venture farther, but since all their needs are met within a small space, they probably remain close to their own colony.

4. How does this differ from the range of mound-building ants as a population?

   As a population, these ants once had a range throughout the Midwest. They can still be found in this general area, but their numbers have greatly diminished.

5. How does this compare to human ranges? Bison?

   Humans have the capacity to transport themselves using machines. They also can manipulate their environment via shelter, food sources, and communication. Without a direct dependence on the natural world on a day-by-day basis, humans move from place to place relatively easily; other animals, however, are limited by that which nature serves—and humans control. Today, humans are nearly in complete control of bison ranges.

6. Describe limiting factors common to all populations. (Advanced)

   Responses will vary. Anything that obstructs movement, impacts food sources, complicates reproduction, or presents any other health threat is a limiting factor.

You are a Native American living in the 1800s. When you were born, your tribe followed the bison herds. The hunters knew where to find these enormous animals grazing on the vast prairie. They even set fires to ensure rich prairie grass growth the following year. They knew that the bison would return to graze on the thick grass. The adults also knew how to use bison hide for shelter and clothing. The horns were used as cups, horns, and decoration. The meat was dried for food. Even the shaggy hair was woven into fabric. You learned at a very early age not to take more than you could use. Life is precious. Enough bison must remain to reproduce and grow the herd.

While you were still young, your world began to change. Settlers were moving into the prairie. Farms and villages were built. The bison were driven further and further away. Your people followed the herd. You traveled greater distances than ever before, leaving what was familiar for new terrain.

Write a poem, essay, or short story describing your feelings.

Encourage creativity by including mixed media, music, or any other talent a student may possess. Select an assessment option. (See Resources.)

How do abiotic and biotic factors work together to cycle energy and resources through an ecosystem?

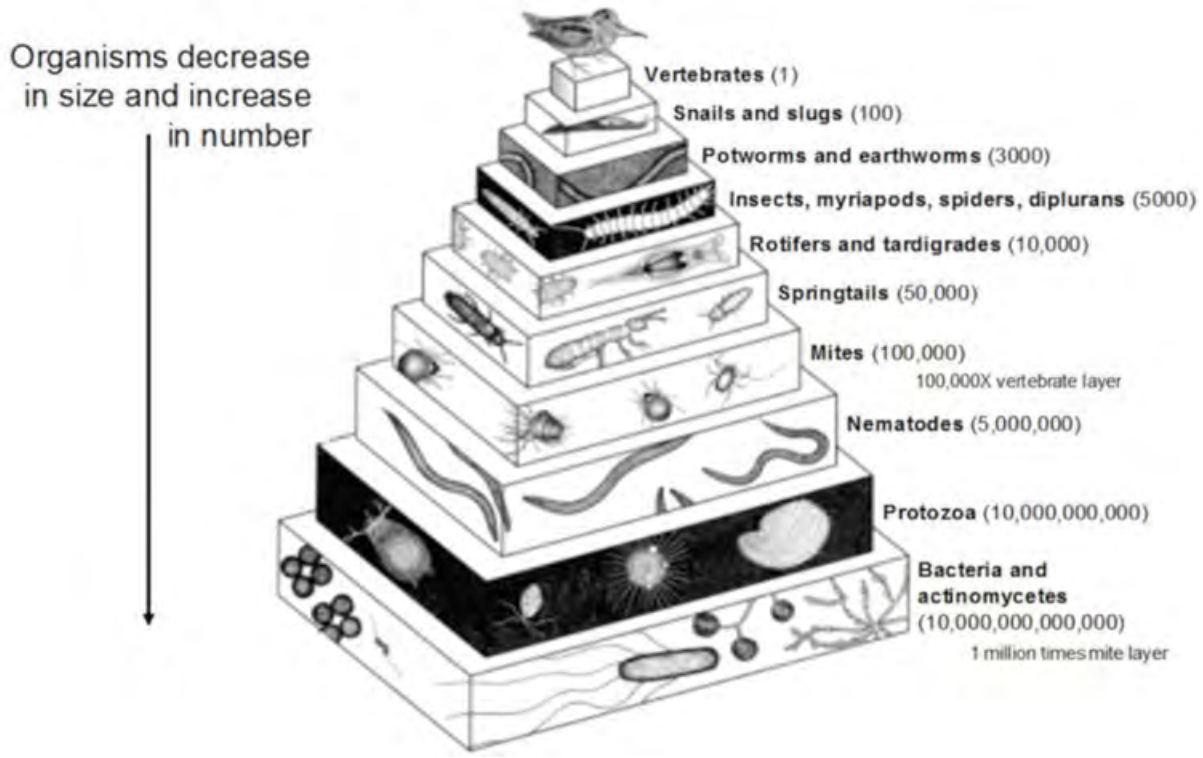
LS1-6. Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms.

LS2-3. Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.

Each of the organisms in an energy pyramid has its niche. They depend on other organisms and the organisms above the soil directly and/or indirectly. Consider the energy pyramid in *Trophic Interactions* and the population graphic below to create a food web. Considering the plant and animal life above soil level, create a food web with text boxes that model energy transfer throughout your ecosystem.

Include at least two types of producers, primary consumers, secondary consumers, tertiary consumers and decomposers. Identify each type of organism in a text box. Include arrows to show energy transfer. Include three text boxes that explain how abiotic factors affect the flow of energy throughout the food web. After the web is complete, estimate the number of organisms in each category. For example, one fox may eat ___ birds, which may eat ___ snails, which will eat ___ springtails, etc.

In one square meter of soil....



Argue for or against the statement that producers are the most important part of your food web model. Use evidence from your learning to support your claim.

_____

_____

_____

_____

_____

Choose a biotic organism that if removed from the food web would affect the energy in the food web the greatest. Explain how the lack of energy would affect the other organisms in the web. Use evidence from your learning to support your claim.

_____

_____

_____

_____

_____

An invasive plant has taken root in your ecosystem and is monopolizing the resources available, lowering the diversity of the plants that live there. How does this affect your food web? Use evidence from your learning to support your claim.

_____

_____

_____

_____

_____

In natural woodland, invasive trees might change the canopy level of the area. Sunlight would be blocked from reaching the native plants below, impeding photosynthesis. Follow the energy path through your food web and predict how less sunlight would affect the organisms within the web? Use your prediction to create an argument for the energy level that would be affected the most by the decrease in photosynthesis.

_____

_____

_____

_____

_____

Peanut Butter and Jelly Sandwich

How do abiotic and biotic factors work together to cycle energy and resources through an ecosystem?

Topic: Sequencing and using quantitative values

Brief Lesson/Lesson Set Description:
Using the misconception model, students will be asked to write a procedure and then look at how it can be misinterpreted by someone else reading and following it. Students should go back and revise their work with a focus on the sequence of their steps and the way they quantify the materials being used.

Science and Engineering Practice: Math and Computational Thinking

Crosscutting Concept: Cause and Effect

INVESTIGATION

Objectives: Students will:
- Design a sequence of steps to complete a simple task—making a PB&J sandwich.
- Recognize and state the importance of clearly stated directions.
- Value the worth of appropriate sequence to understanding.
- State how scientists are affected by the consequences of quantity when following a procedure.

Narrative/Background Information:
Complete this activity early in the year, as it is valuable for reflection. As communication and procedural issues arise, refer back to the experience.

Possible Preconceptions/Misconceptions:
Students will oftentimes assume that their knowledge is common knowledge to all, leaving out important details when creating their own investigations.

Vocabulary: procedure, quantity

Materials:
- Jar of peanut butter with plastic lid
- Jar of jelly with plastic lid
- Loaf of bread
- Butter knife
- Several paper towels

ENGAGE:
Ask if any students know how to make a peanut butter and jelly sandwich.

EXPLORE:
Process:

1. Choose your “victim” carefully. It is important that this be a self-confident student.
2. Position this student across the room with his/her back to you. NO PEEKING.
3. Ask student to verbally provide directions to make the sandwich.
4. Follow the directions precisely.
    a. If the student says “some” peanut butter, put either a tiny amount on the bread or a huge amount.
    b. Be sure to play up ambiguities.
    c. If the student does not specifically tell you which side of the bread to use, use both sides of the same slice.
    d. Continue with the jelly.
5. Present the sandwich to the student participating.

EXPLAIN:
Discuss how this activity turned out differently from what they thought it would be.

ELABORATE:
Ask students to complete the Student Reflection sheet. Ask students to look at a procedure from a published lab and identify how materials are quantified.

EVALUATE:
Formative Assessment: Ask students to self-assess the sequence of their steps and how they quantified their materials. Ask students why quantifying materials is vital when writing a procedure.

Summative Assessment: N/A

Elaborate Further/Reflect/Enrichment: Assemble enough bags of Lego blocks for the number of students in the class. In each bag provide an identical set of 5–6 blocks of different sizes and color. Distribute the bags and ask students to create a figure using all the blocks in the bag and write directions on how to assemble the figure. Have students draw their figure when completed. Exchange directions and see if another student can follow the directions to make an identical figure.

Name: _____

Student Reflection: Peanut Butter and Jelly Sandwich

1. If you had a chance to rewrite your directions, what would you change?

2. What is the effect of using words like some, most, a little when describing quantity?

3. How does the sequence (order) of steps influence the result?

4. Explain how the type of directions given could affect research in a scientific study.

5. It was probably difficult to follow each step of the directions exactly how they were written because you know how to make a PB&J sandwich. During scientific investigations, what are the effects of not following the directions precisely?

Instead of asking a student to verbally communicate direction, ask students to write a procedure for making a PB&J sandwich. The next day, collect the procedures and without revealing the writer's name, follow the precise directions for a few particularly interesting submissions.

Teacher Page

Student Reflection Suggested Responses: Peanut Butter and Jelly Sandwich

Note: Be careful not to personalize the discussion. The student participant may be sensitive.

1. If you had a chance to rewrite your directions, what would you change?

   Responses will vary. Follow up with asking why students would make those changes.

2. What is the effect of using words like some, most, a little when describing quantity?

   Encourage students to realize that some terms have different meanings for different people.

3. How does the sequence (order) of steps influence the result?

   Responses will vary. Look for specific examples to be relevant, depicting pitfalls of illogical sequencing.

4. Explain how the type of directions given could affect research in a scientific study.

   Responses will vary. Look for specific examples to be relevant, depicting real or imagined studies.

5. It was probably difficult to follow each step of the directions exactly how they were written because you know how to make a PB&J sandwich. During scientific investigations, what are the effects of not following the directions precisely?

   Responses will vary. Follow up with asking what may have resulted if the sandwich maker inferred during the creation process and how this idea transfers to a scientist conducting a scientific investigation.

Instead of asking a student to verbally communicate direction, ask students to write a procedure for making a PB&J sandwich. The next day, collect the procedures and without revealing the writer's name, follow the precise directions for a few particularly interesting submissions.

Problem-Based Research Component – Engineering Design

Topic: Engineering Design

Brief Lesson/Lesson Set Description:
Students have been asked to design and plan out an ecosystem on their school grounds. Students should decide on the ecosystem they intend to develop and identify the potential barriers to that development, giving a solution to each of these barriers.

Science and Engineering Practices: Asking Questions and Defining Problems; Developing and Using Models

Crosscutting Concepts: Cause and Effect; Systems and System Models

MS-ETS1-1. Engineering Design
Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution taking into account relevant, scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

MS-ETS1-4. Engineering Design
Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

INVESTIGATION

Objectives: Students will:

- Identify issues considered when analyzing and/or establishing a native ecosystem.
- Develop a solution(s) to overcome barriers when first establishing the ecosystem.
- Synthesize ideas and knowledge developed within the research team to design and build a model of a schoolyard ecosystem.
- Create an action plan to accomplish the task of developing a schoolyard ecosystem. Action plans can potentially be presented to stakeholders in an effort to restore and maintain ecosystems on school property for future study.

Narrative/Background Information:
Energy and Ecosystems: Prairie, Water and Woods students engage in research on several levels: project-based, performance-based, problem-based, and field-based. Additionally, questions posed by the curriculum materials—and, more importantly, the student—foster the inquiry-based platform integral to world-class science education. Problem-based learning (PBL) differs in complexity because it requires the establishment of a carefully constructed, student-initiated action plan.

The problem-based opportunity presented in this activity is designed to connect ecosystem understandings to the real world and culminates in an action plan that

students can put into practice. Students must take their knowledge to a higher level as they investigate a real-world question, such as determining possible explanations for prairie trends, or tackle a local initiative, such as designing a plan to construct a schoolyard habitat. In the process, students will work collegially to implement their action plans, emulating the efforts of scientists and other specialists in the field.

Prior Student Knowledge Expectations: N/A

Possible Preconceptions/Misconceptions:
Students may not look at a problem through several different lenses. Encourage students to identify the criteria and constraints of a problem and its solutions through many different points of view.

Vocabulary: Restoration

Materials: Material list will be dependent upon chosen project.

ENGAGE:
Students should be beginning to develop a sense of why restoration efforts are important and their role in the restoration and maintenance of local ecosystems. Facilitate a discussion that empowers students to become part of their own restoration project at their school; include the benefits of participating in a project like this and the benefits of the project to the local community. Students should feel that their project mimics real-world restoration efforts and could be used as a tool to educate other students and community members.

EXPLORE:
Process:

1. Facilitate a brainstorming session with students with the goal of designing a custom ecosystem within their schoolyard. Students should consider all aspects of the work it would take to create a restored ecosystem such as: the best area to plant, drainage, aesthetics, wildlife that may make their home in the ecosystem, learning opportunities for students, outreach educational opportunities, maintenance during the school year and the summer months, start-up and maintenance costs, etc.
2. Students will begin to prioritize their research topics, conduct their research, and create their plans.
3. As plans culminate, students will create a plan of communication to stakeholders such as school administration, school boards, community members, etc.
4. Provide copies of the Problem-Based Evaluation Rubric to the students.
5. Remind students to maintain journals, complete all of the required paperwork, and produce appropriate notes and materials for participation in the forum or debate. Journal entries should consist of their notes, evidence of active participation as part of a team and a written summary of the steps taken to solve the problem.

6. Recognize that this is a long-term project and may be completed in increments throughout a period of time in conjunction with other investigations.

EXPLAIN:
Students will research development and present their plan to a wider audience.

ELABORATE:
As an example, students planning a prairie should refer to *Things to Consider when Planting a Prairie* and related documents found in the *Resources* section.

EVALUATE:
Formative Monitoring: Refer to Project Rubric found in the *Introduction* section.

Summative Assessment: Refer to Project Rubric found in the *Introduction* section.

Elaborate Further/Reflect/Enrichment: Students present to an audience, such as principal, local school board, town mayor, etc. Create a sustainable ongoing maintenance/enrichment plan for the future.

Ecosystem Services Research Components

The ecosystem services research components portion of the unit is a chance for students to apply new science knowledge by giving practical reasoning for a facility, like their school, to restore an ecosystem on their property. This project will benefit students by giving them another location to conduct research and by giving them an opportunity to participate in a local restoration project. Students will need to understand and apply concepts needed to develop and maintain a restored ecosystem but also be able to communicate the benefits that the restored ecosystem gives back to the community.

Students choose an ecosystem services research component based on interest and relevance to their initial research project. There should be a clear connection to the ecosystem service they choose to research and the benefits to their restored schoolyard ecosystem. For example, if there is a part of the schoolyard that is constantly sunny and dry, possibly even too dry for grass to grow, a prairie restoration might be a good fit for this area. The prairie would add an aesthetic quality with its interesting plants and insects as well as increase pollination for all plants around the school. The prairie would also be able to grow in this hot, dry area, not needing to be watered or maintained throughout the year. This part of the project should add reason to restore an ecosystem on school grounds and can be used as argumentation if students choose to communicate their project to stakeholders in an effort to bring their project to fruition.

The emphasis in this project is the connection between how ecosystems and humans benefit each other. Students should take the opportunity to look at this relationship as valid arguments for restoration projects and should consider all stakeholders when creating this argument. Students should communicate clearly and support arguments with benefits for the restored ecosystem and for the human populations that interact with the restored ecosystems.

Students should be encouraged to look for other ecosystem services and explore further to satisfy their interest. Often a restored ecosystem will provide multiple benefits to communities, not just one. Encourage students to explore questions and ideas as they create their arguments and support ideas.

Ecosystem Services Research Component – Pollination

Topic: How can pollination be increased in a restored ecosystem?

Brief Lesson/Lesson Set Description:
Students will ask a question that can be answered through research. They will design and implement a plan to solve school site problems with the creation of a restored ecosystem (prairie, woodlands, or pond).

Performance Expectations:

ETS 1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

MS-LS1-4. Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants, respectively.

Assessment:
Find the Engaging in Argument from Evidence rubric to progress monitor students' growth through the practices. Find Science and Engineering Practices rubrics in the *Introduction* section.

Objectives: Students will:

- Identify a question about how restored ecosystems can help solve ecological issues.
- Research the question.
- Develop a solution to help contribute to a solution and an implementation plan.
- Communicate conclusions.

Narrative/Background Information:
Student-generated questions foster the inquiry-based platform integral to world-class platform integral to world-class science education. Field-based learning differs from lab-based research in that it is difficult, if not impossible, to control some of the variables.

Field-based research focuses on data collected for an ecosystem over a period of years. In the field, the problem becomes "messy." Without the ability to create controls, a variety of factors can contribute to a situation. Designing research questions takes considerable thought. While students can easily gather data from within their classrooms, if it is possible to provide the unique experience of a field study, it is encouraged.

This activity can easily incorporate all disciplines within the middle school. Research questions can also be differentiated and accommodate all styles of learners.

Encourage students to think about their interests and to spend time brainstorming potential questions before they settle on a topic to investigate.

Possible Preconceptions/Misconceptions:
Students may need direction on how to ask scientific questions that can be researched, how to collect data if conducting field research, and how to analyze that data once it is collected. Mini-lessons on how to conduct research, collect data, make sense of that data, and how to use the findings as support for an argument, could be done throughout student work.

Process:

1. Students explore a few examples of relationships between animals and plants that result in pollination for the plant. Students choose one of the relationships that most intrigues them to research.
2. Students are encouraged to brainstorm questions that could be researched about the chosen relationship. Questions should revolve around how to increase pollination and the effects that the increase of the pollination will have on the ecosystem. Students will conduct the research, taking notes in their science journals. Students may use the *SIMply Prairie* website as well as other sites to search for longitudinal data that has been collected on their question. http://ed.fnal.gov/data/life_sci/prairie/
3. Students should plan a field-based research component to collect additional data on their chosen organisms. This additional data should contribute to solutions that help increase the likelihood that pollination will increase and produce more plant life within the chosen ecosystem.
4. Students need to decide on how they might collect their own data in the field and design protocol for collecting data either at school, at home, or while at Fermilab.
5. Students conduct both classroom and field-based research, collecting data that supports the answer to their question and contributes to their solution. They should work through unexpected variables to collect data in field-based research and remember that the lack of data is data!
6. Students will maintain a science journal to record findings, sketch, create models, record ideas and write down other questions they have.
7. Students make a recommendation for a solution that would add to increased pollination in their ecosystem. A written explanation of why an increase in pollination is beneficial to the ecosystem should be included.

Ecosystem Services Research Component – Erosion Control

Topic: How restoring natural ecosystems can help with erosion control

Brief Lesson/Lesson Set Description:
Students will ask a question that can be answered through research. They will design and implement a plan to solve school site problems with the creation of a restored ecosystem (prairie, woodlands, or pond).

Performance Expectations:

ETS 1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

ESS3-3. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

Assessment:
Find the Engaging in Argument from Evidence rubric to progress monitor students' growth through the practices. Find Science and Engineering Practices rubrics in the Introduction section.

Objectives: Students will:

- Identify a question about how restored ecosystems can help solve ecological issues.
- Research the question.
- Develop a solution to help contribute to a solution and an implementation plan.
- Communicate conclusions.

Narrative/Background Information:
Student-generated questions foster the inquiry-based platform integral to world-class platform integral to world-class science education. Field-based learning differs from lab-based research in that it is difficult, if not impossible, to control some of the variables.

Field-based research focuses on data collected for an ecosystem over a period of years. In the field, the problem becomes "messy." Without the ability to create controls, a variety of factors can contribute to a situation. Designing research questions takes considerable thought. While students can easily gather data from within their classrooms, if it is possible to provide the unique experience of a field study, it is encouraged.

This activity can easily incorporate all disciplines within the middle school. Research questions can also be differentiated and accommodate all styles of learners. Encourage students to think about their interests and to spend time brainstorming potential questions before they settle on a topic to investigate.

Possible Preconceptions/Misconceptions:
Students may need direction on how to ask scientific questions that can be researched, how to collect data if conducting field research, and how to analyze that data once it is collected. Mini-lessons on how to conduct research, collect data, make sense of that data, and how to use the findings as support for an argument, could be done throughout student work.

Process:

1. Students that are interested in the topic of erosion control are encouraged to brainstorm questions that can be researched and will produce data that could contribute to solutions to help decrease the likelihood that erosion will happen to the school grounds. The question should give data that can be used to make an argument for the type of plants used around the school to reduce erosion of the grounds. For example, planting prairie plants around the grounds instead of lawn.
2. Students use the *SIMply Prairie* website as well as other sites to search for longitudinal data that has been collected on their question. http://ed.fnal.gov/data/life_sci/prairie/
3. Students choose a research question and revise it based on what they have learned from exploring the database. Be sure their question provides information that can contribute to solutions that will help decrease erosion in their chosen ecosystem.
4. Students decide on how they might collect their own data in the field and design protocol for collecting data either at school, at home, or while at Fermilab.
5. Students conduct both classroom and field-based research, collecting data that supports the answer to their question and contributes to their solution. They should work through unexpected variables to collect data in field-based research and remember that the lack of data is data!
6. Students maintain a science journal to record findings, sketch, create models, record ideas and write down other questions they have.
7. Students make a recommendation for a solution that would decrease erosion in their school environment.

Ecosystem Services Research Component – Weather/Disturbance Regulation

Topic: How restoring natural ecosystems can help with weather/disturbance regulation

Brief Lesson/Lesson Set Description:
Students will ask a question that can be answered through research. They will design and implement a plan to solve school site problems with the creation of a restored ecosystem (prairie, woodlands, or pond).

Performance Expectations:

ETS 1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

ESS3-3. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

Assessment:
Find the Engaging in Argument from Evidence rubric to progress monitor students' growth through the practices. Find Science and Engineering Practices rubrics in the *Introduction* section.

Objectives: Students will:

- Identify a question about how restored ecosystems can help solve ecological issues.
- Research the question.
- Develop a solution to help contribute to a solution and an implementation plan.
- Communicate conclusions.

Narrative/Background Information:
Student-generated questions foster the inquiry-based platform integral to world-class platform integral to world-class science education. Field-based learning differs from lab-based research in that it is difficult, if not impossible, to control some of the variables.

Field-based research focuses on data collected for an ecosystem over a period of years. In the field, the problem becomes "messy." Without the ability to create controls, a variety of factors can contribute to a situation. Designing research questions takes considerable thought. While students can easily gather data from within their classrooms, if it is possible to provide the unique experience of a field study, it is encouraged.

This activity can easily incorporate all disciplines within the middle school. Research questions can also be differentiated and accommodate all styles of learners.

Encourage students to think about their interests and to spend time brainstorming potential questions before they settle on a topic to investigate.

Possible Preconceptions/Misconceptions:
Students may need direction on how to ask scientific questions that can be researched, how to collect data if conducting field research, and how to analyze that data once it is collected. Mini-lessons on how to conduct research, collect data, make sense of that data, and how to use the findings as support for an argument, could be done throughout student work.

Process:

1. Students that are interested in the topic of weather and how natural areas can help manage the effects of weather are encouraged to brainstorm questions that could be researched and will produce data that could contribute to solutions that help landscapers choose the best ecosystem to restore in a schoolyard.
2. Students should weigh the pros and cons to restoring a prairie, forest or pond in a school courtyard. (This area is entirely surrounded by the building, creating an outdoor area in the center of the school.) Research questions can be focused on the prevention of flooding, the protection of winds and storms, the reduction of heat, etc.
3. Students use the *SIMply Prairie* website as well as other sites to search for longitudinal data that has been collected on their question. http://ed.fnal.gov/data/life_sci/prairie/
4. Students choose a research question and revise it based on what they have learned from exploring the database. Be sure their question provides information that can contribute to solutions that help manage the effects of weather in their chosen ecosystem.
5. Students decide on how they might collect their own data in the field and design protocol for collecting data either at school, at home, or while at Fermilab.
6. Students conduct both classroom and field-based research, collecting data that supports the answer to their question and contributes to their solution. They should work through unexpected variables to collect data in field-based research and remember that the lack of data is data!
7. Students will maintain a science journal to record findings, sketch, create models, record ideas, and write down other questions they have.
8. Students make a recommendation for a solution that would add to managing the effects of weather in their ecosystem.

Ecosystem Services Research Component – Nutrient Cycling

Topic: How restoring natural ecosystems can help with nutrient cycling

Brief Lesson/Lesson Set Description:
Students will ask a question that can be answered through research, design and implement a plan to solve school site problems with the creation of a restored ecosystem (prairie, woodlands, or pond).

Performance Expectations:

ETS 1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

LS 1-6. Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms.

Assessment:
Find the Constructing Explanations and Designing Solutions rubric to progress monitor students' growth through the practices. Find Science and Engineering Practices rubrics in the Introduction section.

Objectives:
The students will:

- Identify a question about how restored ecosystems can help solve ecological issues.
- Research the question.
- Develop a solution to help contribute to a solution and an implementation plan.
- Communicate conclusions.

Narrative/Background Information:
Student-generated questions foster the inquiry-based platform integral to world-class platform integral to world-class science education. Field-based learning differs from lab-based research in that it is difficult, if not impossible, to control some of the variables.

Field-based research focuses on data collected for an ecosystem over a period of years. In the field, the problem becomes "messy." Without the ability to create controls, a variety of factors can contribute to a situation. Designing research questions takes considerable thought. While students can easily gather data from within their classrooms, if it is possible to provide the unique experience of a field study, it is encouraged.

This activity can easily incorporate all disciplines within the middle school. Research questions can also be differentiated and accommodate all styles of learners. Encourage students to think about their interests and to spend time brainstorming potential questions before they settle on a topic to investigate.

Possible Preconceptions/Misconceptions:
Students may need direction on how to ask scientific questions that can be researched, how to collect data if conducting field research, and how to analyze that data once it is collected. Mini-lessons on how to conduct research, collect data, make sense of that data, and how to use the findings as support for an argument, could be done throughout student work.

Process:

1. Students that are interested in the topic of nutrient cycling are encouraged to brainstorm questions that can be researched and will produce data that could contribute to solutions to help increase the likelihood that more energy will increase when more plant life is introduced into an ecosystem. Students should work to decide on an ecosystem to work with (prairie, forest, pond) and decide which one plant could be planted and would impact the energy in an ecosystem the most.
2. Students use the *SIMply Prairie* website as well as other sites to search for longitudinal data that has been collected on their question. http://ed.fnal.gov/data/life_sci/prairie/
3. Students choose a research question and revise it based on what they have learned from exploring the database. Be sure their question provides information that can contribute to solutions that help increase energy available in their chosen ecosystem.
4. Students decide on how they might collect their own data in the field and design protocol for collecting data either at school, at home, or while at Fermilab.
5. Students conduct both classroom and field-based research, collecting data that supports the answer to their question and contributes to their solution. They should work through unexpected variables to collect data in field-based research and remember that the lack of data is data!
6. Students maintain a science journal to record findings, sketch, create models, record ideas, and write down other questions they have.
7. Students make a recommendation for a solution that would add to increased energy within their ecosystem.

Ecosystem Services Research Component - Climate Regulation

Topic: How restoring natural ecosystems can help with climate regulation

Brief Lesson/Lesson Set Description:
Students will ask a question that can be answered through research. They will design and implement a plan to solve school site problems with the creation of a restored ecosystem (prairie, woodlands, or pond).

Performance Expectations:
ETS 1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

ESS2-4. Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and force of gravity.

Assessment:
Find the Developing and Using Models rubric to progress monitor students' growth through the practices. Find Science and Engineering Practices rubrics in the *Introduction* section.

Objectives:
The students will:
- Identify a question about how restored ecosystems can help solve ecological issues.
- Research the question.
- Develop a solution to help contribute to a solution and an implementation plan.
- Communicate conclusions.

Narrative/Background Information:
Student-generated questions foster the inquiry-based platform integral to world-class platform integral to world-class science education. Field-based learning differs from lab-based research in that it is difficult, if not impossible, to control some of the variables.

Field-based research focuses on data collected for an ecosystem over a period of years. In the field, the problem becomes "messy." Without the ability to create controls, a variety of factors can contribute to a situation. Designing research questions takes considerable thought. While students can easily gather data from within their classrooms, if it is possible to provide the unique experience of a field study, it is encouraged.

This activity can easily incorporate all disciplines within the middle school. Research questions can also be differentiated and accommodate all styles of learners.

Encourage students to think about their interests and to spend time brainstorming potential questions before they settle on a topic to investigate.

Possible Preconceptions/Misconceptions:
Students may need direction on how to ask scientific questions that can be researched, how to collect data if conducting field research, and how to analyze that data once it is collected. Mini-lessons on how to conduct research, collect data, make sense of that data, and how to use the findings as support for an argument, could be done throughout student work.

Process:

1. Students that are interested in the topic of climate regulation are encouraged to brainstorm questions that can be researched and produce data that could contribute to solutions that help increase the likelihood that increasing the amount of a restored ecosystem around a school will result in a better "school climate." After choosing which ecosystem should be restored on the grounds of the school, students should identify the benefits—looking at how the ecosystem restoration project will help regulate the climate yearlong.
2. Students use the *SIMply Prairie* website as well as other sites to search for longitudinal data that has been collected on their question. http://ed.fnal.gov/data/life_sci/prairie/
3. Students choose a research question and revise it based on what they have learned from exploring the database. Be sure their question provides information that can contribute to solutions that help regulate climate in their chosen ecosystem.
4. Students decide on how they might collect their own data in the field and design protocol for collecting data either at school, at home, or while at Fermilab.
5. Students conduct both classroom and field-based research, collecting data that supports the answer to their question and contributes to their solution. They should work through unexpected variables to collect data in field-based research and remember that the lack of data is data! Fieldwork may be able to be conducted throughout the year as an ongoing project.
6. Students maintain a science journal to record findings, sketch, create models, record ideas, and write down other questions they have.
7. Students make a recommendation for a solution that would add to a better "school climate" in their schoolyard.

Field Research

Question: How do abiotic and biotic factors work together to restore diversity, promote productive interactions/relationships, and provide ecosystem services?

Brief Citizen Scientist/Naturalist Research Component Description:
Citizen naturalists choose to make a difference in the natural world. Middle level students bring with them an innate interest in nature, but all too frequently have substituted indoor activities for outdoor exploration. These research investigations offer students opportunities to not only become more familiar with natural areas, but also to contribute to the knowledge base of career ecologists by contributing data and observations to ongoing studies.

Fermilab ecologists propose sample ecosystem questions, but students are encouraged to delve into the topics presented in the curriculum and generate questions of their own. These research options are supported by Fermilab's robust historic abiotic condition and prairie plant databases. Additional species data is available for wetlands and woodlands on the Fermilab campus, but not to the extent of prairie data.

Challenges for the students include:

- Add to the organism databases.
- Propose pertinent research questions
- Suggest solutions to problems that span natural areas at Fermilab and throughout Northern Illinois.

What is field research?
Field research is informally defined as any scientific investigation, data collection, observation and/or analysis that takes place beyond the laboratory. Within the realm of ecology, this includes exploring natural areas for the purpose of studying relationships between living organisms and the natural environment. Through field studies, ecologists learn more about how adaptations promote survival, what happens to ecosystems over time in varying circumstances, how energy is exchanged, whether an area has adequate biodiversity, and so much more.

Field research differs from laboratory research primarily because abiotic factors and the mobility of some organisms cannot be controlled as they can be in the laboratory. For these reasons, ecologists control only what they can—protocol. Field ecologists establish rules to which they must abide for the duration of the study. For example, in 1992 when Fermilab's *Particles and Prairies* middle level curriculum was launched, it was decided that species studies would be conducted using a quadrat. The quadrat rules are itemized within the three quadrat-related investigations: *Estimating Percentages, Quadrat: Lawn Study,* and *Quadrat Study*. The first two are skill builders. The final quadrat study takes students into the ecosystems.

This rich, Fermilab student prairie databank, dating back to 1992, is grounded in the quadrat protocol. To change it in 2016 would dilute the reliability of prior data, so this

method remains the mainstay of the species sampling for the ecology program. Other sampling methods including transect lines and circuits are common and may be used to augment the quadrat, but the data collections are not commingled.

The *Energy and Ecosystems: Prairie, Water and Woods* unit is now expanded, which not only includes prairie plants, but also prairie invertebrates as well as plants and invertebrates in and around wetlands/ponds and woodlands. Data collected in 2016 and beyond will enrich the work of Fermilab's ecologists as they continue to study seasonal trends, measure biodiversity using the Floristic Quality Index (FQI; see *Resources*), and engage in restoration and maintenance of the natural areas on the Fermilab site. Student contributors to this database are playing a role in the ongoing sustainability of these natural areas.

Included in the Field Research Set are *Abiotic Factors, Water Quality, Quadrat Study/Insect Observation, Bumblebee Watch and Floristic Quality Index (FQI). Photosynthesis* is a modified research investigation utilizing a computer program. Further information about all these topics plus lab-based photosynthesis opportunities are available in *Resources*.

Why do we care?
The natural world is not simply an outdoor area. It is diverse, dynamic and offers tremendous benefit to humanity in the form of *ecosystem services*. As defined by Dr. Robert Costanza, 1997, ecosystem services include the important benefits for human beings that arise from healthily functioning ecosystems. These ecosystem services include:

- Gas regulation (including production of oxygen) – **MS-LS1-6; MS-LS2-3; MS-ESS2-4**
- Climate regulation – **MS-LS1-5; MS-PS3-4**
- Disturbance regulation (storm protection/flood control) – **MS-LS2-4; MS-ESS3-3**
- Water regulation – **MS-ESS2-4**
- Erosion control/sediment retention – **MS-LS2-4; MS-ESS3-3**
- Soil formation – **MS-LS2-3; MS-ESS2-4**
- Nutrient cycling** (storage, nutrient cycling, biochemical breakdown) – **MS-LS2-3**
- Waste treatment** (recovery of mobile nutrients and removal of xenic/toxic substances)
- Pollination – **MS-LS2-4; MS-LS1-8**
- Biological control (trophic dynamic relationships/keystone species) – **MS-ESS3-3**
- Refugia (habitat for migration/visiting species) – **MS-LS2-1; MS-LS2-2**
- Food production – **MS-LS2-1**
- Raw materials (biofuels) – **MS-LS1-6; MS-LS2-3; MS-ESS2-4**
- Genetic resources**
- Recreation*
- Culture*

*N/A within Next Generation Science Standards context

**Concepts beyond middle level

Understanding and appreciating ecosystem services is integral to Next Generation Science Standards and to the Fermilab middle level ecology program.

Prior Student Knowledge Expectations:
Students require practice in field research survey skills (provided in Set 1 activities); plant and animal (primarily invertebrates) identification skills; including practice in using field guides (provided in Set 2 activities); accuracy in recording data; and ability to critically look at data to recognize trends or otherwise interpret these data.

Next Generation Science Standards (NGSS) for the Field Research Set Possible Research Topics and Questions:

MS-LS1-4. Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of plants and animals respectively.

Topics*: Migration; monitoring which insects are seen when (aka blooming times); expand on seasonal flora in prairie, ecotone, understory of forest; spring forest plants are generally easier to identify; hummingbirds pollinate red flowers generally; moths pollinate night blooming flowers, bur oak bark thickness protects against fire, etc.*

MS-LS1-5. Construct a scientific explanation based on evidence for how environmental and genetic factors influence growth of organisms.

Topics: *Measure oak tree growth in seedlings and saplings in restored woodlands; percent seed production of flowers that are isolated versus in a core habitat of same species*

MS-LS1-8. Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.

Topics: *Birds avoid monarchs; viceroys mimic; plants are insect-pollinated (don't forget about wind pollination too); bison eating grass, elk and deer preferring to eat native legumes; effects on pollination, reproduction; moths at night; bees see UV light; flowers of blue and purple and white are colors that attract and guide the bees.*

MS-LS2-1. Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.

Possible Research Questions Posed by Ecologists:

- *What is wildlife response to plant community restoration in a given area?*
- *Is oak sapling regeneration limited by the amount of light or by deer browse?*

Topic: *Inherent in the data collection are many opportunities to relate to resource availability.*

MS-LS2-2. Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.

Topics: *Practically apply prior research data on prairie vs. abiotic data provided by Fermilab to recognize trends and suggest cause/effect; suggest/predict future trends; effects of human interventions positive or negative; compare burn history of prairie tracts with floristic quality data over time; positive correlation or not?*

MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

Possible Research Questions Posed by Ecologists:

- *How do current plant species surveys differ from Plot 16B and Eola Road grasslands?*
- *How do archived plant species surveys from Plot 16 collected 5, 10, 20 years ago differ from the Eola Road grasslands?*
- *How do grassland/prairie burns affect subsequent years' FQI rankings for the same plot?*
- *Considering the archived data from an ecosystem, propose ways to increase diversity in the area. Support your proposition with scientifically based explanations.*

Topics: *Effect of restoration in natural areas, particularly woodlands; invasive species control; prescribed burning; native seed enrichment. These topics are best studied over time. NOTE: Water is highly controlled at the Lab, so this is probably not a viable topic.*

Review your lists of biotic and abiotic disturbances in Midwest ecosystems. Include climate, fire, grazing, tree fall, flooding, tornado, insect outbreaks, pathogens, invasive species, etc. Drought helped shape prairies.

MS-LS2-5. Evaluate competing design solutions for maintaining biodiversity and ecosystem services.

Topics: *Long range suggestions for continual restoration and sustainability of natural areas; ongoing monitoring and suggestions for mediation in the wake of specific abiotic and/or human activity*

MS-ESS 2-4. Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and force of gravity.

There are three significant watersheds on site. Feel free to utilize and understand them. (See Fermilab Watersheds in *Resources* section.)

MS-ESS 3-3. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

Topics: *Any native plant refugia on any of the 90% of private land in Illinois is a good thing; schoolyard prairies or other ecosystems qualify; does a teacher have a school site parcel from the past that could be used as monitoring projects?*

MS-ESS 3-4. Construct an argument supported by evidence for how increases in human population and per capita consumption of natural resources impact Earth's systems.

Topics: *Review population growth across Illinois since settlement and compare that with rate of tallgrass prairie loss over the same timeframe; highlight why we care about natural ecosystems; tie in with data on prairie plants and carbon sequestration. (This is an advanced option; carbon sequestration is a means by which some believe humankind can slow down the accumulation of marine and atmospheric greenhouse gases, which are released by fossil fuels.)*

MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

Topics: *There is considerable research on stream restoration and re-meandering; planting natives along shorelines, riffles and weirs, riparian corridor restoration, agricultural grass buffers along streams and grassed waterways; look up the goals of the Federal Conservation Reserve Program.*

MS-PS3-4. Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.

Topics: *Think of the concrete jungle and heat island effect vs. prairies and local-level cooling of air temperature; soil microbes are stimulated by O_2, but many don't thrive in waterlogged environments; water is a buffer to heat; microbes are probably most active in warm, moist environments; heat transfer, soil formation, nutrient cycling*

Abiotic Study

How do abiotic factors affect biotic factors in an ecosystem?

Topic: A study of the nonliving components of an ecosystem

Time Needed: Onsite Field Experience

Brief Lesson/Lesson Set Description:
Students will compare the environmental (weather/climate) and soil conditions of the prairie, forest or woodland, and a pond area. Following the field experience, students will use historical Fermilab abiotic data to observe weather trends.

Science and Engineering Practices: Planning and Carrying Out Investigations; Analyzing and Interpreting Data

Crosscutting Concept: Cause and Effect

INVESTIGATION

Objectives: Students will:

- Cooperate within a team to record data accurately.
- Analyze and interpret data to provide evidence for how environmental factors influence the growth of organisms.
- Predict the abiotic trends of each ecosystem visited; revisit these predictions following the field experience, and use evidence to explain the accuracy of the predictions.
- Considering soil as a natural resource and using firsthand and researched data, draw conclusions regarding the dramatic shift from prairie to farming in Illinois.
- Draw conclusions based on evidence about why plants grow where they do.
- Construct an argument supported by empirical evidence that changes to the physical or biological components of an ecosystem affect populations.

Narrative/Background Information:
The term *abiotic* refers to a nonliving factor in an environment; e.g., light, water, temperature, etc. Some ecosystems separated by elevation, distance, and/or geographical elements are expectedly different. For example, the abiotic conditions of an ocean shore differ significantly from that of tundra on a mountain. These different ecosystems have very different environments, and the organisms living at these sites have adapted to the environment.

However, it is possible for ecosystems in close proximity to experience different abiotic conditions. Prairie remnant and restoration ecosystems, especially since the mid-1800s when most of the prairie fell to the settlers' plows, often exist in very close proximity to other ecosystems such as woodlands, forests and ponds. In this case, many abiotic

factors such as the amount of rainfall are remarkably similar. Yet, these ecosystems are, in many ways, dissimilar.

The organisms living in the ecosystems are evidence of this dissimilarity. In the prairie, different plants bloom from mid-spring through the fall. In the forest next to the prairie, we primarily observe early spring wildflowers. The plants found in these two ecosystems are different even though the two ecosystems may be right next to each other. Why is this? There must be reasons why the two ecosystems contain such different plants. In this study, the students collect the abiotic data that might help explain these differences.

Soil Building (See also *Life in a Log – Soil Structure.)*
One important abiotic factor in an ecosystem is the soil. Therefore, students should know about how soil is formed. The land areas of the earth once were primarily barren rock with no soil cover. Winds, rains, ice (glaciers), and water constantly acted upon these exposed rocky masses. The rocks began to break down. When the first land plants (pioneer plants) moved onto the land, they were small and adapted to hold onto rock surfaces. The weathering actions of the physical forces along with the chemical influences of the early plants continued the breakdown of the rocks; plants died and their bodies added nutrients to the soil in the making that gave it some of the properties we look for in productive soil. After a long period of time, all of these forces produced soil pretty much like the soils of today. Soil building is still going on in many places, and some aspects of the process can be observed.

Mosses and lichens were among the first pioneer plants, though any plant that makes way for an ecosystem may be considered a pioneer. Mosses and lichens are adapted to living on rock surfaces, and they contribute to the disintegration of the rocks over long periods of time as part of the soil building. You can find exposed rocks or boulders in wooded areas and adjacent places. Many will already have begun to break down and will have lichens and mosses attached as well as some other plants that managed to find a place to grow in a tiny crevice or in an accumulation of materials in a depression or cavity on the rock's surface. The nature of the nutrients, including the minerals found in the soil, is a key to the types of plants that will find success in that area.

Soil building, even when promoted by the action of plants, is dependent on abiotic conditions. Wind, temperature, water, and sunlight all contribute to the abiotic nature of an ecosystem. In this activity, students examine some of the qualities of the soil as well as weather information in an effort to understand the qualities that contribute to a healthy ecosystem.

Water-Holding Capability (See also *Life in a Log – Soil Structure.)*
Soil is a major reservoir of water needed by organisms. Depending on the soil composition, its structure enables it to hold enormous quantities of water that fall as rain or snow. Soils differ in their ability to hold water. The texture of the soil also depends on the soil's composition. Though many substances make up soils, there are only three primary soil textures: sandy (small inorganic particles of rock and minerals), loam

(primarily organic products of decomposition), and clay (extremely tiny particles of inorganic material).

The soil percolation test demonstrates the water-holding capacity of the soil in a particular area. It is advisable, when practical, to select several sites in the immediate area around the test site. Areas that consistently dry out faster generally have a different plant species than areas that are typically wetter.

Combination soils with all three textures and plenty of loam, along with their plant cover, can absorb and hold much more water than extremely sandy soils. Clay can be nearly impervious to water and is effectively used as a natural base for landscaped ponds. Soil that is primarily clay will not support the same plant populations as soils containing a significant portion of loamy soil.

See the activity *Soil Texture* for a “down and dirty” soil texture experience.

Soil Chemistry (Optional)

The soil pH is very important to the plants of any ecosystem because proper pH determines which nutrients will be soluble and, therefore, available to the plants. This is because plants can only take in nutrients that are dissolved in water. If the pH is wrong, then a nutrient might be present in the soil but not dissolved in the water around the plant and therefore cannot be taken in by the plant. At or near 6.7, the nutrients most plants need are soluble and, therefore, available. However, some plants such as certain coniferous trees that require more acidic (lower pH) conditions thrive in a soil pH that is lower than 6.7 while other plants require a slightly higher pH; pH extremes are typically lethal to living organisms.

The soil supplies the needed nutrients for the plants in both forest and prairie ecosystems. Unfortunately, the Fermilab prairie, like most modern prairies, is not a virgin prairie with the thick rich soil common to prairies of the past. This area had been farmed for many years, thus altering the soil. Before the emergence of agriscience, farmers did not know that the soil nutrients would eventually deplete. Today, modern farming methods replace nutrients that once were naturally returned to the soil by the prairie organisms.

Three of the most important nutrients for good plant growth are nitrogen (N), phosphorus (P), and potassium (K). Nitrogen is essential for proper plant cell metabolism and protein formation. Nitrogen gives plants their dark green color and helps the growth of leaves and stems. Phosphorus is a soil nutrient responsible for the formation of healthy roots. Phosphorus also encourages the blooming of flowers, seed formation, resistance to disease, and helps the plant withstand weather extremes. Potassium is a soil nutrient that stimulates flowering and helps produce sugar and starch during photosynthesis.

Soil contains microorganisms, decaying organic matter, earthworms and other insects. Soil is a living environment. The earthworms and insects aerate the soil and add to the organic matter of the soil through their waste and when their bodies decay.

Dirt is basically dead soil. It does not contain any of the above. You can add organic matter (compost) to dirt to revitalize it. The organic matter will provide food for beneficial microorganisms so that the ecological system can regenerate.

Prior Student Knowledge Expectations:

- General understanding of soil structure (Connection: *Life in a Log – Soil Structure*)
- Ability to utilize measuring methodology (Complete *Measure Up!* activity.)
- Willingness to take time and work accurately to collect complete data sets
- General understanding and acceptance of collaborative behaviors

Possible Preconceptions/Misconceptions: Students may believe that:

- Abiotic conditions within an area are generally the same. (Stepping into a woodland or forest from a prairie can yield dramatic differences, especially if it is a sunny day.)
- Abiotic conditions are generally the same from year to year within a season. (Studying archived weather data from the Fermilab website shows temperature and precipitation trends that tend to change often from year to year.)
- Abiotic factors are key to soil building.
- Soil is soil—essentially the same within an ecosystem.
- Fertile soil from different parts of the world has different essential components and all are dependent in large part on abiotic factors for its structure. (Fertile soil capable of growing plants all has the same essential ingredients—living organisms, nutrients from decomposition, minerals from rock structures, moisture (water), and organic by-products.)
- Soil is DIRT! In fact, dirt is depleted soil.
- Soil is a nonliving substance. (Soil is very much alive, teeming with microorganisms and invertebrates.)
- Soil remains soil over vast periods of time. (That depends on what is grown. Natural areas tend to replenish themselves, but areas that are farmed or landscaped need diligent care to maintain.)

Vocabulary: abiotic, atmosphere, biotic, data, drought, eutrophication, forest floor, humus, infiltration, percolation, precipitation, radiation, transpiration, water cycle

Materials:

- Student data sheets
- For each group:
    - Thermometer
    - Wind gauge
    - Psychrometer
    - Light intensity meter
    - Soil moisture meter
    - Soil percolation tube

    - Water supply
    - Waste container
- Soil test kit with laminated instructions
- Stopwatch or wristwatch
- Meter stick
- Access to Fermilab historic weather data: http://www-esh.fnal.gov/pls/default/Weather.html

ENGAGE:
As field scientists, students experience taking data in various ecosystems.

EXPLORE:
Process: *At school prior to Fermilab field trip*

1. Determine whether you will include the optional soil experiences: *Soil Chemistry* (included in this activity) and *Soil Texture* (separate activity) on the school site. These options are NOT part of the Fermilab docent experience.
2. Familiarize the students with the processes of soil building as noted in the background section of this activity. Relate these processes to the abiotic factors influencing ecosystems.
3. Instruct the students in the use of the meters and gauges used in the activity by referring to student sheet provided in this activity.
4. Test for pH by making a mixture of a small amount of soil, adding water to almost fill the container. Cap the container and shake. Test with pH paper and compare to the pH scale.
5. Instruct students in data collection procedures as experienced in *Measure Up!* Emphasize accuracy and complete data records.
6. Encourage students to highlight or star particularly interesting data as they conduct their field study. These could be unexpected readings, readings that do not jive from trial to trial, or simply points of interest. Remind students to acknowledge human error.
7. Debrief, emphasizing that the data collected represents a very small sample. Encourage students to investigate long-term abiotic data on the Fermilab website at http://www-esh.fnal.gov/pls/default/Weather.html.
   Fire website isn't direct: http://www.fnal.gov/cgi-bin/ecology/burn and http://www.fnal.gov/ecology/map/fmadisplay.shtml?FILE=fmadata&ICOL=3&Scheduled

EXPLAIN:
Prior to the Fermilab field trip (or alternative field experience), instruct students to predict abiotic trends at all sites to be monitored. Bring these predictions to the field sites. After the field experience, ask students to compare their predictions with the actual readings. How do they compare? Students will offer explanations based on the field experience as to why they were accurate or not. As explanations emerge, misconceptions or inaccuracies will be evident.

ELABORATE:
Ecosystem services are the important benefits for human beings that arise from healthy functioning ecosystems (Costanza). A few selected relevant services are listed. Ask students to consider one of these services (a different service for each group) and describe a connection with their abiotic survey. How might longer-term data assist in the land management of these areas?

Consider:

- Gas regulation (production of oxygen) – **MS-LS1-6; MS-LS2-3; MS-ESS2-4**
- Climate regulation – **MS-LS1-5; MS-PS3-4**
- Disturbance regulation (storm protection/flood control) – **MS-LS2-4; MS-ESS3-3**
- Water regulation – **MS-ESS2-4**
- Erosion control/sediment retention – **MS-LS2-4; MS-ESS3-3**
- Soil formation – **MS-LS2-3; MS-ESS2-4**
- Nutrient cycling** (storage, nutrient cycling, biochemical breakdown) – **MS-LS2-3**
- Pollination – **MS-LS2-4; MS-LS1-8**
- Biological control (trophic-dynamic relationships/keystone species) – **MS-ESS3-3**
- Refugia (habitat for migration/visiting species) – **MS-LS2-1; MS-LS2-2**
- Food production – **MS-LS2-1**
- Raw materials (biofuels) – **MS-LS1-6; MS-LS2-3; MS-ESS2-4**

**Concepts beyond middle level

Web Links
Fermilab website: http://www-esh.fnal.gov/pls/default/Weather.html
Fire website isn't direct: http://www.fnal.gov/cgi-bin/ecology/burn and http://www.fnal.gov/ecology/map/fmadisplay.shtml?FILE=fmadata&ICOL=3&Scheduled

EVALUATE:
Formative Monitoring: Use Student Reflection questions for discussion throughout the investigation.

Summative Assessment: After enough practice, students could be assessed on how they analyze the data collected. Use Student Data Collection Sheet.

Elaborate Further/Reflect/Enrichment: Ask students how this data could apply to the work of a field ecologist.

Name: _____

Student Data Collection Sheet

ABIOTIC STUDY – General Abiotic Analysis

In the prairie and the pond, different flowers bloom from the spring through the fall. In the woodland next to the prairie, we often observe only the spring wildflowers. The plants found in these three ecosystems are different even though the ecosystems are close by. Why is this? There must be some reason why the three ecosystems contain such different plants. In this study, you will collect the abiotic data that might help explain the plant differences.

Factor	**Prairie**	**Woodland**	**Pond**
Temperature in Celsius			
1 meter above ground	_____	_____	_____
15 centimeters above ground	_____	_____	_____
Ground level	_____	_____	_____
5 centimeters below surface	_____	_____	_____
Wind	_____	_____	_____
Humidity	_____	_____	_____
Light Intensity	_____	_____	_____
Soil Moisture	_____	_____	_____
Percolation Test	_____	_____	_____

How did the diversity of the woodland, prairie, and pond compare? Where did you find more plant species in the same sized area? (Woodland, prairie, or pond?) Using your data, explain why you believe this phenomenon occurred.

Field Notes and response to prediction: Use the back of the page.

ABIOTIC DATA COLLECTION

Hypothesis – Prairie and Forest:

_____

_____

PRAIRIE

Prairie Atmospheric Conditions

	Site 1	Site 2	Site 3	Average
Relative Humidity	%	%	%	%
Wind Speed	mph	mph	mph	mph
Light Intensity*				

*For light intensity use A = 1, B = 2, etc. for averaging purposes.

Prairie Soil Conditions

	Site 1	Site 2	Site 3	Average
1 meter above	°C	ºC	ºC	ºC
15 centimeters above	ºC	ºC	ºC	ºC
Ground level	ºC	ºC	ºC	ºC
5 centimeters below surface	ºC	ºC	ºC	ºC
Soil moisture				

Soil Percolation: minutes per liter - Prairie _____

FOREST

Forest Atmospheric Conditions

	Site 1	Site 2	Site 3	Average
Relative Humidity	%	%	%	%
Wind Speed	mph	mph	mph	mph
Light Intensity*				

Forest Soil Conditions

	Site 1	Site 2	Site 3	Average
1 meter above	°C	ºC	ºC	ºC
15 centimeters above	ºC	ºC	ºC	ºC
Ground level	ºC	ºC	ºC	ºC
5 centimeters below surface	ºC	ºC	ºC	ºC
Soil moisture				

Soil Percolation: minutes per liter _____

Psychrometer Differential Table – Wet Bulb/Dry Bulb

Dry-Bulb Temperatures (^{0}C)	Difference between Wet-Bulb and Dry-Bulb Temperatures																			
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
0	81	64	46	29	13															
2	84	88	52	37	22	7														
4	85	71	57	43	29	16														
6	86	73	60	48	35	24	11													
8	87	75	63	51	40	29	19	8												
10	88	77	66	55	44	34	24	15	6											
12	89	78	68	58	48	39	29	21	12											
14	90	79	70	60	51	42	34	26	18	10										
16	90	81	71	63	54	46	38	30	23	15	8									
18	91	82	73	65	57	49	41	34	27	20	14	7								
20	91	83	74	68	59	51	44	37	31	24	18	12	6							
22	92	83	76	69	61	54	47	40	34	28	22	17	11	6						
24	92	84	77	71	62	56	49	43	37	31	26	20	15	10	5					
26	92	85	78	72	64	58	52	46	40	34	29	24	19	14	10	5				
28	93	85	78	73	65	59	53	48	42	37	32	27	22	18	13	9	5			
30	93	86	79	74	67	61	55	50	44	39	35	30	25	21	17	13	9	5		
32	93	86	80	75	68	62	57	51	46	41	37	32	28	24	20	16	12	9	5	
34	93	87	81	76	69	63	58	53	48	43	39	35	30	28	23	19	15	12	8	5

Name: _____

Student Reflection: Abiotic Study

1. Why do we find different species of plants living in these two ecosystems?

2. In the prairie the spring flowers are usually short followed by taller summer blooming plants and then very tall fall blooming plants. Why do you think this is?

3. In the woodland we do not find this layering effect of flowers to the degree that we do in the prairie; we often only find spring wildflowers. Why do you think this is?

4. How does the water-holding capability of the prairie, woodland and pond soils compare?

5. What are some possible reasons for these differences?

6. Was there any difference in the soil pH between our three ecosystems?
   If so, what was it?

7. If there was a difference, which ecosystem had a pH closer to the ideal?

8. High wind, low relative humidity and high temperatures all cause water to be lost from plants. In order to survive in an area like this, the plants must be specially

adapted. In which of our two ecosystems would we probably find more plants adapted to prevent water loss? _____

Explain your response.

9. Why do you think so few plants grow on the woodland floor?

10. Construct an argument supported by the data evidence you gathered to suggest that changes to the physical or biological components of an ecosystem affect populations. Share your points with the class. Are all in agreement? What aspects of the beliefs of others are acceptable to you and why?

11. Examine historic weather and fire data on the Fermilab website. How does your data support trends evident in the Fermilab database? Why is your class data less reliable?

12. At Fermilab, typically only the prairie areas are burned. What role(s) might fire play in the abiotic conditions on the soil in the Fermilab prairies?

Language Arts Common Core Connector

Think about your sensual observations of the abiotic conditions in the pond, woodland and prairie. With a partner, brainstorm your experiences and make a list of descriptive words for the plants in these ecosystems. Create a Haiku for the prairie and another for the forest using descriptors from your observations.

<u>Haiku</u>

- 3 lines of 5, 7 and 5 syllables
- Emphasis on syllables – NO RHYME

Example:

The deep, dark forest
Fragrant, humid air hangs low
Biting insects—SCRAM!

Teacher Page

Student Reflection Suggested Responses: Abiotic Testing

1. Why do we find different species of plants living in these two ecosystems?

   Responses will vary. Expect the student to relate abiotic factors and adaptations within the response.

2. In the prairie the spring flowers are usually short followed by taller summer blooming plants and then very tall fall blooming plants. Why do you think this is?

   Responses will vary. Expect the student to understand that this is an expected progression related to the blooming time of plants. Spring bloomers commit much energy to their early blooming schedules and typically do not grow as tall as the later bloomers.

3. In the woodland we do not find this layering effect of flowers to the degree that we do in the prairie; we often only find spring wildflowers. Why do you think this is?

   Responses will vary. Expect the student to include an understanding of the differences in the abiotic factors in the spring when the leaves are still buds as opposed to the summer when the leaves are fully developed. Consider also the canopy effect of the tree leaves shading the understory and woodland floor.

4. How does the water-holding capability of the prairie, pond and woodland soils compare?

   Responses will vary significantly depending on the amount of recent rain. Under the best of circumstances, the prairie soil retains water better than the forested areas at the peak of the season.

5. What are some possible reasons for these differences?

   Responses will vary. Expect the student to note the nearly impenetrable prairie root system (hard to push the device into the ground), comparative consistency of the prairie soil, and protection of the prairie soil from abiotic elements by the dense prairie plants.

6. Was there any difference in the soil pH between our two ecosystems? If so, what was it?

   Responses will vary.

7. If there was a difference, which ecosystem had a pH closer to the ideal?

   Responses will vary. Generally, the prairie soil' is closer to the 6.7 ideal pH.

8. High wind, low relative humidity and high temperatures all cause water to be lost from plants. In order to survive in an area like this, the plants must be specially adapted. In which of the ecosystems would we probably find more plants adapted to prevent water loss? _____

   Explain your response.

   The prairie forbs and grasses are more directly in contact with abiotic factors than the understory of the forest. Sunlight, wind, precipitation, and temperature extremes are more intense on forbs and grasses lacking the protection of trees.

9. Why do you think so few plants grow on the woodland floor?

   Responses will vary. Expect the student to relate abiotic factors such as lack of sunlight and wind for pollination to the lower diversity typically found in the woodland.

10. Construct an argument supported by the data evidence you gathered to suggest that changes to the physical or biological components of an ecosystem may affect populations. Share your points with the class. Are all in agreement? What aspects of the beliefs of others are acceptable to you and why?

    Responses will vary. Expect at least one example of an abiotic factor change and the specific cause/effect relationships between this abiotic factor and organisms.

11. Examine historic weather and fire data on the Fermilab website. How does your data support trends evident in the Fermilab database? Why is your class data less reliable?

    Responses will vary. Expect at least 2–3 connections to one factor based on student-generated and Fermilab data, understanding that the student data is very limited due to numerically small samples and human/instrument error.

12. At Fermilab, typically only the prairie areas are burned. What role(s) might fire play in the abiotic conditions on the soil in the Fermilab prairies?

    Responses will vary. Expect evidence that the student understands that when the prairie burns down, the soil level is better exposed to the warmth of the sun and direct effect of precipitation. (See *Fire Ecology*.)

Language Arts Common Core Connector
Think about your sensual observations of the abiotic conditions in the pond, woodland, and prairie. With a partner, brainstorm your experiences and make a list of descriptive words for the plants in these ecosystems. Create a Haiku for the prairie and another for the forest using descriptors from your observations.

Haiku
- 3 lines of 5, 7 and 5 syllables
- Emphasis on syllables – NO RHYME

Example:

The deep, dark forest
Fragrant, humid air hangs low
Biting insects—SCRAM!

Expect a degree of sophistication as determined by the teacher and communicated to the student prior to assigning this task.

Quadrat Species Sampling – Plants and Invertebrates

How do abiotic factors affect biotic factors in an ecosystem?

Lesson Number 3 in a Series of 3 (if completed in Set 1); also found in Research section

If completed within the Research section, note that skill builders, *Estimating Percentages* and *Quadrat Study: School Lawn*, are prerequisites.

Topic: Utilizing estimating skills, identifying plants, recognizing the relationship between specific plants, invertebrate and other animal populations and collecting data to indicate health of an ecosystem by looking at the biodiversity of an ecosystem

Brief Lesson/Lesson Set Description: ***(Connection to Fermilab Natural Areas)***
Students will engage in quadrat sampling, a land management surveying technique. Plants and animals, especially invertebrates, within a meter square will be observed, identified or categorized, and counted. Special note will be taken to establish relationships and interactions between organisms to identify adaptations and behaviors.

Species sampling is integral to the ongoing wellbeing of the Fermilab natural areas. After establishing a baseline of what exists in an ecosystem, ongoing monitoring is essential to assess the health and progress or decline of the area. Noting which species are evident in a study site from year-to-year and sometimes season-to-season enables researchers to predict future trends, enrich and/or take preventative measures as deemed appropriate. Longitudinal data is a critical component of land management. (See *Resources – Land Management* documents.)

Science and Engineering Practice: Using Mathematics and Computational Thinking

Crosscutting Concept: Scale, Proportion and Quantity

INVESTIGATION

Objectives: Students will:

- Investigate the floristic quality, species diversity and importance value of plants on a designated plot.
- Observe and record invertebrate activity on the plot.
- Interpret these data over time to draw conclusions about the progress of woodland, pond and/or prairie restoration as well as the affinity of specific invertebrates to specific plants. NOTE: Prairie data is available from 1992. Woodland, pond and invertebrate data will be available beginning in 2017.
- Write a concise summary of these findings.
- Apply these findings to other comparable restoration sites—recognizing that weather, fire and other abiotic factors influence the ecosystems.
- Determine past trends and speculate about future trends using current and historic data.

Narrative/Background Information:

Plants

The student quadrat studies on the Fermilab site were originally completed only in prairie sites. The prairie land presently on site at Fermilab is reminiscent of the original tallgrass prairie that once covered 400,000 square miles of the Midwest and around 40,000 square miles in Illinois. Currently, over 1,100 acres of prairie has been planted on the Fermilab site. This reconstruction process has been in progress since 1975. As prairie plants have been added, careful notice has been taken as to the progress and the succession of these plants. This survey has been accomplished via plot observation and by quadrat studies executed primarily by middle level students. The *Particles and Prairies* data began in 1992 and provides a wealth of information representing thousands of quadrats. Long-term data coupled with abiotic measurements is critical in determining trends. The quadrat sampling is now expanded to include woodlands, ecotones and pond species. Even sessile or slower-moving pond organisms can be surveyed using a quadrat method.

A quadrat is an area of predetermined size (Fermilab uses M^2), ideally selected randomly to avoid bias, which is used to survey the organisms within its confines. Plants, insects and other organisms may be recorded, noting abundance, surface area covered and/or any other data desired. Relationships and interactions between organisms are often revealed by careful observation of the quadrat.

One of the goals of the quadrat study is to determine the importance value of any given species. Importance value is calculated by considering the relative dominance + relative frequency + relative density. Importance value is not simply asking which organism is present in the greatest number; it involves much more criteria. For example, what if one organism is much larger than another or common only in one location? The importance value gives a more accurate picture of which organisms have the greatest impact. This information is critical when trying to predict future trends and better succeed in managing ecosystems.

Species diversity reflects how many different species are present. In a healthy natural area, we may find hundreds of different species. Restored natural areas can take a long time to approach this number. In time, maintenance methods and natural succession may increase the species diversity of native plants and invertebrates and decrease the diversity of invasive species. A common indicator of the maturity and health of a natural area is its species diversity. Quadrat studies help to quantify these trends.

Ecologists at Fermilab are especially interested in floristic quality or FQI. FQI (Floristic Quality Index) formula is: (mean of coefficients of conservation (C) of all the plants found) times (the square root of the number of species (N) in that area). Per Swink and Wilhelm ([1]Swink, 1994), the FQI is an indication of native vegetative quality for an area: 1–19 indicates low vegetative quality, 20–35 indicates high vegetative quality, and above 35 indicates “Natural Area” quality. FQI is the indicator used to measure the success of restorations on Fermilab.

[1]Literature cited: Swink, F. and G. Wilhelm. 1994. *Plants of the Chicago Region*, 4th ed., Indiana Academy of Science, Indianapolis.

***Refer to the Resources section for more information about the FQI and the formula used to calculate Floristic Quality Index and the importance of abundant data to establish a reliable ecosystem analysis.*

FQI is calculated in the same manner for prairies, woodlands and wetlands. The native mean C is also an indication of native vegetative quality. For the 2015 Fermilab prairie quadrats, with mean of C = 7.6, N = 47, there is an FQI = 52, which is considered diverse in native plants. As students collect data from woodlands and ponds, longitudinal data for those ecosystems will provide ongoing information to support these areas.

Invertebrates

As students collect plant data, they also will observe invertebrates within the quadrat. Notable specimens such as bumblebees, butterflies, dragonflies, etc., within close proximity to the quadrat may also be recorded as *observed*, but not counted with the data. (See Quadrat Invertebrate Data student sheet.) It is important to make careful note of which invertebrate is visiting specific plants. This relationship is integral to understanding the interactions within the ecosystem. It is also linked to biodiversity; the more diverse the plant community, the more diverse the invertebrate community.

The wings, legs and mouthparts of the invertebrate hold clues as to its niche. A leaf-chewing invertebrate has different adaptations than a predatory organism, most dramatically in the mouthparts. Invertebrates that feed solely on vegetation are primary consumers, dependent frequently on a specific plant, such as monarch butterflies and milkweed. Monarch larvae prefer the fleshy leaves of the milkweed plants and are often found on plants of the milkweed genus Asclepias. Interestingly, mature female monarchs subsist on a liquid diet, including nectar from many species of forbs, juicy fruits and even a picnic watermelon slice. Male monarchs have been known to absorb minerals through their feet in an act known as “mud-puddling.”

At one time, there were at least eight species of bumblebee species foraging on the Fermilab ecosystems. Tongue length plays a major role on which bumbles are found on specific plants. For example, only the long-tongued bumblebees such as *Bombus pennsylvanicus*, frequent the Monarda plant. The long tongue of this species can reach deep into the individual vase-like corollas of this forb. The short-tongued *Bombus affinis* prefers the centers of disc forbs like multiflora rose and sunflowers.

Invertebrates are critical elements in an ecosystem serving as pollinators, decomposers, nutrient providers, eliminator of pests, food for other organisms, and all-around fascinating critters. In the Fermilab ecosystems, invertebrates *native* to the area fulfill an important niche and are to be guarded. Unfortunately, exotic (non-native) invertebrates often are evident, notably the Asian beetle. This iridescent beetle causes tremendous damage to many plants, especially showy tick trefoil.

Other Organisms

Ecosystems are not composed only of plants and invertebrates. Fish and amphibians are present in the ponds, lakes and streams; reptiles, including a variety of snakes and turtles, are occasionally seen; birds adapted to wetlands, woodlands and prairies are prolific; and mammals abound, though all students may see is the evidence of their presence. Scat,

tracks, matted grass or browse lines imply deer in an area. Students should be aware and document indications that other animals have been in an ecosystem, remembering that many animals move from ecosystem to ecosystem depending on their needs. Deer, for example, hang out in woodlands during the heat of the day, graze and often bed down in the prairie, and drink where there is fresh water. All the organisms play specialized roles within the ecosystems. (See *Trophic Interactions and Food Webs* – Set 3.)

Abiotic Factors
Organisms, both plant and animal, are highly dependent on abiotic factors. As students collect biological data, they should also record as many abiotic details as possible, including but not limited to time of day, weather conditions, soil temperature and saturation level, light intensity, etc. (See *Abiotic Study* – Set 1.)

History
Many of the organisms found on a site are influenced by the history of the site. Is the plot a virgin site, in succession phase or fully restored? Much of the Fermilab campus was once farmland and homesteads. Prior to that period, it was mostly prairie. Historical information is available on the Fermilab website at http://history.fnal.gov/prehistory.html. (See resource *Fermilab: Past, Present and Future – Introduction.*)

Prior Student Knowledge Expectations:

- Complete *Estimating Percentages* and *Quadrat Study: School Lawn* from Set 1.
- Familiarity with the characteristics of the most common plants and invertebrates in the ecosystem
- Ability to use a field guide and/or key to assist in identification
- General understanding of collaborative behaviors

Possible Preconceptions/Misconceptions:

- Underestimation of the diversity in a flourishing ecosystem
- Unfamiliarity with the strength of the form vs. function factors/interconnections of organisms
- Underestimation of the importance of abiotic factors in the balance of nature

Vocabulary: canopy, estimate, percentage, quadrat, understory, FQI, niche

ENGAGE:
Students have prior knowledge gained from the estimating percentages and lawn quadrat activities. Ask students to share in their research teams what they feel might be the biggest challenges as they work in a natural ecosystem. How do they plan to overcome these challenges? After a brief discussion, show the video and ask students if the challenges they suggested need to be amended. How will they meet these challenges?
https://www.youtube.com/watch?v=sCs1d8GLzKU

Quadrat
This is a field experience involving identifying and counting plants within a meter square using scientific protocols; collecting and using data over time to recognize and predict trends.

This investigation may be completed in conjunction with the Invertebrate and Other Animals segment that follows.

Materials: (per student group)

- Meter square quadrat
- Meter sticks (at least 2)
- Small metric ruler
- Flora Field Guide
- Quadrat Data sheet
- 1 decimeter square
- Access to "Report Your Data: Find Your Teacher/Leader" on the Fermilab website: http://eddata.fnal.gov/lasso/quadrats/teacher-q3.lasso

Process:

1. Complete *Estimating Percentages* and *Quadrat Study: School Lawn* from Set 1.
2. Access the data collection link website and review data resources.
3. Familiarize students with the quadrat procedures found at http://ed.fnal.gov/data/life_sci/data/prairie_watch.html.
4. Students will work in groups of three or four. Prior to the lab, establish student roles. Assign one student as recorder, one as counter, and commission everyone to a collective effort to identify plants.
5. Proceed to a natural area site. Use a "random site generator" (hurled Frisbee, hat, etc.) to identify student quadrats. Open and place quadrat meter square tool on selected area.
6. If requested, students will carefully note invertebrates and their habits within their quadrat on the Quadrat Invertebrate Data sheet using available identification tools.
7. Using meter sticks and the following data sheets, students will map the location of the plants in their quadrat, drawing the most abundant first.
8. Once plants are drawn, students will use the meter sticks to get the exact location of each larger plant within the quadrat.
9. Before students complete the plant sheets, remind them to informally note on the Quadrat Invertebrate Data sheet any invertebrates on and around specific plants within the quadrat. Informally note also other animals and/or evidence of their recent presence. Organisms and/or evidence of organisms beyond the quadrat are notable as observations, but will not be part of the formal data.
10. Students will generate an accurate count for each plant present in their quadrat and record this on the code sheet. (This will be easy for the larger individual species; more difficult for the abundant species.) For very abundant organisms such as grasses, we count each soil surface clump as a separate plant. If there is simply too much to count this way, count a representative 1% section of your quadrat and multiply by the appropriate number of similarly covered sections as learned in the *Quadrat Study: School Lawn*.
11. Determine the percent cover for each plant species.
12. Enter into the computer the number of different species of plants found in the quadrat and the estimated percent cover. Repeat this procedure for the number of different non-native (weed) species found. The computer will use the class data and calculate the importance value and species diversity for each.

Invertebrates and Other Animals

Field experience involving identifying and counting invertebrates within a meter square using scientific protocols and collecting data to contribute to a database that will be accessed by students and ecologists in the years to come; observation of other animals by actual sightings and/or evidence helps students make inferences about relationships/interactions.

This investigation may be completed in conjunction with the quadrat study.

Materials: (per student group)

- Meter square quadrat
- Meter sticks (at least 2)
- Small metric ruler
- Invertebrate Field Guide/ID materials, including Common Insect Orders Guide
- Bug boxes and magnifiers
- Student sheets – Quadrat Grid; Quadrat Invertebrate Data; Other Animal Evidence
- 1 decimeter square
- Access to data collection tool on the Fermilab website: TBA

Process:

1. Complete *Estimating Percentages* and *Quadrat Study: School Lawn* from Set 1.
2. Access the data collection link website and review data resources.
3. Familiarize students with the invertebrate observation procedures found at TBA.
4. Students will work in groups of three or four. Prior to the lab, establish student roles. Assign one student as recorder, one as counter, and commission everyone to a collective effort to identify invertebrates.
5. Proceed to a natural area site. Use a “random site generator” (hurled Frisbee, hat, etc.) to identify student quadrats. Open and place quadrat meter square tool on selected area.
6. Students will note invertebrates and their habits in their quadrat on the Quadrat Invertebrate Data sheet.
7. Enter observations on other animals on the Other Animal Evidence sheet. Short essay questions may be completed back in the classroom.
8. Using meter sticks and the grid data sheet, students will map the location of invertebrates and/or animal evidence in their quadrat, noting the specific plant(s) they are visiting.
9. Students will attempt to get an accurate count for each insect order and other invertebrate and record this on the data sheet. Remind them to look under leaf litter above the soil.

EXPLAIN:

Encourage students to share plant/invertebrate/other animal sightings and/or evidence observations and the interrelationships perceived with other teams. Collectively, compare data and offer explanations for similar/dissimilar observations. Students working in the same ecosystem should compare data to make a generalization about the diversity in that ecosystem using the data from all samples.

ELABORATE:
Ecosystem services associated with this lesson:

- Disturbance regulation
- Water regulation
- Soil formation
- Pollination
- Biological control
- Refugia (safe habitat for organisms endangered or threatened)
- Food production
- Raw materials

How might ecosystem population and biodiversity studies relate to each ecosystem service?

EVALUATE:
Formative Monitoring: Students report their data at the conclusion of the activity, sharing successes and challenges, as each quadrat is different. The Student Reflection questions can be a driving factor in these discussions. It may be beneficial to project a picture of the quadrat or share the drawings so students can visualize the plant growth and learn from each other.

Summative Assessment: Based on your understanding of relationships and interactions, design a community based on your quadrat that could be self-sustaining. Make note of everything needed and the connections between each organism and abiotic components as well as to one another.

Elaborate Further/Reflection/Enrichment: What further questions do students generate? Research specific invertebrate/plant relationships; what form/function connection(s) are revealed? Based on your research, specifically what do you predict would happen if one or the other of these organisms disappeared?

Name: _____

Quadrat Study: Reconstructed Prairie

1 m^2 quadrat, scale 1 cm = 10 cm

Please do not remove meter sticks and quadrat marker until your docent has checked your work and initialed here. _____

Quadrat Number Assigned by Computer | |

School	Date	Teacher	Recorder's Name

Key	Prairie Plants	Number	%	Key	Invasive Plants	Number	%
	Prairie Grasses				**Invasive Forbs**		
	Big Bluestem			1	Black Raspberry		
	Indian Grass			2	Daisy Fleabane		
	Little Bluestem			3	Wild Carrot		
	Prairie Cord Grass			4	Sweet Clovers (tall)		
	Switch Grass			5	Yarrow		
				6	Curled Dock		
	Prairie Forbs			7	Common Ragweed		
A	Saw-toothed Sunflower			9	Ground Cherry		
B	Black-eyed Susan			10	Tall Goldenrod		
C	Compass Plant			11	Common Milkweed		
D	Prairie Dock			12	Clovers (ground)		
E	Wild Bergamot			13	Thistle		
F	Showy Tick Trefoil			18	Hairy Vetch		
G	Yellowish Gentian			19	Hairy Aster		
K	Culver's Root			27	Drummonds Aster		
L	Blazing Star			28	Dandelion		
M	Mountain Mint			30	Heal-all		
N	New England Aster			31	Evening Primrose		
O	Nodding Wild Onion						
P	Pale Purple Coneflower						
Q	Wild Quinine						
R	Rattlesnake Master						
S	Stiff Goldenrod						
T	Tall Coreopsis						
U	Purple Prairie Clover						
V	White Prairie Clover						
W	Rosinweed				**Unlisted Invasive Plants**		
X	White Wild Indigo			34	Unlisted Grass-Like		
Y	Yellow Coneflower			33	Unlisted Oval Leaf		
Z	Cup Plant			32	Unlisted Round Leaf		
b	Bush Clover			35	Unlisted Triangular/Pointed Leaf		
d	Compass Dock Hybrid						
f	Foxglove Beardtongue						
g	Golden Ragwort						
r	Balsam Ragwort						
	# of Types of Prairie Plants Found				# of Types of Invasive and Unlisted Plants Found		

Date _____ **Names:** _____

Weather _____

Quadrat Invertebrate Data Sheet

Type of Invertebrate (Name/Sketch/Describe)	**Location of Invertebrate** (On Plant - Name Plant/ On Ground/On Web/Etc.)	**Abundance**	**Interaction between Plant and Invertebrate** (Pollinating/Eating/Etc.)

Type of Invertebrate (Name/Sketch/Describe)	**Location of Invertebrate** (On Plant – Name Plant/ On Ground/On Web/Etc.)	**Abundance**	**Interaction between Plant and Invertebrate** (Pollinating/Eating/Etc.)

Student Team Data Sheet – Other Animal Evidence

What evidence of other animals did you note in your ecosystem? Based on evidence, what animals do you think were in the area? Use the back of the page if needed.

ANIMAL	EVIDENCE SKETCH/DESCRIPTION

List at least five relationships/interactions that you think brought the animals to your site.

1. _____
2. _____
3. _____
4. _____
5. _____

Use another page if necessary to complete this page.

Select the relationship/interaction that you believe is the most significant and explain why you believe this to be true.

_____

_____

_____

_____

_____

_____

_____

_____

What do you believe could happen to the ecosystem if this animal leaves the area?

_____

_____

_____

_____

_____

_____

_____

_____

Suggest a plan to help ensure ongoing health and biodiversity in your ecosystem based on your understanding of why ecosystem relationships/interactions are important. Evaluate all the plans, noting the most practical and effective parts of each plan.

_____

_____

_____

_____

_____

_____

_____

_____

Name: _____

Student Reflection: Quadrat Species Sampling – Plants and Invertebrates

1. If data has been collected at the Fermilab prairie, compare your class data with the data from 1992. What has stayed the same? What has changed? Why do you believe this is so?

2. If your data was collected at another natural area, how does the diversity compare with the existing prairie data? How do you explain your findings?

3. The natural world is filled with relationships and interactions. Which interaction(s) and/or relationship(s) did you witness? Why are those relationships important?

4. Comparing data from the prairie to prior years, how do you think the prairie ecosystem is doing this year? What could account for your findings? If you collected data from a woodland or pond site, how do you think that site looked 10 years ago? Support your response. [HINT: Check the Fermilab website for fire data (prairie), prevailing weather conditions, and/or evidence of other disturbance.]

5. Based on historic data, if you feel it was a more or less productive year than prior years, explain whether you believe it was due to environmental or genetic factors.

6. What were the abiotic conditions on the day(s) you observed and collected your data? How might these conditions have altered, deterred or enhanced your findings?

7. Consider your quadrat and mentally remove the most prominent organism. What do you think would occur within the first day? Month? Decade? Why would it matter?

8. Imagine that climate change boosts the average temperature each month over ten years by 3 degrees. What do you believe will happen to the existing organisms? Utilize historic data from the Fermilab website to support your claim.

9. Why do we care? What ecosystem services does the ecosystem you surveyed provide? Why are these services important?

Design a plan to use the relationships between plants and insects to promote a restoration project for the ecosystem you studied. Summarize your plan in several paragraphs.

Teacher Page

Student Reflection Suggested Responses: Quadrat Species Sampling – Plants and Invertebrates

1. If data has been collected at the Fermilab prairie, compare your class data with the data from 1992. What has stayed the same? What has changed? Why do you believe this is so?

   Answers will vary. Explanations should be supported with data.

2. If your data was collected at another natural area, how does the diversity compare with the existing prairie data? How do you explain your findings?

   Answers will vary. Explanations should be supported with data.

3. The natural world is filled with relationships and interactions. Which interaction(s) and/or relationship(s) did you witness? Why are those relationships important?

   Answers will vary. Correct identification of relationships is essential.

4. Comparing data from the prairie to prior years, how do you think the prairie ecosystem is doing this year? What could account for your findings? If you collected data from a woodland or pond site, how do you think that site looked 10 years ago? Support your response. [HINT: Check the Fermilab website for fire data (prairie), prevailing weather conditions, and/or evidence of other disturbance.]

   Answers will vary.

5. Based on historic data, if you feel it was a more or less productive year than prior years, explain whether you believe it was due to environmental or genetic factors.

   Answers will vary. Students should support their claim with evidence.

6. What were the abiotic conditions on the day(s) you observed and collected your data? How might these conditions have altered, deterred or enhanced your findings?

   Answers will vary. Students should include a variety of abiotic data points.

7. Consider your quadrat and mentally remove the most prominent organism. What do you think would occur within the first day? Month? Decade? Why would it matter?

Answers will vary. Explanations should be supported with data.

8. Imagine that climate change boosts the average temperature each month over ten years by 3 degrees. What do you believe will happen to the existing organisms? Utilize historic data from the Fermilab website to support your claim.

   Answers will vary. Explanations should be supported with data.

9. Why do we care? What ecosystem services does the ecosystem you surveyed provide? Why are these services important?

   Answers will vary.

Design a plan to use the relationships between plants and insects to promote a restoration project for the ecosystem you studied. Summarize your plan in several paragraphs.

Use agreed-upon criteria and media approach to support the communication of science concepts and ideas to the general public.

Airborne and Crawling Invertebrate Survey

How can biotic factors increase the likelihood of survival?

Topic: Invertebrate survey and observation

Time Needed: Onsite Field Experience

Brief Lesson/Lesson Set Description:
Students use sweep nets and field observation tools to capture invertebrates, observe, classify by order and count. The organisms will be released back into the selected ecosystem. Data charts may be debriefed in the classroom.

Science and Engineering Practices: Planning and Carrying Out Investigations; Analyzing and Interpreting Data

Crosscutting Concepts: Patterns; Scale, Proportion, and Quantity; Structure and Function

INVESTIGATION

Objectives: Students will:

- Identify some of the invertebrates native to the Fermilab ecosystems.
- Classify specific invertebrate species.
- Identify adaptations of invertebrates that help ensure their success in this environment.
- Appreciate the invertebrates' niche and its importance to the ecosystem.

Narrative/Background Information:
Flying and crawling invertebrates are vital to the success of ecosystems. They pollinate the plants, are a food source for many other organisms, and help eradicate unwanted species. The prairie can support an amazingly wide diversity of invertebrates. In fact, invertebrate diversity mirrors plant diversity to a great degree—the more different species of plants, generally the more different species of invertebrates.

With sweep nets, students will collect a tremendous number of invertebrates. Many are so small that, without the observation cloth, they might go unnoticed. It is interesting to note that many seemingly identical invertebrates are actually different species! For example, eight separate and distinct species of bumblebees forage on the Fermilab prairie as discovered during a field study:
http://ed.fnal.gov/help/prairie/Franzen/fnal_species.html.

Access http://www.earthlife.net/insects/six.html for an interesting, student-friendly website with a glossary of insect related terms.

Prior Student Knowledge Expectations:

- Basic vocabulary to describe stages of an invertebrates' life cycle
- General understanding of proper handling of invertebrates and the need for caution when trying to capture them for observation; recognition of the value of each organism within the ecosystem
- Ability to use field guides and collection/observation tools with care and respect
- Willingness to participate in the investigation unless known to have allergic reactions
- General understanding and acceptance of collaborative behaviors

Possible Preconceptions/Misconceptions:

- Many students are fearful of invertebrates, believing that all invertebrates can hurt them. In reality, few are a threat. Students should avoid trying to capture known stinging invertebrates.
- The abundance of the numbers and relative diversity of an ecosystem's invertebrate populations is staggering. Students likely have no frame of reference for the magnitude of this observation.
- Students may believe that invertebrates are expendable and that it does not matter if they are harmed. Some invertebrates are rare and/or fill a very specific niche. Care when handling or transporting organisms must be done with care and respect.
- Young invertebrates do not necessarily resemble the adult stage.

Vocabulary: niche, diversity, population, community, complete and incomplete metamorphosis life cycle stages, classification terms (See *The Key to the Keys.*)

Materials:

- Sweep nets
- Observation cloth
- Hand lenses
- Viewing boxes
- Insect Field Guides
- Student data sheets
- Optional – Field access to Internet – Insect Keys:
    - *Earthlife* – Very complete but requires careful reading and more sophisticated terminology http://www.earthlife.net/insects/orders-key.html#key
    - *Discover Life* website offers an easy to use pictorial key to identify the insect orders. http://www.discoverlife.org/mp/20q?guide=Insect_orders

Optional – Aspirator (To be done at school; DO NOT BRING TO FERMILAB.)

- Wide-mouth jars
- Acetone

- Cotton balls
- Glue
- Tissue

Responsibilities:
Docent:
- Provide equipment.
- Facilitate activity on field trip.

Teacher:
- Appropriate preparation
- Provide data sheet for each research group.
- Debrief after trip.

ENGAGE:
Field Experience – The investigation is the engagement.

EXPLORE:
Process:
- Students collect insects by making wide sweeps with nets, fanning out in several directions within an area.
- Grasping the center of the net to contain insects in the bottom, students carefully deposit collections on a white observation cloth.
- Examine the insects and record on the data sheet.
- Temporarily capture organisms in viewing boxes or magnifying lenses. (Inform students to resist the urge to focus light on the organisms, causing discomfort or death.)
- Use a key or field guide to identify unknown invertebrates.
- OPTIONAL: Make aspirators (killing jars), if desired, by attaching cotton balls with glue to the lid of a wide-mouthed jar, adding several drops of acetone to the cotton, tucking some tissue into the jar to keep wings intact, and collecting insects. (NOTE: Keep the lid tightly closed for several hours, as insects may revive if exposed to fresh air too soon.)

EXPLAIN:
Debrief data sheets, encouraging students to share specific adaptations noted that help the organism survive in its ecosystem.

ELABORATE:
Invertebrates provide much to an ecosystem. In fact, the ecosystem is dependent on them. How do invertebrates contribute to the following ecosystem services?

- Nutrient cycling** (storage, nutrient cycling, biochemical breakdown)
- Pollination – **MS-LS2-4; MS-LS1-8**
- Biological control (trophic dynamic relationships/keystone species) – **MS-ESS3-3**

- Refugia (habitat for migration/visiting species) – **MS-LS2-1; MS-LS2-2**
- Food production – **MS-LS2-1**

**Concepts beyond middle level

EVALUATE:
Formative Monitoring: Students report their data at the conclusion of the activity, sharing types, abundance, and adaptations of invertebrates observed. Student Reflection questions can be a driving factor in these discussions. It may be beneficial to share drawings so students can visualize the invertebrates and learn from each other.

Summative Assessment: Completion of student data sheet

Elaborate Further/Reflect/Enrichment: Students may wish to build an invertebrate collection for the classroom. For this project, consider researching invertebrates found in the area to establish target collection organisms and note the advantages of having these invertebrates as part of the ecosystem. Are there any non-native invertebrates present? How might these organisms be controlled by natural means? Determine the relative risk of using chemicals or means other than nature to keep unwanted organisms in check.
https://www.bing.com/videos/search?q=insect+sweep+net&&view=detail&mid=E20ECB1626C562D8693FE20ECB1626C562D8693F&FORM=VRDGAR

Make your own sweep nets from old tennis racquets, pillowcases and other easy-to-find materials. www.lostladybug.org/files/SweepNet09.pdf

Names: _____

Invertebrate Data Collection

Organism (Sketch/Describe)	Abundant (too many to count) Common (2 or more) Unusual (1)	Possible Identification by Order (Confirm ID if possible.)

Organism (Sketch/Describe)	Abundant (too many to count) Common (2 or more) Unusual (1)	Possible Identification by Order (Confirm ID if possible.)

Name: _____

Student Reflection: Airborne and Crawling Invertebrate Survey

1. What aspect of this field experience investigation surprised you the most?

2. Which organism appeared to be the most abundant? Why do you think this is so?

3. Describe the adaptations of your most interesting organism. How do these adaptations help the organism be successful in the ecosystem?

4. Considering this same organism, what do you believe would occur if suddenly this species disappeared from the ecosystem? Support your belief with a scientifically-based rationale.

5. If you were to describe this activity to your family, what would you say you would do differently next time?

Teacher Page

Student Reflection Suggested Responses: Airborne and Crawling Invertebrate Survey

1. What aspect of this field experience investigation surprised you the most?

   Responses will vary. Expect such ideas as abundance, diversity, etc.

2. Which organism appeared to be the most abundant? Why do you think this is so?

   Responses will vary. Expect a logical rationale.

3. Describe the adaptations of your most interesting organism. How do these adaptations help the organism be successful in the ecosystem?

   Responses will vary. Students should look at appendages, including legs, wings, exoskeleton and especially mouthparts.

4. Considering this same organism, what do you believe would occur if suddenly this species disappeared from the ecosystem? Support your belief with a scientifically-based rationale.

   Responses will vary. Students should base the belief on information that is verified, as in a field guide or reputable web source.

5. If you were to describe this activity to your family, what would you say you would do differently next time?

   Responses will vary. Expect a logical, constructive change in process.

Pollinators and Consumers – CSI Ecosystem

How do abiotic and biotic factors work together to cycle energy through an ecosystem?

Topic: Adaptations and interrelationships between organisms

Brief Lesson/Lesson Set Description:
Students note the varied invertebrates in and around the quadrat or general area. They study the interrelationships between specific plants and invertebrates, focusing upon the structure/function and adaptations of organisms. (Suggested prerequisites: *Critical Attributes – Prairie Plants and Invertebrates* and *Adaptations*)

Science and Engineering Practice: Obtaining, Evaluating and Communicating Information

Crosscutting Concept: Structure and Function

INVESTIGATION

Objectives: Students will:

- Establish the niche of specific organisms in an ecosystem.
- Observe, collect, and report data pertaining to interrelationships of organisms noted in the ecosystem.
- Explain the nature of adaptations of these organisms.
- Evaluate the effectiveness of the structure to the function of organism attributes.
- Interpret data and utilize it to explain the natural relationships in the ecosystem.

Narrative/Background Information:
A typical native Midwest ecosystem often includes an immense diversity of organisms. Each organism occupies a unique ecological niche. This refers to the role played by an organism in a biological community including its food preferences, requirements for shelter, special behaviors, and the timing of its activities (e.g., nocturnal, crepuscular—active at twilight, or diurnal). The ecological niche of an organism has little to do with where it is found, but much more to do with its function or role (e.g., predator, consumer, decomposer) and how it performs that function.

Pollination, decomposition, and predation are necessary events in an ecosystem. The other residents of the ecosystem continually visit the plants. The most abundant group of organisms, as with virtually every ecosystem on earth, is the invertebrates. Invertebrates, specifically insects, are responsible for most of the pollination and often much of the foliage damage noted. In fact, at the hands (or mouths!) of herbivorous and carnivorous insects, the ecosystem can sometimes appear to us as sites worthy of a crime scene investigation (CSI)!

In order for plant reproduction to take place, pollen must be removed from the stamen's anther on one plant and introduced to the pistil's stigma on another plant, usually of the same species. Sometimes self-pollination occurs, but most plants require pollinators to perform this service. Wind and, to a much lesser degree, water are pollinators, but much pollination is dependent upon insects. Insects are also responsible for what may initially be considered detrimental. In order to maintain a healthy ecosystem, *native* insects do a certain amount of plant damage and some prey upon other insects. These acts are not purely destructive; rather, they are important in the maintenance of the ecosystem.

Because of the diversity of insects, the student will likely concentrate on bumblebees and butterflies as pollinators because they are generally more easily followed, realizing, of course, that many other insects are involved in this process. The observations of the insect consumers (herbivores and carnivores) will be generic. A general description of the consumer will be sufficient (i.e., spider, beetle, larva, etc.). Description of anatomical structure and function will focus on such observations as protective coloration, long tongues for collecting nectar from forbs such as *Monarda fistulosa* (wild bergamot) with deep corollas, or pollen sacs on bumblebee legs to gather pollen.

Students will focus on a wide variety of forbs and should be familiar with the primary ecosystem plants. Prior to taking students to the field, the Fermilab website database and visualization tools for prairie plants will prove helpful. (Woodlands and pond areas to come) http://ed.fnal.gov/data/life_sci/vis_tools/

This exercise can also be accomplished on an open field site near a school building with students observing insects on common flowers such as clover, dandelions, or garden flowers. Encourage students to describe organisms with pictorial as well as textual/verbal details.

The data collection table provided is designed to be a quick, simple way to record invertebrates in the field. Identification by order is sufficient for this exercise. (See Common Insect Orders Guide.) If students have access to digital cameras or cell phones, encourage taking photos for more precise identification.

Prior Student Knowledge Expectations:

- General understanding of what is meant by form/function and adaptations (See *Critical Attributes – Prairie Plants and Invertebrates* and *Adaptations*.)
- Recognition of some plants and invertebrates common to the ecosystem studied
- Ability to use observation skills and collect data within a short time frame
- Willingness to approach invertebrates with confidence
- General understanding and acceptance of collaborative behaviors

Possible Preconceptions/Misconceptions:

Diversity within the invertebrate world is typically underestimated. Encourage students to look closely at the Common Insect Orders Guide for a general grouping, but note also

distinguishing characteristics such as size, color, flight pattern, etc. ALL insects are capable of pollination regardless of niche. Some are more specialized for this task. NOTE: Students may express concern about observing invertebrates, especially insects such as bees and arachnids (spiders). The attitude of the instructors/chaperones is critical. Even stinging organisms are typically far more interested in foraging than bothering humans—provided they are not antagonized. Extra care should be taken and medication readily available if there is a participant with a specific allergy.

Vocabulary: diversity, pollinators, invertebrates, adaptation, abundance, consumer

Materials:

- Fermilab website access (Preparation – Identifying ecosystem plants)
- Field guides
- Common Insect Orders Guide
- Clipboard
- Data sheets
- Pencils with erasers
- Watch with second hand or stopwatch
- Insect medication if allergic to specific insect bites
- Perseverance, energy, and PMA (Positive Mental Attitude)

ENGAGE:
Ask students to envision a natural setting and name a few invertebrates that might inhabit the area. What is that organism's niche? Watch *The Beauty of Pollination*.
http://www.youtube-nocookie.com/embed/xHkq1edcbk4?rel=0

EXPLORE:
Process:
Pre-Lab

1. Prior to field experience, students should design a research question and develop hypotheses for an informal research question such as the following:
    - Will pollinators tend to visit only one kind of flower, or several different species? (Conclusion: If so, what are these relationships and what structural adaptations are evident?)
    - Will a favored forb (showy flower) have specific features that make it more attractive? (Conclusion: If so, what are the structure and function of these characteristics?)
    - Will you see evidence of any animals eating or, in any way, damaging plants in the ecosystem? (Conclusion: If so, what occurred and what adaptations are utilized?)
    - Will you see evidence of any animals eating or, in any way, damaging other animals in the ecosystem? (Conclusion: If so, what occurred and what adaptations are utilized?)
    - *Solicit additional questions from students*. Facilitate adoption of additional questions by confirming that they are researchable. Formulate conclusion prompts accordingly.

2. Ask students to individually contemplate their hypotheses to each question and write them down on Data Sheet 1. (The conclusion segment will be considered after the analysis of field research data.) Explain that different teams will research different questions and debrief findings to the class.
3. As a class, discuss hypotheses. Use newsprint or some other permanent method to record individual thoughts and, where indicated, class consensus.
4. Remind students that at the end of the exercise, they will use their data (and data collected by classmates) to draw conclusions as part of their post-lab debriefing.

Lab Field Experience

1. Assign students to research groups of 3–4 students.
2. Assign (or have students design) a question to investigate from the previously suggested list.
3. Instruct students to design a plan for observation and data acquisition and divide observation and data collecting tasks within their group. (NOTE: It is best to encourage a plan that does not involve movement beyond a relatively small area.) Suggested roles may include:
    - Organizer (project manager, timekeeper, quality control, etc.)
    - Recorder (Record data in an appropriate manner.)
    - Reporter (Present data for class debriefing.)
    - Artist/Interpreter (Draw or otherwise interpret data, assist recorder and reporter.)
4. Visit the ecosystem and collect data.
5. Instruct students to complete Data Sheet 2.

Post-Lab

1. Present the list of hypotheses from pre-lab experience. Re-establish which student research groups will present each set of data and instruct teams to prepare data for debriefing.
2. Compare data collected with the pre-lab hypotheses.
3. Debrief as a class. (Process data collected for hypotheses from pre-lab and establish trends; note observations from other teams, and note sources of error.)
4. Analyze data from all sources and compose conclusions. (NOTE: This step may be class collaboration or an individual effort through which students will compile all data. Ask students to note all similarities and tendencies to construct class conclusion. Include all topics covered in these hypotheses. Consider sources of error.)

ELABORATE:

Invertebrates provide much to an ecosystem. In fact, the ecosystem is dependent on them. How do invertebrates contribute to the following ecosystem services?

- Nutrient cycling** (storage, nutrient cycling, biochemical breakdown)
- Pollination – **MS-LS2-4; MS-LS1-8**
- Biological control (trophic dynamic relationships/keystone species) – **MS-ESS3-3**
- Refugia (habitat for migration/visiting species) – **MS-LS2-1; MS-LS2-2**

- Food production – **MS-LS2-1**

**Concepts beyond middle level

EVALUATE:
Formative Monitoring: Use Student Reflection questions for discussion throughout the investigation.

Summative Assessment: N/A

Elaborate Further/Reflect/Enrichment: Consider the advantages/disadvantages of the lives of pollinators and consumers, select an insect, and write a story about a day in its life. Provide details about the insect's adaptations for survival.

Name: _____

Pollinators and Consumers – Data Sheet 1

Think about the kind of invertebrate life you may see in the ecosystem. What might these spiders, insects or other invertebrates be doing? How might they be affecting the plants and other animals around them? Take time to write a well-constructed hypothesis for each of the questions below. The data evidence will be collected in the field and conclusions will be considered at the end of the lab field experience.

Construct a research question of your own and ask your teacher for approval before you proceed. Follow the protocol noted below for your investigation.

QUESTION:

Hypothesis:

Data Evidence (Brief):

Conclusion:

Other research questions from which to select:

1. Will pollinators tend to visit only one kind of flower, or several different species? (Conclusion: If so, what are these relationships and what structural adaptations are evident? If no correlation is evident, why might this be so?)

Hypothesis:

Data Evidence (Brief):

Conclusion:

2. Will a favored flower have specific features that make it more attractive? (Conclusion: If so, what are the structure and function of these characteristics? If no correlation is evident, why might this be so?)

Hypothesis:

Data Evidence (Brief):

Conclusion:

3. Will you see evidence of any animals eating or, in any way damaging plants in the ecosystem? (Conclusion: If so, what occurred and what adaptations are utilized? If no evidence is apparent, why might this be so?)

Hypothesis:

Data Evidence (Brief):

Conclusion:

4. Will you see evidence of any animals eating or damaging other animals in the ecosystem? (Conclusion: If so, what occurred and what adaptations are utilized? If no evidence is apparent, why might this be so?)

Hypothesis:

Data Evidence (Brief):

Conclusion:

Name: _____

Pollinators and Consumers – Data Sheet 2
Data Evidence

DIRECTIONS: Determine whether your research question refers to pollinators or consumers (herbivores or carnivores) and record data in the appropriate section. Use the table format as a suggested model. Reconstruct on your own paper.

Pollinators

Research Question: _____

_____

Invertebrate	**Abundance** (1–2; 3–10; etc.)	**Forb(s) Visited**	**Adaptations Observed** (Include both plant and animal adaptations.)	**Sketch/Description** (color, patterns, etc.)
1.				
2.				
3.				

Use back of page to add more lines as needed.

Conclusion:

Consumers (Plant Damage)

Research Question: _____

_____

Invertebrate	**Abundance** (1–2; 3–10; etc.)	**Forb(s) Visited**	**Adaptations Observed** (Include both plant and animal adaptations.)	**Sketch/Description** (color, patterns, etc.)
1.				
2.				
3.				

Use back of page to add more lines as needed.

Conclusion:

Consumers (Predation)

Research Question: _____

_____

Invertebrate	**Abundance** (1–2; 3–10; etc.)	**Forb(s) Visited**	**Adaptations Observed** (Include both plant and animal adaptations.)	**Sketch/Description** (color, patterns, etc.)
1.				
2.				
3.				

Use back of page to add more lines as needed.

Conclusion:

Name: _____

Student Reflection: Pollinators and Consumers - CSI Ecosystem

1. Which original hypothesis was best supported? Which were rejected? Are you surprised? Why? Why not?

2. Suggest sources of error in the data collection process.

3. Considering all the invertebrates you noticed, were any NOT pollinators? Support your belief with evidence.

4. Which forb appeared to be most popular the pollinators? Why do you think this is so?

5. Were there any forbs not visited by pollinators at all? How might they be pollinated if not by insects?

6. Which pollinators are also consumers? Name them and indicate your evidence.

7. Explain how some consumers can be both detrimental (harmful) and helpful.

8. Can we survive without pollinators and/or consumers? Why or why not?

9. Decide whether you believe insects are good or bad for the ecosystem. Justify your response with data collected.

10. Considering all the data collected by your classmates, which invertebrate appears to be the most common? Why do you believe this is so? Note the plant(s) this organism visits. How would eradication of this plant or this invertebrate affect the ecosystem in the short and long term?

11. In what way(s) were your observations similar to a crime scene investigation (CSI)? Describe ways your student research teams modeled the strategies of a crime scene investigator.

Teacher Page

Student Reflection Suggested Responses: Pollinators and Consumers - CSI Ecosystem

1. Which original hypothesis was best supported? Which were rejected? Are you surprised? Why? Why not?

   Responses will vary. Expect specificity within the responses. Evidence should be clearly stated.

2. Suggest sources of error in the data collection process.

   Responses will vary. Expect specificity. Errors, human or otherwise, should be clearly reported.

3. Considering all the invertebrates you noticed, were any NOT pollinators? Support your belief with evidence.

   Responses will vary. Check to ensure that the evidence is noted on the data page(s).

4. Which forb appeared to be most popular with the pollinators? Why do you think this is so?

   Responses will vary. Check for logical rationale supported by data evidence.

5. Were there any forbs not visited by pollinators at all? How might they be pollinated if not by insects?

   Responses will vary. Ideas should note a logical rationale.

6. Which pollinators are also consumers? Name them and indicate your evidence.

   Responses will vary. Check to ensure that the evidence is noted on the data page(s).

7. Explain how some consumers can be both detrimental (harmful) and helpful.

   Responses will vary. Explanations should be logical and supported by evidence wherever possible.

8. Can we survive without pollinators and/or consumers? Why or why not?

Responses will vary, but students should be aware that pollination is a critical ecosystem service. Humankind may survive short term without pollination, but the long-term projection of life without pollinators is grim.

9. Decide whether you believe insects are good or bad for the ecosystem. Justify your response with data collected.

   Responses will vary. Check to ensure that the data evidence noted is on the student data sheets.

10. Considering all the data collected by your classmates, which invertebrate appears to be the most common? Why do you believe this is so? Note the plant(s) that this organism visits. How would eradication of this plant or this invertebrate affect the ecosystem in the short and long term?

    Responses will vary. Expect a logical rationale with data evidence.

11. In what way(s) were your observations similar to a crime scene investigation (CSI)? Describe ways your student research teams modeled the strategies of a crime scene investigator.

    Responses will vary. Expect a logical rationale with specific methodologies noted.

Aquatic Diversity and Water Quality

How do abiotic factors affect biotic factors in an ecosystem?

Topic: A study of the quality of water and the diversity and macroinvertebrates in an aquatic ecosystem

Time Needed: Onsite Field Experience

Brief Lesson/Lesson Set Description:
Students will judge the quality of a body of freshwater based on the macroinvertebrates collected and the chemical makeup of water.

Science and Engineering Practices: Planning and Conducting Investigations, Analyzing and Interpreting Data

Crosscutting Concept: Stability and Change

INVESTIGATION

Objectives: Students will:

- Identify aquatic animals and count the types (aquatic species diversity).
- Evaluate the relative water quality of a stream or a pond based on chemical and physical tests as well as species present (water quality).
- Recognize the correlation between the types of organisms found and the quality of the water.

Narrative/Background Information:
The question of water quality on the Fermilab site is of considerable interest to biologists, physicists, and ecologists. Water is of great importance to the physicists of Fermilab because it is the primary cooling source for computers, accelerators, and the Central Utility Building. The source of this water comes principally from precipitation that falls on the site that is then collected and contained in the Industrial Cooling Water pond system. In a normal year, precipitation accounts for approximately 78 billion gallons of water collected.
During periods of drought, additional water for the system may also come from other sources including groundwater collected from the NuMI tunnel, water pumped from Fox River, or a deep onsite well.

The water on the Fermilab site is cycled year-round and parts of the water system do not freeze. Cycling the water also helps the summer water temperatures to stay reasonably cool. However, an unnaturally warm environment sometimes exists in portions of the lab. This may promote eutrophication, a condition in still ponds, which results in an imbalance between plants and animals. Eutrophication generally is due to the natural aging process coupled with the addition of certain types of runoff. Unnatural warmth, fertilizers from surrounding farms, and industrial pollution are all contributing

factors. Higher goose populations result in elevated nutrient loads, which is also a concern.

Aquatic Diversity

While the geese are among the most widely recognized wildlife noted at Fermilab, hundreds (perhaps thousands) of other species, primarily invertebrates, thrive on site. Many of these are evident in the water system. Fish, crayfish, salamanders, and frogs are found sitewide. An examination of macrobiotics (organisms large enough to be seen by the naked eye) reveals a myriad of water-dwelling organisms collected in dip nets. An investigation of rocks just below the riffle (where water tumbles over an obstruction such as a rock or dam) reveals evidence of even more animal life.

A wide diversity of organisms generally indicates better water quality. However, the specific types present need to be considered because some organisms are more tolerant of pollution than others. The benthic species criteria that students use at Fermilab consist of four categories of organisms. Level I organisms demand a nearly pristine environment. Level IV organisms live in relatively impure waters. Most of the organism indicators found at Fermilab are in level II. Check out this website for information about benthic species and their importance to monitoring water quality. https://www.epa.gov/national-aquatic-resource-surveys/indicators-benthic-macroinvertebrates

The actual biomass or amount of living material may increase due to pollution, but the diversity generally goes down. An example of this phenomenon is extensive algae growth on a still pond. When algae get out of hand, other life forms cannot obtain essential nutrients, gases, and/or sunlight. Some organisms cannot survive and their decomposition may add to the distress of the pond. Regular monitoring of the living organisms in a water source is a reliable method to evaluate the quality of water in the system.

Water Quality

Chemical analysis is another way to monitor water quality. However, it reveals the chemical values for a system at only one place and time. The water collected on a particular day in the spring may not indicate a chemical imbalance or toxic condition that was present earlier. However, a change in diversity of species could be a sign of a problem. Chemical analysis generally includes many tests, among which the most common are dissolved oxygen, nitrate, phosphate, and pH level.

Oxygen enters the water through plant photosynthesis and by diffusion from the atmosphere. It is removed by animal and plant respiration and the decomposition of organic matter. The temperature, the amount of plant biomass, the depth of light penetration, the flow velocity, and the amount of organic material to be decomposed affect the amount of dissolved oxygen in a body of water.

High nitrate concentrations may mean pollution from fertilizers, sewage, animal waste, or the natural decay of dead organisms. At Fermilab, the adjacent farm fields and high

goose population increases the importance of monitoring the nitrate concentration. Nitrates and phosphates accelerate the eutrophication process. Nitrate levels indicating a concentration above 0.30 parts per million (ppm) is considered high and can contribute to excessive algae growth.

Phosphates enter the water from the same sources as nitrates. A phosphate concentration that exceeds an annual average of 0.015 ppm can contribute to excessive algae growth as well. If the reading is greater than 0.1 ppm, the water has probably become polluted from outside sources.

Most natural bodies of water capable of sustaining life have pH values ranging from 5.0 to 8.5. The water systems of Fermilab are generally within normal.

A Secchi disk is used to measure the turbidity of a body of water. The turbid waters decrease light penetration into water, thereby reducing the area available for submerged aquatic plants to grow. Lower Secchi disk readings would indicate very clear water and a small amount of suspended matter. Readings are used to compare light penetrations between different bodies of water or the same body over a period of time. There are no absolute “good” or “bad” readings.

Prior Student Knowledge Expectation:

- Quality observations are key when identifying macroinvertebrates; students should pay special attention to all body parts of the macros.

Possible Preconceptions/Misconceptions:

- Students often rush through the identification process and incorrectly identify organisms.
- Students are often confused by nymph and larva stages of macroinvertebrates. A life cycle mini-lesson on incomplete and complete metamorphosis would be beneficial.
- Students can be quick to think a water sample does not contain anything living. Students need to take the time to look at what is moving after their samples have been collected and pick through all the vegetation carefully.
- Students do not always read directions; this can lead to serious problems during chemistry labs. Students should be urged to read through all directions before following any of the steps.

Vocabulary: aquatic, complete metamorphosis, cycles, ecological niche, edge effect, entomologist, incomplete metamorphosis, larva, life cycle, metamorphosis, molting, parts per million, population, Secchi disk, sediment, species, turbidity, wetlands

Materials:

Macroinvertebrate Study:

- Aquatic Organisms Field Guide
- Student Aquatic Diversity Data sheet

- Sampling equipment, such as nets, trays, assorted containers
- Plastic tubs, white
- Magnifying lenses
- Eyedroppers
- Forceps
- Fermilab Site Map

Chemical Testing
- Water quality test kit
- Thermometer
- Meter sticks or tape measure

Responsibilities:
Docent:
- Provide equipment for collection.
- Provide all chemicals for water testing.
- Facilitate activity on field trip.
- Help students stay on task.

Teacher:
- Appropriate preparation
- Provide data sheet for each research group.
- Help students stay on task.
- Debrief after trip.

ENGAGE:
As field scientists, students have a chance to experience taking data in various ecosystems. Ask students to come up with their own protocol for different parts of this data collection and have them participate in a discussion on the safety guidelines when conducting fieldwork. Also, ask students to identify group members' strengths and assign tasks and leadership roles to each member of the group depending on those strengths. Most students have not been in the field and do not know what to expect.

EXPLORE:
General
- At each sampling site, it is necessary to constantly monitor students' behavior. Students are not to go into the water and any rocks that are examined should be returned to their original location.
- Ideally, these activities should be repeated at other sites or at different times of the year. At least one water source should be a running stream. If only one field trip site is feasible due to time constraints, a site near school might provide an interesting comparison.

Aquatic Diversity

- After placing about five centimeters of water into the plastic trays, students should collect as many animals as possible and place them into the trays. Look on and under rocks and logs. Some organisms will be attached to these substrates.
- Students should complete the Aquatic Diversity Data Collection sheet. Some of these data will not be available until they have completed the chemical test in the lab.
- When the observations are completed, all of the organisms should be carefully returned to the stream or pond.

Water Quality

- Water qualities will be done at the pond site guided by the docent.
- Follow the water test kit instructions precisely! Monitor the students closely.
- Students will have the opportunity to test the pH and the dissolved oxygen levels during lab time.

The movement of water within an ecosystem helps maintain high water quality. The pond at the Lederman Science Education Center is aerated to help prevent stagnation and improve the oxygen levels in the pond. This is not a natural condition. If a flowing stream is available for students to observe, they can measure water velocity in a more natural setting. To measure the water velocity, mark a ten-meter distance on the shore. Measure the amount of time it takes a floating object (small stick) to go the ten meters. With a sweep second hand, determine the exact time it takes the object to travel the ten-meter distance. Then divide ten meters by the number of seconds; this gives you the velocity of the water in meters per second.

EXPLAIN:
Students should be able to make a statement about the health of the studied body of water based on the variety, or lack thereof, of macroinvertebrates and the results of the water chemistry test.

ELABORATE:
Construct a food web with the organisms you identified. Make sure to have a producer.

EVALUATE:
Formative Monitoring: Student data collection sheet

Summative Assessment: After enough practice, students could be assessed on how they analyze the data collected.

Elaborate Further/Reflect/Enrichment: N/A

AQUATIC DIVERSITY DATA COLLECTION SHEET

Name_____

Hypothesis:

Water Temperature _____ **Air Temperature** _____ **Free Chlorine** _____

Total Chlorine _____ **Hardness** _____ **Alkalinity** _____ **pH** _____

Organism (Sketch/Describe)	Abundant (more than 10) Common (3–10) Sparse (1 or 2)	Possible Identification	Adaptations

Organism (Sketch/Describe)	Abundant (more than 10) Common (3–10) Sparse (1 or 2)	Possible Identification	Adaptations

Name: _____

Student Reflection: Aquatic Diversity and Water Quality

1. Did the sampling site(s) have a high or low degree of diversity? Justify your response.

2. A variety of different kinds of plants and animals are usually an indication of a healthy ecosystem. What evidence did you see that makes you believe your site(s) is a healthy (or unhealthy) environment for the living creatures in the area?

3. Do you think the diversity changes with the seasons? How could you find out?

4. Why are the ecologists concerned with water quality?

5. How might the water quality be maintained and/or improved?

6. If you notice abnormally high or low readings at your site(s), what explanation can you provide?

7. What strategies would you use to make the water at the site(s) a better environment for living organisms and/or maintain the existing health of the ecosystem?

You have just explored the aquatic diversity and water quality of a water system. Compile the data collected by your classmates and conduct further research on the Internet to discover more about water environments. Design a plan for maintaining and/or improving an existing water system such as a neighborhood pond or stream. Discuss the audience intended for your plan and how you would communicate this information and share your work.

Teacher Page

Student Reflection Suggested Responses: Aquatic Diversity and Water Quality

1. Did the sampling site(s) have a high or low degree of diversity? Justify your response.

   Responses will vary. Expect the justification to quantify the student's interpretation of "high" and "low."

2. A variety of different kinds of plants and animals are usually an indication of a healthy ecosystem. What evidence did you see that makes you believe your site(s) is a healthy (or unhealthy) environment for the living creatures in the area?

   Responses will vary. Expect a minimum of three details to justify the student's response.

3. Do you think the diversity changes with the seasons? How could you find out?

   Responses will vary. Some students may believe that, like migrating birds, invertebrates also retreat to warmer climates in the winter. Research suggestions such as winter macroinvertebrate studies or monthly stream monitoring may be offered.

4. Why are the ecologists concerned with water quality?

   Responses will vary. Students should understand that the water quality impacts other organisms—including humans!

5. How might the water quality be maintained and/or improved?

   Responses will vary. Expect specific, logical suggestions.

6. If you notice abnormally high or low readings at your site(s), what explanation can you provide?

   Responses will vary. Human error should not be discounted.

7. What strategies would you use to make the water at the site(s) a better environment for living organisms and/or maintain the existing health of the ecosystem?

   Responses will vary. Expect specific, logical justification.

You have just explored the aquatic diversity and water quality of a water system. Compile the data collected by your classmates and conduct further research on the Internet to discover more about water environments. Design a plan for maintaining and/or improving an existing water system such as a neighborhood pond or stream. Discuss the audience intended for your plan and how you would communicate this information and share your work.

Expect a degree of sophistication as determined by the teacher and communicated to the student prior to assigning this task.

Fermilab: Past, Present and Future

MS-LS1-4. Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of plants and animals respectively. (Set 3) Marginal depending on the depth students attain with the data analysis.

MS-LS1-5. Construct a scientific explanation based on evidence for how environmental and genetic factors influence growth of organisms. (Set 2) Marginal depending on the depth students attain with the ecosystem services.

MS-LS1-6. Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms. (Set 2) Marginal depending on the depth students attain with the ecosystem services.

MS-LS2-1. Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem. (Set 2)

MS-LS2-2. Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems. (Sets 1 & 3)

MS-LS2-3. Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem. (Set 2) Marginal depending on the depth students attain with the ecosystem services.

MS-LS2-5. Evaluate competing design solutions for maintaining biodiversity and ecosystem services. (Engineering Components) Marginal depending on the depth students attain with the ecosystem services.

MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions. (Set 3)

MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem. **Connect: MS-LS2-5** (Set 3)

Topic: History and land management

Brief Lesson/Lesson Set Description:
This is a three-part activity that includes all the Fermilab natural areas, but is most closely aligned with prairie since this ecosystem represents the richest organism database.

Part 1: Exploring the prairie from a historical perspective timeline, focusing on the reasons for and effects of human intervention.
Part 2: Identifying present-day natural areas and explore/understand the ecosystem services they provide on the Fermilab campus.

Part 3: Utilizing current databases to predict the future of the present Fermilab natural area ecosystems relative to the needs of the organisms and the work of a high-energy physics laboratory.

Science and Engineering Practices: Asking Questions and Defining Problems; Planning and Conducting Investigations; Analyzing and Interpreting Data; Engaging in Argument from Evidence

Crosscutting Concepts: Cause and Effect; Mechanism and Prediction

INVESTIGATION

Objectives:
- Develop an appreciation for the size and span of the original tallgrass prairie.
- Establish a timeline from glaciation to the present, explaining land management practices from the time of indigenous tribes to the contemporary Illinois.
- Compare the decline of the prairie to the restoration of the tallgrass prairie on the Fermilab site.
- Analyze present natural areas at Fermilab with consideration for lab growth and development utilizing a Fermilab site map with present land use noted.
- Predict the success of Fermilab's natural areas based on current databases, Floristic Quality Indices and recorded weather trends and controlled burns.
- Defend predictions using documented evidence.

Narrative/Background Information:
See Resources.
- *FQI Fermilab Sites*
- *Floristic Quality Index (FQI) Skill Builder*
- *Ecosystem Services – Students*

See Introduction.
- *Habitat Communities of Fermilab*

See Field Research.
- *Fermilab Land Management Map*
- *Fermilab Land Management*

Land management is defined as the process of managing for the use and development in urban, suburban and rural settings of land resources. Land resources are used for a variety of purposes beyond residential and commercial buildings. As a resource, land is essential to organic farming (preferred by the environmental community over commercial farming), reforestation and/or general restoration of natural areas, water resource management and eco-tourism. Appropriate land management is critical to maintaining ecosystem services.

Ecosystem Services: the important benefits for human beings that arise from healthy functioning ecosystems (Costanza; see Resources.) NGSS alignments included. NOTE: Student resource page with examples of benefits and no NGSS is provided.

- Gas regulation (Production of oxygen) – **MS-LS1-6; MS-LS2-3; MS-ESS2-4**
- Climate regulation – **MS-LS1-5; MS-PS3-4**
- Disturbance regulation (storm protection/flood control) – **MS-LS2-4; MS-ESS3-3**
- Water regulation – **MS-ESS2-4**
- Erosion control/sediment retention – **MS-LS2-4; MS-ESS3-3**
- Soil formation – **MS-LS2-3; MS-ESS2-4**
- Nutrient cycling** (storage, nutrient cycling, biochemical breakdown) – **MS-LS2-3**
- Waste treatment (recovery of mobile nutrients and removal of xenic/toxic substances)
- Pollination – **MS-LS2-4; MS-LS1-8**
- Biological control (trophic dynamic relationships/keystone species) – **MS-ESS3-3**
- Refugia (habitat for migration/visiting species) – **MS-LS2-1; MS-LS2-2**
- Food production – **MS-LS2-1**
- Raw materials (biofuels) – **MS-LS1-6; MS-LS2-3; MS-ESS2-4**
- Genetic resources**
- Recreation*
- Culture*

*N/A within NGSS context
**Concepts beyond middle level

Sustainable land management (SLM) refers to practices and technologies that aim to integrate the management of land, water, biodiversity, and other environmental resources to meet human needs while ensuring the long-term sustainability of ecosystem services and livelihoods. The term *sustainable land management* is used in regional planning and soil or environmental protection, as well as in property and estate management.

*Noidoo, R., Adamowicz, W. (2005). "Economic benefits of biodiversity exceed costs of conservation at an African rainforest reserve." PNAS **102** (46): 16712–16716.* http://www.pnas.org/content/102/46/16712.full

An environmental management scheme is a mechanism used by landowners and other individuals and bodies responsible for land management who are sometimes

incentivized to properly manage the natural areas. At Fermilab, designation as a National Environmental Research Park (NERP) opened the door to a broader view of land management and provided resources to improve the natural areas, keeping in mind the true purpose of the lab as a high-energy physics laboratory.

The ecology team at Fermilab is engaged in wildlife management, attempting to balance the needs of wildlife with the human needs on the Fermilab campus. In addition to serving as council as new projects are considered at Fermilab, this team monitors native species onsite and maintains a database with population number estimates and locations. Efforts are made to protect conservative (rare) species as well as promote the general health of the natural areas.

This effort includes regular monitoring of the deer population. In the late fall, winter and early spring, observation and counts are sometimes completed from the air. While an important primary consumer on the Fermilab food chain, the deer have few natural enemies onsite. Hunting on a federal complex requires special permits, which are occasionally recommended and strictly monitored to keep the deer population at a healthy level for the herd and the other species—including the humans who drive on the Fermilab roads.

Prior Student Knowledge Expectations:

- Basic vocabulary to describe and explain land management strategies and the impact on the environment
- General understanding of the aspects of ecosystems that help ensure sustainability and provide ecosystem services
- Ability to read maps, gather information from databases and extrapolate based on trends
- Willingness to dig deeply for information, form and defend opinions, and identify reliable information sources
- General understanding and acceptance of collaborative behaviors

Possible Preconceptions/Misconceptions: Students may believe that:

- Rural Illinois was always primarily farmland.
- It takes a long time to change an ecosystem.
- It takes a short time to bring back an ecosystem.
- The plants and animals in restored areas have not changed over the years.
- Plant and animal populations in natural areas do not change from year to year.

ENGAGE:

Students view images depicting the reduction of prairie ecosystem in Illinois since the time of the glaciers. http://eddata.fnal.gov/lasso/slides/show-slides.html Select History and scroll to Maps. Also, see the Illinois prairie loss map in Resources.

Ask:

- What do you think our state looked like 15,000 years ago? *Show the image: Glaciers once covering Illinois.*

- Soon after the glaciers retreated? *Show the image: Original prairies of the U.S.*
- In 1820? *Show the image: Illinois prairie in 1820s.*
- 1990? *Show the image: Prairie remnants in 1990.*
- What do you think occurred between these timelines to change the ecosystem so dramatically? *Wait for responses. Prompt with hints, directing thought toward pioneer settlers and improvements (steel plow) in farming methods. Take care not to demonize the farm industry. We need our farmers now as well as then. The takeaway is the need to act on opportunities to preserve and/or restore our natural areas as they provide valuable ecosystem services.*

EXPLORE:
Materials:
Part 1:
- Images
  - Maps noted in Engage section
  - Illinois original prairie land 1840
  - Fermilab site map (for reference): http://news.fnal.gov/wp-content/uploads/2015/08/Fermilab_SiteMap.pdf
- Access to online or classroom history resources
- Rolls of white, unwaxed, shelf paper or butcher paper
- Sticky notes
- Markers

Part 2:
- Student copy of Fermilab site (link in Part 1) and sensitive areas maps: http://fesspsde.fnal.gov:8095/gisdocs/PrintableMaps/FermilabEcologicalSensitiveAreas_2015.pdf
- Student copy of current *Land Management Map* (colored parcels) (Field Research Components)
- Copy of *Ecosystem Services – Student Resource* (*Resources* section)
- Colored pencils – one set per student
- Student Sheet 2

Part 3:
- Student map created in Part 2
- *Land Management Map* (colored parcels)
- FQI Fermilab Sites (Resources)
- Access to Fermilab databases and external research sites including:
  - Burn history: http://www.fnal.gov/cgi-bin/ecology/burn
  - Weather trends: http://www-esh.fnal.gov/pls/default/weather.html
  - Plants monitored including *Floristic Quality Index (FQI)* (Resources)
- Student Sheet 3
- Optional: *Floristic Quality Index (FQI)* and *FQI Skill Builder* (Resources)

Methods/Process (student-driven as much as possible)

Part 1:

1. Review background. (See introduction and other Resource materials noted under *background*.) Emphasize historical evolution of area, including Native Americans, pioneers, emergence of towns, railroads, farms, etc.
2. Establish student research teams if not already in place.
3. Instruct students to develop timeline—teamed research. (Suggest 100-year increments. Most dates will fall in last 200 years. Students will note vast expanse of time from original prairie to present.) Designate individuals or teams of students to find dates for the following:
    - Glaciation
    - Pine/Spruce forest
    - Hardwood forests
    - Prairie succession
    - Tribal encampments (approximate)
    - Lewis and Clark Expedition
    - First towns in area (Chicago)
    - Illinois statehood
    - Founding of your town
    - Abraham Lincoln's presidency
    - Civil War (See poem, Sandburg's *Grass*.)
    - Important events in your community (research)
    - Fermilab established
    - First Fermilab prairie site planted
    - Interpretive trail constructed
    - Any other historical event deemed pertinent (research)
4. Record events on timeline. Use butcher paper or shelf paper and markers. Paper may encircle room when completed depending on scale. *Consider a math exercise first to ensure practicality in the design*.
5. Compare timelines and place markers to designate periods of natural area development, decline and restoration.
6. Discuss the human needs throughout the timeline and determine opinions about land management practices from the time of the Native Americans to the present.
7. Prepare to support these opinions with evidence gathered from reliable resources.
8. Complete Student Sheet 1.

Part 2:

1. In the same groups, using *Fermilab Land Management Map* as a guide, complete Fermilab line map for a selected ecosystem (one per team; large areas may be divided between two or more teams), clearly coloring the ecosystem as follows:

Prairie	Yellow [NOTE: MR Quads are largely prairie.]
Grassland	Orange

Farmland	Brown
Woodland/Forest	Dark Green
Marsh	Light Green
Pond/Lake	Blue

The map created will be used in Part 3. Teachers ensure that all ecosystems are represented by asking students to choose, pull from a container or by assigning. Exclude lab buildings.

2. Discuss as a team the areas that perhaps could be improved to better serve the varied species onsite as well as the needs of Fermilab. Offer a rationale.
3. Determine the ecosystem services provided from the selected ecosystem. Students may use *Ecosystem Services – Student Resource* page to begin. Offer a rationale.
4. Report out by research team until all have presented and all ecosystems are covered. Prepare to defend your stances.
5. Use Student Sheet 2 to create a compilation of the ecosystem services provided on the Fermilab campus.
6. Complete Student Sheet 2.

<u>Part 3</u>:

1. Students will predict/suggest future needed land management strategies for their specific Fermilab natural areas, keeping in mind the scientific purpose of Fermilab.
2. Students will now isolate the ecosystem they are researching and circle other representations of this ecosystem type, if any, on the colored *Fermilab Land Management Map* used in Part 2. For example, there are many prairie and woodland plots. If another team is researching the same ecosystem type, they may collaborate.
3. Access research sites to learn more about the selected areas' general ecosystem characteristics before beginning the task. *(Resource items referenced in the Narrative/Background are fair game for student use.)*
4. Access Fermilab's database archives for burning, weather trends, plants monitored including Floristic Quality Index (FQI) and any other available FNAL resource deemed pertinent.
5. Complete Student Sheet 3. Discuss/debate as a class
6. OPTIONAL: For higher functioning students, present FQI information and FQI Skill Builder to calculate FQI from available data.

EXPLAIN:

Concepts explained using vocabulary in context

Land Management, Sustainable Land Management (SLM), Wildlife Management, Floristic Quality Index, Gas regulation (Production of oxygen), Climate regulation, Disturbance regulation (storm protection/flood control), Water regulation, Erosion control/sediment retention, Soil formation, Nutrient cycling (storage, nutrient cycling, biochemical breakdown), Waste treatment (recovery of mobile nutrients and removal of

xenic/toxic substances), Pollination, Biological control (trophic dynamic relationships/keystone species), Refugia (habitat for migration/visiting species), Food production, Raw materials (biofuels), Genetic resources, Recreation, Culture

As students debate ideas about historical land management methods and compare them to modern, scientifically based land management tactics, conceptualization of the need to promote land management from the perspective of ecosystem services will emerge. There will be significant discussion and exchange of ideas. Prepare to dispel misconceptions as they arise.

ELABORATE: Applications and Extensions
Illinois was inhabited by Native Americans long before Columbus discovered America. Explorers are known to have ventured to Illinois as early as the 1600s. Check out the timeline posted in Resources that spans the 1600s to 1996. Select any period of 20 years, roughly a generation, and describe the changes you might have observed during that period. Write a story from the perspective of a child growing up during this period. Use other historical resources to enhance your story.

Explore websites provided and expand to find additional online articles, images and/or videos. Submit these selections to Fermilab for possible inclusion in the ongoing Resource list.

EVALUATE:
Formative Monitoring
Part 1:

1. When do you think the tallgrass prairie first emerged as an ecosystem? How long did it exist as a tallgrass prairie before it began to disappear?

2. What caused the prairie to disappear so rapidly? Could this trend have been changed? Why or why not?

3. As the prairie disappeared, what impact did that have on the area?

4. Is it important to restore some of the tallgrass prairie? Why? Why not?

5. What should Fermilab do about prairie restoration when it interferes with facility progress?

6. Considering the cycle of the prairie in Illinois, specify the most consistent reasons why there were periods of vast prairie, then very little, and now more prominent prairies? What factors contributed to these cycles?

Part 2:

1. Which natural areas are most prevalent at Fermilab? Why do you believe this is so?

2. Which areas should be improved to better serve the varied species onsite as well as the needs of Fermilab? Why?

3. Ecosystem services are provided by each type of ecosystem that are on the Fermilab Land Management Map. If you were to select the three you believe are most important, what would they be and why?

4. Of the ecosystem services remaining, are there any that humankind can live without for an extended period of time? Explain.

5. Compare the ecosystem services you believe are essential and non-essential with classmates. Do you all agree? Why?

6. Considering ecosystem services, is there one ecosystem that is most valuable at Fermilab? Prepare to defend your response.

Part 3:

1. Why is it important to think ahead about land management strategies for Fermilab natural areas?

2. Keeping in mind that the scientific purpose of Fermilab is physics, why do you think there is such an interest in the natural areas of the site?

3. The many ecosystems of Fermilab may be diverse, but there are striking similarities. What are some of these similarities?

4. How do burning, weather trends, and the current Floristic Quality Index (FQI) inform us as to how to plan for land management?

5. Citizen scientists provide much assistance to ecologists. What are some ways you can assist?

Common Core Language Arts/Mathematics Connections

Language Arts Common Core Connector

Imagine that the Department of Energy wants to build another accelerator booster that will impact a section of a Fermilab natural area. Take the position of either a Fermilab physicist encouraging the development of the booster or a naturalist, intent on maintaining the natural areas. Write a letter of support for your position to be presented at a classroom forum.

Mathematics CC

- Part 1: Pre-planning of timeline increments for practicality
- Part 3: Predictions based on compilation of data from database archives

Summative Assessment: N/A

Name: _____

Fermilab: Past, Present and Future

Student Sheet 1

Part 1 – Past:
Analytical Timeline
With your student research team, research the development, nearly complete demise and restoration of the tallgrass prairie at Fermilab. Record your timeline on the materials supplied. Plan your increments such that you can include more than one event within a small time frame. Label your timeline events. Suggestions include but are not limited to:

- Glaciation
- Pine/Spruce forest
- Hardwood forests
- Prairie succession
- Tribal encampments (approximate)
- Lewis and Clark Expedition
- First towns in area (Chicago)
- Illinois statehood
- Founding of your town
- Abraham Lincoln's presidency
- Civil War (See poem, Sandburg's *Grass*.)
- Important events in your community (research)
- Fermilab established
- First Fermilab prairie site planted
- Interpretive trail constructed
- Any other historical event deemed pertinent (research)

Compare timelines and place sticky note markers to designate periods of natural area development, decline and restoration.

Factors that formed and/or nurtured the prairie and natural areas	Factors that damaged or destroyed large portions of prairie and natural areas	Evidence of industrial progress that impacted the prairie and natural areas	Factors that are now uniting to restore and preserve the prairie and natural areas

Student Sheet 1 (continued)

Discuss the human needs throughout the timeline and determine ***opinions*** about land management practices from the time of the Native Americans to the present.

Time Frame	Native Americans	Pioneers and Settlers	Modern Humans

Prepare to support these opinions with evidence gathered from reliable resources.

Source List

Name: _____

Fermilab: Past, Present and Future

Student Sheet 2

Part 2 – Present:
In the same groups, using *Fermilab Land Management Map* as a guide, complete Fermilab line map for your selected ecosystem (one per team; large areas may be divided between two or more teams), clearly coloring the ecosystem as follows:

Prairie	Yellow [NOTE: MR Quads are largely prairie.]
Grassland	Orange
Farmland	Brown
Woodland/Forest	Dark Green
Marsh	Light Green
Pond/Lake	Blue

Discuss as a team how your area could be improved to better serve the varied species onsite as well as meet the needs of Fermilab. If you need more room, create a chart of your own for your ideas.

Improvement	Rationale

Determine the ecosystem services provided from the selected ecosystem and why they are important. Students may use *Ecosystem Services – Student Resource* page to begin. If you need more room, create a chart of your own for your ideas. It is possible that all of the ecosystem services on the list belongs on your chart.

Ecosystem Service	Why is this ecosystem service important?

Report out by research team until all have presented and all ecosystems are covered. Prepare to defend your stances.

In conclusion, use comments of your classmates to create a compilation of the ecosystem services provided on the Fermilab campus. Use more room if needed.

At Fermilab, these ecosystem services are provided: I know this because:

Name: _____

Fermilab: Past, Present and Future

Student Sheet 3

<u>Part 3 – Future</u>:
Return to the *Fermilab Land Management Map* and think about the ecosystem services identified in Part 2. In Part 3, your team will predict and/or suggest future needed land management strategies for your specific Fermilab natural area(s) based on current conditions and predictions based on trends from the past found in databases. Keep in mind the scientific purpose of Fermilab.

Carefully read the map and note other representations of your ecosystem type, if any. For example, there are many prairie plots and woodland areas. If another team is researching the same ecosystem type, you may collaborate.

What do you know about your ecosystem? Describe the general characteristics of your ecosystem—and be sure to note your sources.

Ecosystem Type: _____

Location: _____

Characteristics:

_____
_____
_____
_____
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_____

Sources:

_____
_____
_____
_____
_____

Student Sheet 3 (continued)

- Access Fermilab's database archives for burning, weather trends, plants monitored including Floristic Quality Index (FQI) and quadrat data. Record these trends in a chart of your own design.

- Analyze the trends and predict what you believe your natural area parcel will appear in 20 years when you bring your children or students to Fermilab.

- Support your prediction with *specific data and clearly defined rationale*. Your team will present your findings to the class for discussion and/or debate.

Imagine that the Department of Energy wants to build another accelerator booster that will impact a section of a Fermilab natural area. Take the position of either a Fermilab physicist encouraging the development of the booster or a naturalist, intent on maintaining the natural areas. Write a letter of support for your position to be presented at a classroom forum.

Teacher Page

Student Reflection Suggested Responses: Fermilab: Past, Present and Future

Part 1:

1. When do you think the tallgrass prairie first emerged as an ecosystem? How long did it exist as a tallgrass prairie before it began to disappear?

   Responses will vary. Consider this suggested response, but encourage other appropriate ideas.

   Best evidence suggests that tallgrass prairie flourished in the Midwest since the glaciers retreated and left the rich mixture of materials known as glacial loess. This was conducive to the prairie plants and, after the prairie biomass was established, it remained the dominant feature until the advent of the steel plow in the mid-1800s.

2. What caused the prairie to disappear so rapidly? Could this trend have been changed? Why or why not?

   Responses will vary. Consider this suggested response, but encourage other appropriate ideas.

   The steel plow allowed settlers to cut through the dense prairie sod. Prior to this time, farmers preferred to clear forested areas to plant crops because the prairie was unyielding. These farmers were not intent in destroying an ecosystem. They were feeding hungry families, towns, and nations. In retrospect, some prairie parcels should have remained, but much of the understanding of the prairie's attributes were not readily known in those days. Now we recognize the medicinal, nutritive, and aesthetic qualities of the prairie and seek to restore prairie ecosystems.

3. As the prairie disappeared, what impact did that have on the area?

   Responses will vary. Consider this suggested response, but encourage other appropriate ideas.

   The loss of the prairie allowed rich farmland to produce vast quantities of food for the world. Unfortunately, in the midst of this progress, soil was rapidly depleted of essential nutrients left by the prairie plants. Scientific research endeavors have helped farmers of today replenish the soil, but croplands cannot do what the prairie plants did naturally—provide an ongoing nutrient cycle.

4. Is it important to restore some of the tallgrass prairie? Why? Why not?

   Responses will vary. Consider points indicated in previous suggested responses.

5. What should Fermilab do about prairie restoration when it interferes with facility progress?

   Responses will vary. Fermilab is, first and foremost, a vibrant physics laboratory. Physics initiatives must come first at this site. However, the Fermilab restored prairie and physical plant have worked in relative harmony for many years.

6. Considering the cycle of the prairie in Illinois, specify the most consistent reasons why there were periods of vast prairie, then very little, and now more prominent prairies? What factors contributed to these cycles?

   Responses will vary depending on background knowledge of the student. Most will suggest human intervention took away large portions of prairie with the advent of the steel plow, but many will not connect that human efforts are also currently promoting restoration of all types of natural ecosystems as evidenced at Fermilab. Climate change is also a contributing factor.

Part 2:

1. Which natural areas are most prevalent at Fermilab? Why is if difficult to be precise?

   Responses will vary as the map is not clear. For instance, the directional MR Quads are largely prairie/grassland with some marsh and woodlands. In general, grasslands/prairie parcels prevail.

2. Which areas should be improved to better serve the varied species onsite as well as the needs of Fermilab? Why?

   Responses will vary based on student team research. Look for solid rationale.

3. Ecosystem services are provided by each type of ecosystem on the Fermilab Land Management Map. If you were to select the three you believe are most important, what would they be and why?

   Responses will vary, but gas regulation, nutrient cycling and pollination should receive many votes. Accept any based on rationale.

4. Of the ecosystem services remaining, are there any that humankind can live without for an extended period of time? Explain.

   Responses will vary. Recreation and culture are often placed last, but both are significant and should not be overlooked as ecosystem services.

5. Compare the ecosystem services you believe are essential and non-essential with classmates. Do you all agree? Why?

Responses will vary. Encourage discussion and debate.

6. Considering ecosystem services, is there one ecosystem that is most valuable at Fermilab? Prepare to defend your response.

   Responses will vary. Encourage discussion and debate.

Part 3:

1. Why is it important to think ahead about land management strategies for Fermilab natural areas.

   Responses will vary. Fermilab is by design a particle physics laboratory. Its first responsibility is to this endeavor. Perhaps a new building is needed or a road needs to be paved. The natural areas are considered in these decisions, but the needs of the lab prevail if efforts to preserve the natural areas impede the work of the facility.

   On a season-to-season and year-to-year basis, needs of the natural areas are met through budgeted allotments. Care is taken to make the most ecologically minds and fiscally responsible decisions for the ongoing maintenance and improvement of the natural areas.

2. Keeping in mind that the scientific purpose of Fermilab is physics, why do you think there is such an interest in the natural areas of the site?

   Responses will vary. It is well known that many of the scientists working onsite are strong advocates for the natural areas. They serve as stewards, volunteers and frequent visitors to these areas, enjoying the sights, sounds and smells of nature.

3. The many ecosystems of Fermilab may be diverse, but there are striking similarities. What are some of these similarities?

   Responses will vary. All of the natural areas provide the potential for most if not all of the ecosystem services noted.

4. How do burning, weather trends, and the current Floristic Quality Index (FQI) inform us as to how to plan for land management?

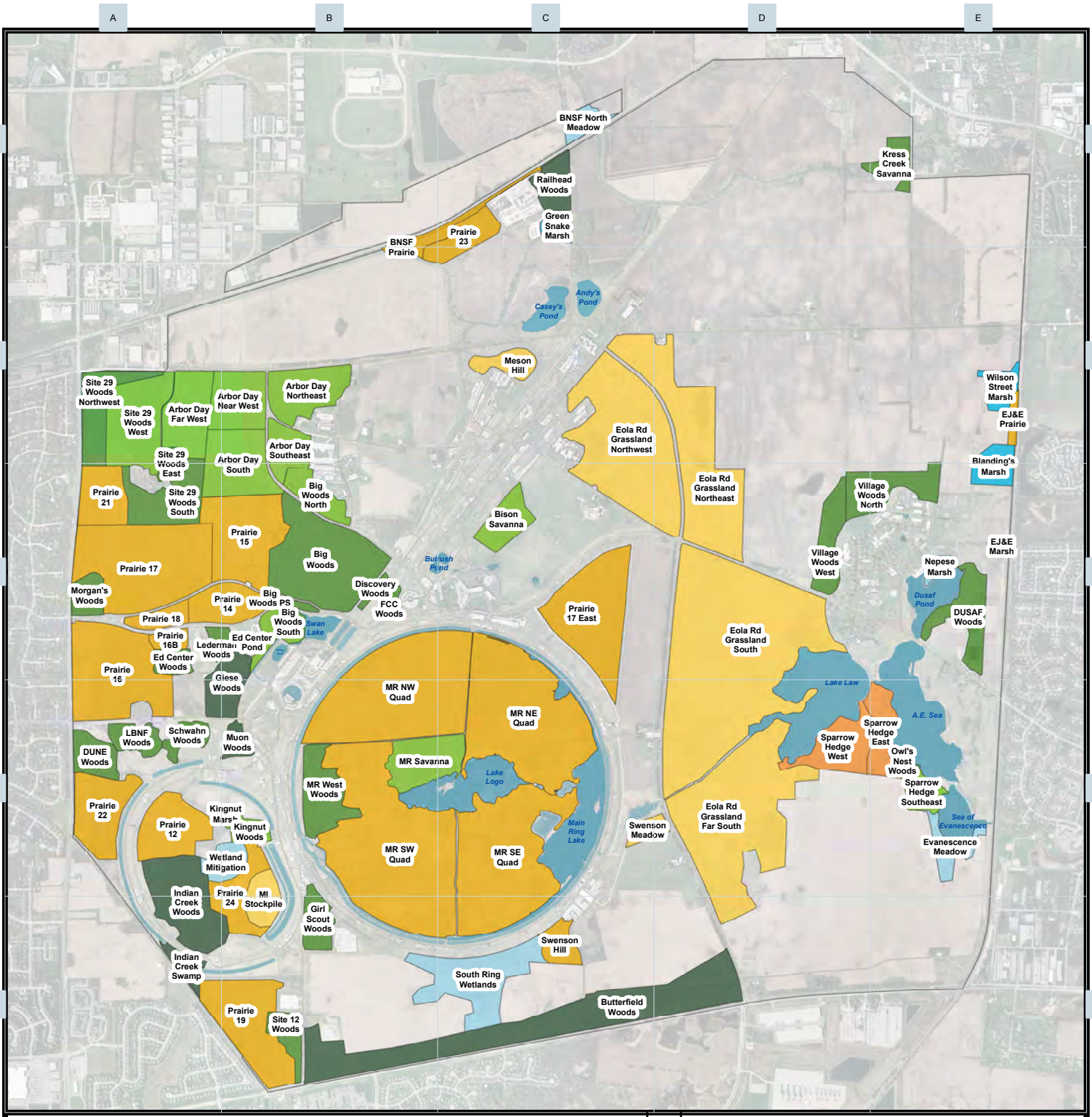
   Responses will vary. Archival data for controlled burns and weather trends tend to influence to diversity of plants in the area. For example, diversity is often greater post-burn, provided that the weather conditions are conducive. Many factors come into play when looking at which plants grow where. This in turn dictates where specific birds and insects will be. Few milkweed? Few monarch butterflies.

5. Citizen scientists provide much assistance to ecologists. What are some ways you can assist?

   Responses will vary. Serving as plant and insect monitors (example: www.bumblebeewatch.org), seed collectors and weed abatement helpers are all ways we as individuals can assist ecologists promote natural areas.

Imagine that the Department of Energy wants to build another accelerator booster that will impact a section of a Fermilab natural area. Take the position of either a Fermilab physicist encouraging the development of the booster or a naturalist, intent on maintaining the natural areas. Write a letter of support for your position to be presented at a classroom forum.

Expect a degree of sophistication as determined by the teacher and communicated to the student prior to assigning this task.



Land Management Units By Community Type

- Prairie
- Forest
- Shrubland
- Woodland
- Grassland
- Savanna
- Marsh
- Sedge Meadow
- Developed

N

Land Management Units

Compiled by: Fermilab GIS, Ext. 5391
Content Source: Fermilab Enterprise GIS
Publication Date: 9/30/2016 1:37:25 PM

Fermilab

0 0.125 0.25 Miles

1 in = 660 feet

PLEASE NOTE: GIS content is dynamic and is updated frequently. Please visit the Fermilab GIS Portal at http://fermilabgis.fnal.gov:8095/ArcGISPortal/index.html for access to the most current GIS information. Email fermilabgis@fnal.gov with comments and suggestions.

Fermilab Land Management

*Compiled from the Fermilab and Fermilab Natural Areas Website*s

The Bureau of Land (BOL) is responsible for the protection and restoration of land and groundwater resources in the State of Illinois. The BOL administers a broad variety of solid and hazardous waste management and cleanup programs. The mission of the Bureau of Land is to:

1. Ensure that hazardous and non-hazardous wastes are managed in an environmentally sound manner;
2. Encourage the recycling and recovery of waste materials through suitable incentive/disincentive efforts; and
3. Provide remedial responses and/or provide oversight to the uncontrolled releases of hazardous and petroleum substances into the environment.

Fermilab's 6,800-acre site is divided into the technical and infrastructure areas such as buildings, roads and tunnels, as well as open areas. In an effort to continue and expand the restoration and conservation activities at Fermilab, Fermilab Natural Areas (FNA) was created. FNA is an independent not-for-profit corporation that is dependent on volunteers for most activities and on members' dues and donations and grants for 100% of its funding. It assists with funding and other facets of the management of natural areas at the lab. FNA and Fermi Research Alliance, LLC (FRA) are signatories to a Memorandum of Understanding that governs their relationship.

http://sustainability.fnal.gov/land-stewardship.html

Fermilab Natural Areas

The Fermilab Natural Areas organization, formed in 2006, is a not-for-profit, all volunteer network dedicated to restoring, managing and enhancing the natural areas and resources of Fermilab in order to maintain and improve their ecological health and biodiversity. We do not receive funding from Fermilab or the federal government and depend on membership, donations and grants to fund our operations. Throughout the year, we conduct work events where volunteers come together to participate in organized restoration projects. We welcome all volunteers, donations and memberships to FNA.

Our mission is to conserve, restore and study the natural areas within Fermilab while encouraging employees and neighbors to experience and enjoy Fermilab's natural beauty.

Our vision is to see that Fermilab's natural areas and ecosystems are rich in biodiversity, that conservation and restoration are sustainable activities, that Fermilab is a regional leader in natural areas research, and that the people of the surrounding communities consider the enjoyment of our open spaces to be a valuable contributor to a high quality of life.

http://www.fermilabnaturalareas.org/

National Environmental Research Park
In 1989, Fermilab was designated a National Environmental Research Park. There are currently six such research parks across the nation (in South Carolina, Washington, Idaho, New Mexico, Tennessee and Illinois). These parks have been established over the years by the Department of Energy in partial response to the National Environmental Policy Act. They can be thought of as protected outdoor laboratories for studying some of the complex and poorly understood ecological issues that confront humanity. Qualified investigators from universities, environmental organizations, or the private sector are encouraged to submit research proposals.

Fermilab is considered unique among the research parks because the site contains most of the major types of ecosystems representative of the Midwest. These include tallgrass prairie, oak savanna, agricultural fields, woodlands, grasslands, and wetlands. Studies can take advantage of the contrasting natural habitat at Fermilab and the nearby metropolitan area of Chicago. Because Fermilab contains no weapons and carries out no classified research, site access for NERP participants is far simpler than at other Department of Energy research parks.

http://sustainability.fnal.gov/ecology/park/index.html

Fermilab Conservation – Electricity and Water

Electrical Energy Conservation
With the encouragement and support of the Department of Energy, Fermilab has undertaken a number of energy conservation projects. The most significant is the development and use of superconducting magnets in the accelerator and some experimental beam lines and apparatus. Other energy-saving projects include: metal halide lighting to provide better illumination at lower cost than fluorescent lights, replacement of large pump motors with smaller more efficient units, and the installation of controls to reduce magnet current to zero during no-beam conditions.

Water Conservation
Extreme care is taken to avoid depletion or contamination of natural water sources in the area. Cooling water for the accelerators and other equipment is obtained from specially developed water retention basins for runoff from on-site rainfall, supplemented during periods of high water usage by water taken from the Fox River.

The water system that cools the Booster accelerator is an example of an air cooling system used to preserve the natural water supply and to eliminate the need for mechanical cooling towers. Water circulates through the Booster to remove the resistive heat generated in the magnets. The heated water is then pumped into an outdoor

waterway where it flows in a full circuit through two large ponds, cooling on the way. These ponds form natural habitats for fish, geese, ducks, and swans even through cold Illinois winters.

http://sustainability.fnal.gov/ecology/conservation/index.html

Ecological Land Management Committee

The Laboratory director created the Ecological Land Management (ELM) Committee to oversee and make recommendations to facilitate the restoration of the available tracts of land. One of the responsibilities of the committee is to create a roadmap for the prairie restoration effort. This plan is intended to fulfill that responsibility.

The Fermilab Ecological Land Management (ELM) Committee's Long-Range Management Plan provides long-range plans for managing the available areas of the Laboratory site according to principles of ecosystem management and restoration. The planning process recognizes the value of and seeks to build upon the many different habitats present on the Fermilab site. Thus, the available area is divided into tracts, whose boundaries recognize the rich habitat diversity, e.g., uplands, woodlands, and wetlands.

The Ecological Land Management Committee, or ELM Committee, oversees the land use and land management activities at Fermilab. The committee is made up of volunteers that cover many different areas of environmental and ecological expertise. These committee members come not only from Fermilab, but from local organizations such as Forest Preserve Districts.

The committee meets on the first Thursday of each month at lunch time (12:00 to 1:00) in Wilson Hall. Restoration activities, habitat management, and land use issues, among other environmental topics, are discussed. Recommendations for land use and management are made to Fermilab's director.

http://sustainability.fnal.gov/ecology/elm/index.html

ELM Documents
Links to documents outlining the restoration plan as well as committee membership, and a Glossary. Included in the following links:

Tract Management
ELM Plan: The site ecological management plan for the current year.

Tract List: A list of links to tract summaries from the latest approved ELM plan.

Tract Map: An interactive map showing the locations of the various ELM tracts.

Fire Management
Non-Structural Fire Management Plan: (Microsoft Word Document)

Burn Histories: View the burn histories for the relevant ELM tracts.

Map of Proposed Burns for the current or upcoming fire management season.
This map is interactive and can also display the locations of past burn sites.

Particles and Prairies Introduction for clips of prairie restoration, history, ecology, and students experiencing a Fermilab field trip.

Bumblebee Watch – Citizen Scientist

How do biotic and abiotic factors work together to cycle energy and resources through an ecosystem?

Topic: Evaluating the ecosystem services provided and determining the status of the bumblebee populations in a specific area

Brief Lesson/Lesson Set Description:
In the role of citizen scientists, students will contribute to the Xerces Society database as they photograph, observe, record and tentatively identify bumblebees foraging in natural areas and/or residential/community gardens. Using this information, students will suggest ways to improve school ground and/or residential habitat to attract pollinators.

Science and Engineering Practice: Planning and Carrying Out Investigations

Crosscutting Concepts: Patterns; Systems and System Models

INVESTIGATION

Objectives: Students will:

- Recognize and explain the role of pollinators, specifically bumblebees, in the cycle of nutrients in nature.
- Determine the role of bumblebees within a food web and predict the consequences if this pollinator were to disappear.
- Describe the pattern of pollinator/plant relationships and explain why certain bumblebees are more likely to be found on specific plants.
- Analyze observations made at different times under different abiotic conditions and predict optimum conditions, times and places to observe bumblebees.
- Extrapolate from understandings about bumblebees to other pollinators, such as hummingbirds and bats.
- Contribute as citizen scientists to an ongoing scientific research database.
- Produce a plan to improve school ground and/or residential habitat to attract pollinators.

Narrative/Background Information:
See *Bumblebees* (*Resource*s section) and explore online resources provided.

Prior Student Knowledge Expectations:

- Food web/food chain and nutrient cycle activities or understandings (See Set 3 activities.)
- Basic vocabulary to complete data observations made and recorded on the *Bumble Bee Watch* website.
- General understanding of field observation practices
- Ability to use observation and note taking skills as well as able to appropriately record data on the website

- Willingness to step into the natural world in an unfamiliar role
- General understanding and acceptance of collaborative behaviors

Possible Preconceptions/Misconceptions:

- Many individuals are reluctant to get close to bumblebees, fearing a sting. In reality, bumbles are docile creatures that are far more interested in foraging than in harming humans. If the observer is quiet and makes no effort to swat at the bumbles, there should be no issue.
- Bumblebees may sting if agitated; they do not bite. The mouthpart feature that looks like a stinger is actually a straw-like tongue.
- It is true that bumbles, as with many insect pollinators, rarely visit the same forb (showy flower) twice. They also can tell if another insect has visited. This is because insects leave a chemical called a pheromone that can be detected by other insects. Thus, if considerable activity is noted on a specific plant, it may be prudent to search for another plant of that species in a different area.

Vocabulary: pollinator, species, citizen scientist, survey

Materials:

- Access to natural areas
- A digital photograph of a bumblebee to demonstrate data recording
- Website access and preview of www.bumblebeewatch.org
- Student data sheets
- Writing instrument/s
- Digital camera or cell phone
- Extra paper, if desired, to create a pollinator attracting natural area
- Follow up bumblebee websites for further investigation as desired.

ENGAGE:

- Ask: When you think of a pollinator, what comes to mind?
  Wait for responses. Students will likely include bees and bats in their responses. If not, suggest these organisms.
- Ask students how they feel about these organisms and do a "Thumbs UP; Thumbs down" exercise for the most common pollinators, including bumblebees.
- Present video footage of birds, bats, butterflies, honeybees and bumblebees as pollinators. 4:18 min. (Select *The Beauty of Pollination*.)
  http://nortonsafe.search.ask.com/search?geo=en_US&prt=&o=APN11910&chn=&ver=&q=pollinators&tpr=10&ctype=videos

EXPLORE:

Process:

1. Review the *Bumblebee* background presented in the *Resources* section.
2. Divide students into research teams and conduct a KWHL (What do you **K**now? **W**ant to know? **H**ow will you find out? What did you **L**earn?) and establish research topics from the *What to Know* list.

3. Present bumblebee websites suggested and encourage further investigation as required. Each team will make a short presentation to the class on their topics per student data sheet, Bumblebee Basics Research.
4. Create individual reflective conclusions as noted on student data sheet, Bumblebee Basics Research.
5. Proceed to a natural area to observe, photograph and collect bumblebee data.
6. Submit data to www.bumblebeewatch.org per student data sheet, Bumblebee Observation.
7. After the field experience, prepare proposals for the pollinator enhancement project.

EXPLAIN:
Listen carefully to the KWHL discussion, and ask students to explain incorrect or inconsistent comments or implications. Encourage students to research for clarification. Isolate research topics from the *Want to Learn* set, keeping a copy of the original statements. Allow students to clarify prior misconceptions within their topical presentations.

ELABORATE:
Concepts explained using vocabulary in context

Considerable information is available online in addition to resources provided. Encourage further investigation of bumblebees as they provide valuable ecosystem services, including:

- Nutrient cycling** (storage, nutrient cycling, biochemical breakdown) – **MS-LS2-3**
- Pollination – **MS-LS2-4; MS-LS1-8**
- Biological control (trophic dynamic relationships/keystone species) – **MS-ESS3-3**
- Food production – **MS-LS2-1**

**Concepts beyond middle level

EVALUATE:
Formative Monitoring: Use Student Reflection questions for discussion throughout the investigation.

Summative Assessment: Field research experience data

Elaborate Further/Reflect/Enrichment: Access web links in *Resources*. Monitor ongoing progress within the *Bumblebee Watch* program.

Name: _____

Bumblebee Basics Research

1. Complete a bumblebee KWHL in class with your teacher's guidance.
2. Considering the *Want to Learn* topics, select one for your research team to investigate. You may use websites provided or find others, but all sites must be noted.
3. Prepare a short (not to exceed 10 talking points) presentation for your class.
4. Individually, present a conclusion in the space provided on the next page.

TOPIC: _____

1. _____

2. _____

3. _____

4. _____

5. _____

6. _____

7. _____

8. _____

9. _____

10. _____

Information Sources:

- _____
- _____
- _____

Use more space on the back of the page if needed.

Reflective Conclusion: Think back to your Thumbs UP; Thumbs DOWN exercise in class. Did you vote UP or DOWN for bumblebees? _____

Has your vote changed? _____

Why or why not? Provide at least three reasons for your response.

1. _____
2. _____
3. _____

AFTER your field experience, design a pollinator garden.

Suggest improvements to your schoolyard natural areas. What might you do to help attract and maintain a community of pollinators? On the back of the paper, sketch your design; clearly note at least three specific changes and note why you propose each change.

Name: _____

Bumblebee Observation

Many bumblebee species forage on Illinois prairies and other natural areas. Seven species noted at Fermilab are illustrated on the diagram page, but other species have been sited. Collecting sighting data is critical to understanding how to best maintain populations as well as discovering which species are in an area. The website www.bumblebeewatch.org provides an opportunity for citizen scientists to contribute to this important research.

STEP 1: Register on the website: www.bumblebeewatch.org

STEP 2: Photograph bumblebees foraging on native (preferably) plants.

STEP 3: Collect observations, which should include:

- Date/time of observation

  _____

- Abiotic conditions (current weather including temp, humidity, wind speed and, if possible, barometric pressure)

  _____

- Location and description of the area (GPS preferred). An interactive map on the website is provided to pinpoint location.

  _____

  _____

- Forb upon which the bumblebee was foraging (provides hints as to long/short tongue)

  _____

- Possible ID of bumblebee (Help is provided on the Bumblebee watch website after basic observations are noted.) The images included may prove helpful.

  _____

- Explanation of how the species was determined (field markings, expert co-observer, another source)

  _____

  _____

- Unusual behaviors or notable observations

  _____

  _____

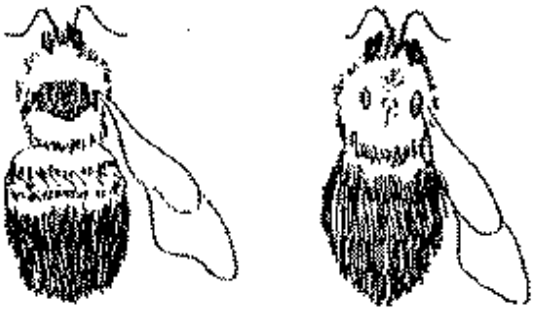
STEP 4: Upload the picture to the website and submit required information.

STEP 5: An expert will verify your information and species ID.

CONGRATULATIONS!

You have just contributed to a valuable scientific research project!

Species Verified as Foraging on the Fermilab Prairie in 2004



B. affinis

B. impatiens

B. fervidus

B. vagans

B. pennsylvanicus/
B. auricomus

B. bimaculatus

B. griseocollus

NOTE: Bombus auricomus and Bombus pennsylvanicus have nearly identical field markings. The primary external difference is the placement of the three single vision eyes (ocelli) on the occipital ridge (forehead), a feature far too minute to be noted without a scope.

Name: _____

Student Reflection: Bumblebee Watch

1. How does pollination fit into the nutrient cycle?

2. Determine the role of bumblebees within a food web and predict the consequences if this pollinator were to disappear.

3. Describe the pattern of pollinator/plant relationships and explain why certain bumblebees are more likely to be found on specific plants.

4. Analyze observations made at different times under different abiotic conditions and predict optimum conditions, times and places to observe bumblebees.

5. Extrapolate from understandings about bumblebees to other pollinators, such as hummingbirds and bats.

6. Develop and design a plan to improve school ground and/or residential habitat to attract pollinators.

Teacher Page

Student Reflection Suggested Responses: Bumblebee Watch

1. How does pollination fit into the nutrient cycle?

   Without pollination, plants would not be able to reproduce—diminishing and eventually removing producers. Without producers, life, as we know it on Earth, will eventually perish.

2. Determine the role of bumblebees within a food web and predict the consequences if this pollinator were to disappear.

   Bumblebees are primary consumers. Without bumblebees, overall pollination ratios would be impacted, diminishing the overall productivity of the producers. This would in turn impact the organisms that are dependent on these producers for food.

3. Describe the pattern of pollinator/plant relationships and explain why certain bumblebees are more likely to be found on specific plants.

   They are critical pollinators for plants, displaying a degree of specificity determines by specialized features that correspond to complementary features on specific plants. For example, long-tongued bumblebees tend to forage on plants with long corollas. Without pollination, these plants would perish.

4. Analyze observations made at different times under different abiotic conditions and predict optimum conditions, times and places to observe bumblebees.

   Responses will vary.

5. Extrapolate from understandings about bumblebees to other pollinators, such as hummingbirds and bats.

   Responses will vary, but likely show a pattern similar in some, but not necessarily all, aspects to bumblebees.

6. Develop and design a plan to improve school ground and/or residential habitat to attract pollinators.

   Responses will vary.

Planning Your Fermilab Field Trip

General Information

The *Energy and Ecosystems: Prairie, Water and Woods* field trip is a nature-filled opportunity for middle school students to explore Fermilab's habitats. Usually the field trip will occur in the middle of your ecosystem study unit so that students can examine their collected data back in the classroom.

Reservations need to be made at least three weeks in advance by either calling or e-mailing the registrar at 630-840-5588, edreg@fnal.gov, or online at http://eddata.fnal.gov/lasso/fieldtrips/fieldtrip-request.shtml. Once your field trip is scheduled, you will receive your registration via mail or e-mail. Look this over and make sure the date, arrival and departure times and the number of students are correct. Please make your activity selections and complete the information page and return them by mail, e-mail, or fax. Fermilab wants to make this field trip meet the needs of your class.

Remind students to be prepared for inclement weather. The field trip may be conducted in rainy and/or cold weather. In case of thunder or lightning, the trip will be canceled.

Students should wear long pants and appropriate shoes and socks for walking in the prairie and the woods.

Plan to have lunch at the Lederman Science Education Center picnic area. Lunches and drinks must be brought from school. There are no trash cans in the picnic area, so please bring garbage bags to transport trash to the dumpster located south of the picnic area. The docents will point this out for you.

We assign one docent for every 20 students, with a maximum of 180 students per visit. No docent group may have more than 20 students. Thus, if you have 43 students, you will be assigned three docents. You must have at least two chaperones per docent group. It is helpful if these adults know in advance what the students will be doing and know that their function is to keep the students focused and on task. We expect the chaperones to take an active part in the day's activities and have this be a positive experience for all involved. We do not want our docents to have to be disciplinarians.

Research Team Format

Groups must be assigned prior to arriving at Fermilab and should not exceed 20 students each. Subgroups of three to four students within this format may be necessary. Be prepared. Please have students wear name tags.

The time requirements for on-site lab and field studies vary considerably. The field trip consists of a nature walk, 45-minute lab time, and one or two field studies. Teachers may choose one field study if the total on-site time is four hours or less. If staying longer than four hours, choose two field studies. Something that helps our staff, and we are sure will make your field trip here go more smoothly and be more meaningful, is to have

your students fully prepared. They should have completed the pre-visit activities that are required for a particular field experience. We cannot stress this enough. In this way they will know how to use most of the equipment and what type of data they are expected to obtain. They should know precisely what they are going to do for the day. The student research groups should bring all the field study data sheets that they will need for the various activities.

Special Education Considerations

Special education accommodations are readily implemented in the *Fermilab Ecology* curriculum. The diverse teaching strategies utilized, coupled with the wide variety of student experiences, offer appropriate options for students with individualized education programs (IEPs). Teacher creativity based on individual student needs is encouraged and initiatives to promote inquiry learning at the student level are recommended.

General Strategies

- Work cooperatively with the special education specialist to adapt the *Fermilab Ecology* curriculum for individual learners.
- Resist assessing student capability based exclusively on their standardized test history. Rather, observe students in the classroom setting utilizing authentic assessment tools.
- Determine the learning style of the student; consider strengths upon which to build and weaknesses to strengthen. Consult with specialists and parents/guardians to best plan for student success.
- Encourage exceptional (disabled, disadvantaged, and/or gifted) students to participate in class discussion and activities. Challenge gifted students to lead discussions and plan activities. Allow all students to contribute. Recognize that incorrect responses are opportunities to learn and provocative responses present new, and often positive, challenges.
- Promote the accumulation of student work in portfolios to provide a record of progress.
- Use high-interest science topics to reinforce skills in other disciplines. Mathematics, social science, art, music, reading and language arts all complement thematic science-based topics. The special needs student on all points of the spectrum may experience educational synergy and improved achievement when he/she practices integrated learning.
- Provide for peer mentoring/peer tutoring. Effecting partnerships are often mutually beneficial. The mentor/tutor may experience a richer depth of understanding when allowed to express concepts in a meaningful manner to another student. The recipient of the tutelage may better understand the concept when explained in the terms of a peer.
- Work cooperatively with parents/guardians. Design a communication conduit in the form of regular phone calls, letters, newsletters, e-mails, student research journals, etc.
- *Support inquisitive behavior* – Regardless of physical or cognitive ability, encourage questions and provide appropriate avenues for further study based on the individual learner's needs and abilities.

Suggestions by Category

- Mental Challenged – Allow the student to experience the sensual nature of ecosystems. For example, differentiate between square (mints), triangular (sedges), and round (reeds and rushes) stems. This student may distinguish

between the different odors of pungent plants such as mints, yellow coneflower seed heads and wild bergamot, and Queen Anne's lace roots. Break tasks into small, manageable steps while providing guidance and support to ease frustration.

- Physical/Health Disorders – Determine the tolerance level of the student and challenge him/her to experience the maximum. For example, the child in a wheelchair may have access to a balloon-tired vehicle that will allow access to the ecosystem. Never, EVER compromise the child's health or general condition. Close communication with parents/guardians and specialists is of utmost importance when planning appropriate natural area experiences.

- Learning Disabilities – The sensual/tactile nature of the natural world allows learning-disabled students multiple modalities through which to learn. For example, visual learners may opt for herbarium mounts and other artifacts, online video and slides, and ecosystem field trips. The auditory learner may learn best through spirited classroom discussion and appreciate the online narrated video clips.

- Attention Deficit Disorder/Attention Deficit Hyperactive Disorder (ADD/ADHD) – The interactive, fast-paced nature of natural science may inspire the ADD/ADHD student to remain on task and motivated. Within cooperative student research teams, provide active roles requiring engagement and diverse tasks appropriate for the learner.

- Vision and Hearing – The visual- and auditory-impaired student's challenge is not one of comprehension, motivation, or interest. Rather, visual impairment affects only the modality by which instruction is effective. Creative manipulation of the activities will result in a meaningful ecology experience. Provide tactile options as well as peer support within student research teams.

- Behavior Disorders – Among the most positive attributes of engaged science experiences such as ecosystem study are the myriad of interactive learning options. The behavior-disordered student needs careful supervision but often responds well to the venue. Implement consistent, and wherever possible, class-generated rules. Insist upon accountability and have clearly stated, easily understood consequences for irresponsible behavior.

- Autism – The wide range of specialized problems associated with autism require expert advice. Consult with experts when designing modifications for the autistic student.

- Gifted/Talented – Gifts and talents are as diverse as debilitations. Students may demonstrate artistic, musical, academic, and other special gifts. When in a cooperative learning team, encourage students to discover the strengths of each student. Sometimes the gifted student may not have demonstrated the gift in the

classroom setting due to shyness and/or lack of opportunity. Allow a certain degree of flexibility to allow students to use their gifts.

- Psychological/Emotional – Students with psychological and/or emotional problems may exhibit unexpected and/or bizarre behaviors that are disconcerting to educators and other students. These emotional behaviors may interfere with their ability to learn and disrupt the learning environment of other learners. Appropriate interpretation of these behaviors is integral to success. Involvement in engaging science activities may be an important therapy for these students. Interaction with classmates within the student teams and positive reinforcement from peers and teachers may offer these students the opportunity to interact appropriately and enhance their likelihood of improvement. Careful supervision and conscientious communication with mental health professionals is critical when working with psychologically and/or emotionally challenged students.

- English as a Second Language (ESL) – Cultural and language barriers are important considerations. While *Fermilab Ecology* is not currently available in other languages, the common allure of the natural world is an educational asset. Students who are offered the opportunity to use their senses to experience nature, learn. Sight, smell, sound, and touch (in science, we rarely rely on taste) create common experiences for students and help develop a foundation from which to achieve.

Common Fermilab Site Prairie Grass Identification Key

1. Plants with leaves not parallel-veined. **(See Prairie Forbs Identification Key.)**

   1a. Plants with narrow, long leaves that are parallel-veined **(Go to 2.)**

2. Inflorescence (flower cluster) arching, leaves 1–3 feet long – **Prairie Brome Grass, *Bromus kalmii***

   2a. Inflorescence not arching **(Go to 3.)**

3. Inflorescence shaped like a turkey's foot, leaves 3–7 feet long – **Big Bluestem, *Andropogon gerardii***

4. Inflorescence fuzzy, growing in a clump, leaves 1–3 feet long – **Little Bluestem, *Schizachyrium scoparium***

   4a. Inflorescence not appearing fuzzy **(Go to 5.)**

5. Clump, with long, narrow basal leaves only and smells like burnt popcorn when in bloom, leaves 1–3 feet long – **Prairie Dropseed, *Sporobolus Heterolepis***

5a. Basal leaves present, but the flowering stem is taller and contains a few leaves **(Go to 6.)**

6. Inflorescence appearing feather-like, leaves 3–6 feet long and make a 45° angle to the stem where they attach – **Indian Grass, *Sorghastrum nutans***

6a. Inflorescence not appearing feather-like **(Go to 7.)**

7. Inflorescence widely branched, leaf edges not sharp, leaves 3–6 feet long – **Switchgrass, *Panicum virgatum***

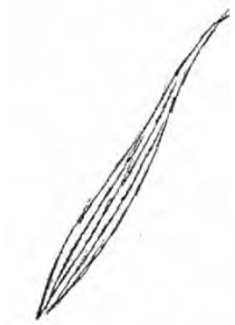
7a. Inflorescence appearing cone-like with leaf edges very sharp, leaves 3–6 feet long – **Prairie Cordgrass, *Spartina pectinata***

Note: Inflorescence – the discrete flowering portion or portions of a plant (grasses, like forbs, have flowering parts; the flowering parts of grasses are generally less showy.)

Reprinted and adapted from the *Particles and Prairies Teacher's Guide* published by the Fermilab Education Office.

Common Fermilab Site Prairie Forb Identification Key

1. Plants with leaves with parallel veins and leaves that are usually long and thin **(See Prairie Grass Identification Key.)**



   1a. Plants with leaves that do not have parallel veins (Except one – Rattlesnake Master) and leaves that are not usually long and thin **(Go to 2.)**

2. Stems that have four edges (square) – Mints **(Go to 3.)**

   2a. Stems that do not have four edges but are round **(Go to 4.)**

3. Opposite, larger leaves, arrow-shaped, velvety, and pink to lavender flowers in a concentric arrangement, blooms in July and August, 1–3 feet tall – **Wild Bergamot, *Monarda fistulosa***

3a. Opposite, thin, grass-like leaves and tiny white cluster of flowers in a flattish head, blooms in July and August, crushed leaves smell very mint-like, 1–3 feet tall – **Mountain Mint, *Pycnanthemum virginianum***

4. Leaves that are long, thick, yucca-like, with teeth or spines along the margin, parallel-veined, with conspicuous teeth or spines that look sharp (but are not). Flowers are very small clustered in a very dense head the size of a quarter, blooms in July and August, 3 feet tall or more – **Rattlesnake Master, *Eryngium yuccifolium***

4a. Leaves not parallel veined **(Go to 5.)**

5. Leaves large, heart-shaped (usually much larger than a slice of bread) and basal-serrated, feel like sandpaper, flowers yellow, flowers near the top of a tall, hairless stem, resembles a sunflower, blooms from July to September, 3–10 feet tall – **Prairie Dock, *Silphium terebinthinaceum***

5a. Leaf upright, basal, deeply divided, sandpapery, points north and south. Flowers on a tall, hairy stalk that resembles a sunflower, blooms from July to September, 3–10 feet tall – **Compass Plant, *Silphium laciniatum***

5b. Leaves not basal, not large (usually smaller than a slice of bread) and grow along an upright stem **(Go to 6.)**

6. Leaves in whorls of four or more, tiny white flowers on a central spike near the top of the plant, stems and leaves velvety, blooms in June and July, 2–6 feet tall – **Culver's Root, *Veronicastrum virginicum***

6a. Leaves not in whorls, flowers pink, orchid or yellow (not white) flowers on a spike or cluster **(Go to 7.)**

7. Spikes of flowers in clusters, pink or orchid, leaves very narrow, similar to grass leaves **(Go to 8.)**

7a. Flowers yellow, not appearing spike-like, but clustered at the top of stem **(Go to 9.)**

8. Flowers arranged closely along spike, blooms in July and August, 2–6 feet tall, hairy stem – **Prairie Blazing Star, *Liatris pycnostachya***

8a. Flowers arranged and spaced like buttons along the spike, blooms in August and September, 1–5 feet tall – **Rough Blazing Star, *Liatris aspera***

9. Yellow flowers smaller than a dime, in clusters forming a cap-like head **(Go to 10.)**

9a. Flowers not forming dense clusters, larger than a dime, flowers with visible yellow petals **(Go to 11.)**

10. Velvety leaves, small yellow flowers clustered at the top, blooms in August and September, plants to 6 feet tall – **Stiff Goldenrod, *Solidago rigada***

10a. Alternate, longer grass-like leaves, much longer than wide, numerous, flowers arranged on a cone-like inflorescence, plants to 6 feet tall – **Tall Goldenrod, *Solidago altissima***

11. Opposite, compound, smooth leaves, 3–5 leaflets or more, yellow flowers the size of a quarter, sunflower-shaped plants to 2–7 feet, blooms in August and September – **Tall Coreopsis, *Coreopsis tripteris***

11a. Opposite or alternate, simple, somewhat hairy, leaves that are usually serrated, yellow flowers the size of a silver dollar near the top of a 2-foot stem, blooms in August and September – **Saw-Tooth Sunflower, *Helianthus grosseserratus***

SUNFLOWER FAMILY

Prairie dock
Compass plant
Prairie blazing star
Rough blazing star
Stiff goldenrod
Tall goldenrod
Tall coreopsis
Saw-tooth sunflower

CARROT FAMILY

Rattlesnake master

MINT FAMILY

Wild bergamot

Mountain mint

FIGWORT FAMILY

Culver’s root

Herbarium Specimen Collection*

How do abiotic factors affect biotic factors in an ecosystem?

*This activity is intended for use with teacher participants in an effort to create visual aids for classroom use. Students who create an herbarium mount should get permission before taking plant cuttings and should do so under adult supervision. Specimens should be taken only after the plant has been identified as not threatened or endangered and not poisonous.

Topic: To develop a permanent set of classroom plant specimens as observation and study references

Brief Lesson/Lesson Set Description:
Students will create pressed plants that can be used for a number of activities as well as bring the artistic side of nature into the classroom.

Science and Engineering Practice: Developing and Using Models

Crosscutting Concept: Structure and Function

INVESTIGATION

Objectives:
- Select and identify specific plants.
- Produce a series of herbarium mounts suitable for classroom display.
- Process the distinguishing critical attributes through specimen identification, analysis, and drawing activity.

Narrative/Background Information:
To successfully facilitate this experience, it is necessary that the teacher have the ability to identify the more common plants of an ecosystem. Even the most highly trained and experienced prairie researchers are baffled at times. Sometimes plant anomalies are present. For example, occasionally a Silphium hybrid between compass plant and prairie dock is discovered. The leaves of this hybrid exhibit characteristics that blend those of the two plants. Find a field guide that is easy to use and regularly model the use of it to your students.

Vocabulary: annual, biennial, broadleaf, flora, forb, herb, indigenous, invasive, perennial, vegetation, weed

Materials:
- Plant keys
- Plant press
    - newspaper
    - waxed paper

    - blotting paper
    - ventilator sheets (corrugated paper)
- Mounting paper
- Elmer's glue – diluted
- Glue brushes
- Plant labels, if not printed on mounting paper
- Selected plant specimens
- Laminator (recommended)
- Drawing paper
- Drawing and coloring pencils

Process:

1. Select specimens.
2. Arrange specimens on plant press in this order: wood frame, ventilator, blotter paper, newspaper with specimen folded in the middle, waxed paper; repeat and end with another wood frame. Tighten plant press straps.
3. Allow specimen to dry for at least one week, if possible; 3–4 days is adequate in a cool, dry place.
4. Dilute glue approximately 2:1 with water; use brush to distribute a thin layer of diluted glue on a nonporous smooth surface.
5. Carefully remove specimen by the stem from the plant press when dry and place one side in the glue and then stick to mounting paper.
6. Position the plant on paper until desired position is obtained.
7. Apply extra glue with the brush paying special attention to the tips of leaves and petals.
8. Label accurately with the scientific name, common name, and short description. See *Prairie Plant Key* (found in *Resources* section) if mounting prairie plants.
9. Laminate.
10. Ask for teacher initials to verify correct identifications.

Possible student activities using herbarium mounts:

- Practice identifying critical attributes.
- Identification of plants using various field research books
- Identification of plants using dichotomous keys
- Use as a visual tool to see actual size/look of plant when planning a restoration project.
- Compare and contrast adaptations of plants.
- Description of plants
- Visuals to enhance the classroom environment

Things to Consider when Planning a School Prairie

1. Purpose/Goal
    - Educational
    - Ecological
    - Aesthetic
2. View
3. City/Neighborhood Ordinances
4. Who will utilize the prairie?
    - Students
    - General public
    - Scout troops
    - Neighbors
5. Hardscape: What is currently on the site or adjacent to it? What features would you like to add?
    - Parking
    - Signage
    - Handicap accessible
    - Path – If so, location, width; mowed grass or wood chips
    - Water supply – important during first two years
    - Firebreaks
    - Borders—mowed grass or wood chips, fencing
    - Area for picnic tables or pavilion
    - Tool shed
    - Viewing tower
6. Management and Support
    - Administration
    - Students
    - Teachers
    - Parents
    - Maintenance personnel
    - Neighbors
7. Equipment
    - Mowers
    - Rakes
    - Hose
    - Etc.
8. Seed/Plant Source (grown within a 50-100 mile radius)
9. Seed Collection and Storage
10. Neighborhood Acceptance
11. Time – long-term commitment (maybe five years before plot looks like a prairie)
12. Cost

13. Site Analysis – Sunlight 70%–100% (Minimum 6 hours)
    Soil type and moisture:

Sand	Dry
Loam	Mesic
Clay	Wet

    Slope – Level is best.

Getting the Students Involved

1. Goal setting
2. Researching city ordinances regarding prairie establishment
3. Meeting with administration to discuss feasibility and find out what information is needed for administration approval
4. Preparing information for parents and neighbors
5. Analyzing cost – initial and long term
6. Management and maintenance responsibilities
7. Site Analysis
    - Number of hours of sunlight
    - Map the area.
    - Survey existing vegetation.
    - Determine slope or flatness.
    - Study drainage of soil and site.
    - Map existing structures (buildings, utilities—above and below). Call J.U.L.I.E.
    - Map traffic/usage patterns (design path, seating areas, etc.).
    - Analyze soil type (sandy, clay, loam).
    - Analyze soil moisture (dry, mesic, wet).
    - Analyze soil nutrients (nitrogen, phosphorus, potassium and pH).
    - Note pattern of shade and light. (Consider angle of shadows cast by buildings, trees, etc., at different times of the year.)
    - Analyze view in an effort to establish feeling of being in a prairie; screen out bad views as much as possible with tall prairie plants.
8. Research history of prairie plot:
    - Investigate the site using old plats, title abstracts, county histories.
    - Check with city historical society for map and old photos.
    - Interview previous owners and older residents.
    - Use original land surveys to determine presettlement vegetation and probable animal species present.
9. Establish a timeline and working calendar that identifies priorities and provides for long-term maintenance.
10. Keep accurate records, journal and photos as prairie establishment progresses.

How to Plant and Maintain a Prairie

1. Size Selection

2. Site Preparation – **most important step in a successful prairie**
    - Smooth, weed-free seed bed
    - Elimination of pre-existing vegetation

3. Seed/Plant Selection (grown within a 50–100 mile radius preferred)
    - For small prairies – transplants (flower quicker, but more costly)
    - For prairies >1000 sq. feet – seeds (take longer to flower, but cheaper)

4. Seed Storage – cool and dry in rodent-proof containers; check label for specific instructions.

5. Planting Dates
    - Transplants – best in the spring
    - Seeds – late spring; early summer (May 15–June 15); fall (late enough to avoid germination)

6. Seeding/Planting Rates – vary according to desired outcome
    - Seeds – 50% grass seed and 50% forb (wildflower); seed by weight (20 lbs./acre or 40 seeds/sq. foot, if hand broadcasting).
    - Transplants – 50-50 ratio for grasses to forbs, spacing randomly 1–3 feet apart

7. Planting Methods – Water regularly first 6-8 weeks (10–15 min.) in the early morning.
    - <u>Seeds</u>
      Hand broadcasting, if less than an acre or two
      Mechanical seed planting with a no-till drill
      Hydoseeding is not recommended.

    - <u>Transplants</u>
      Place deep enough in the soil so that bud/crown is 1" below the soil.
      Gently compress the soil around the plant.
      May mulch with 2–3" of weed-free straw or other mulch.

8. Weed Control – Shallow cultivation is recommended for weed control until planting.
    - <u>1st Year</u>:
      Disturb the soil as little as possible. Cut off large weeds with a shear to prevent seed drop.
    - <u>2nd Year</u>:
      In the spring, mow and rake off plant debris. If weeds persist, repeat in late spring or early summer (but not after prairie plants have reached a height of 1 foot or more).

- 3rd Year:
  Burn schedule can begin in early or mid-spring. Rotational burning of 1/3 to 1/2 annually is recommended. If burning is not an option, mow with raking off of debris in mid-spring.

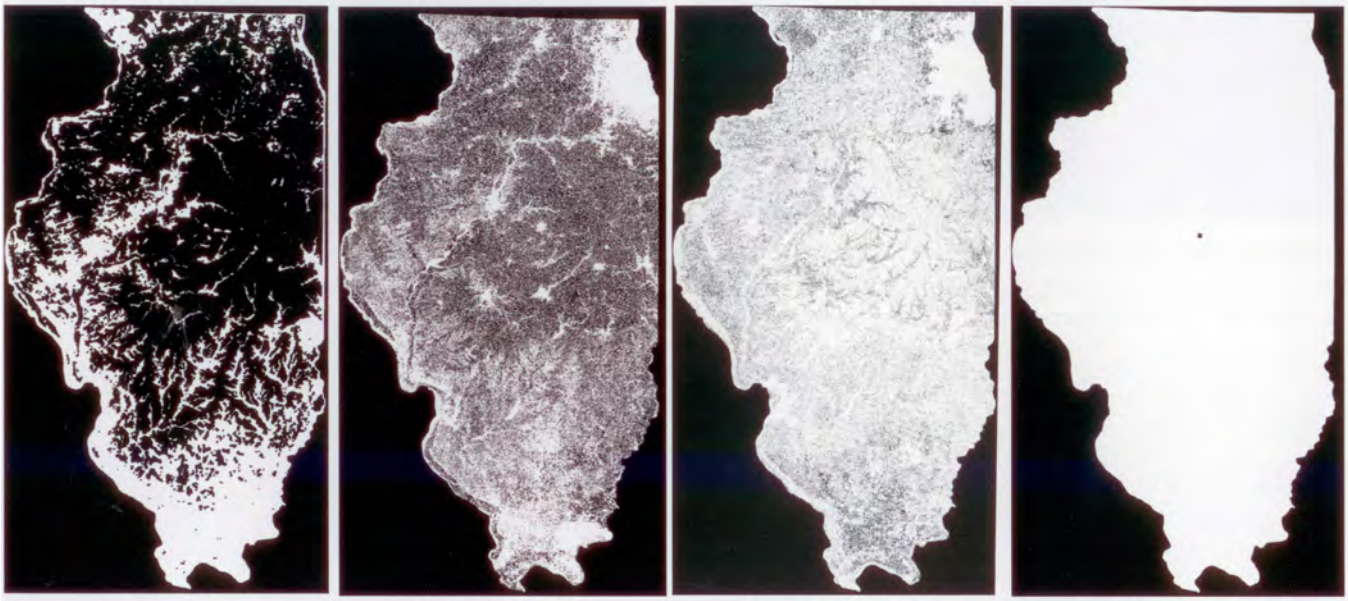
Plant Selection Suggestions for when Students are in Attendance

Early April – Mid-June

Pasque Flower, *Pulsatilla patens*
Pussytoes, *Antennaria neglecta*
Prairie Smoke, *Geum trifolium*
Early Buttercup, *Ranunculus fascicularis*
Prairie Dandelion, *Nothocalais cuspidata*
Common Violet, *Viola pratincola*
Prairie Violet, *Viola pedatifida*
Bird's-Foot Violet, *Viola pedata*
Wild Strawberry, *Fragaria maculatum*
Ground Plum, *Astragalus crassicarpus*
Wild Geranium, *Geranium virginiana*
Lousewort, *Pedicularis canadensis*
Blue-Eyed Grass, *Sisyrunchium campestre*
Shooting Star, *Dodecatheon meadia*
Yellow Stargrass, *Hypoxis hirsuta*
Hoary Puccoon, *Lithospermum canescens*
Prairie Ragwort, *Senecio plattensis*
Indian Paintbrush, *Castilleja coccinea*
Prairie Phlox, *Phlox pilosa*
False Indigo, *Baptisia bracteata*
Golden Alexander, *Zizia aurea*
Prairie Turnip, *Pediomelum esculentum*
False Dandelion, *Krigia biflora*
June Grass, *Koeleria macrantha*
Spiderwort, *Tradescantia bracteata*
Beardtongue, *Penstemon grandiflorus*
Locoweed, *Oxytropis lambertii*
Canada Anemone, *Anemone canadensis*
Soapweed, *Yucca glauca*
Blue Flag Iris, *Iris shrevei*
Prairie Rose, *Rosa arkansana*
Windflower, *Anemone cylindrica*
Spiked Lobelia, *Lobelia spicata*
Prairie Larkspur, *Delphinium virescens*
Swamp Milkweed, *Asclepias incarnata*

Mid-August – Late October

Butterfly Weed, *Asclepias tuberosa*
Hoary Vervain, *Verbena stricta*
Yellow Coneflower, *Ratibida pinnata*
St. John's Wort, *Hypericum sphaerocarpum*
Germander, *Teucrium canadense*
Self Heal, *Prunella vulgaris*
Meadow Sweet, *Spirea alba*
Flowering Spurge, *Euphorbia corollata*
Missouri Goldenrod, Solidago *missouriensis*
Showy Tick Trefoil, *Desmodium canadense*
Rattlesnake Master, *Eryngium yuccifolium*
Partridge Pea, *Chamaecrista fasciculata*
Rosinweed, *Siliphium integrifolium*
Evening Primrose, *Oenothera biennis*
Prairie Blazing Star, *Liatris pycnostachya*
Ironweed, *Vernonia fasciculata*
Hawkweed, *Hieracium umbellatum*
Great Lobelia, *Lobelia siphilitica*
Tall Goldenrod, *Solidago canadensis*
Sneezeweed, *Helenium autumnale*
Round-Headed Bush Clover, *Lespedeza cap*.
Field Goldenrod, *Solidago nemoral*
Flat-Topped White Aster, *Aster pubientor*
Stiff Goldenrod, *Solidago rigida*
Western Sunflower, *Helianthus occidentalis*
Saw-Tooth Sunflower, *Helianthus grosseser*
Jerusalem Artichoke, *Helianthus tuberosus*
Rough Blazing Star, *Liatris aspera*
Lance-Leaved Goldenrod, *Euthamia gramini*
White Sage, *Artemisia ludoviciana*
New England Aster, *Aster novea-angliae*
Aromatic Aster, *Aster oblongifolius*
Smooth Aster, *Aster laevis*
Heath Aster, *Aster ercoides*
Nodding Ladies' Tresses, *Spiranthes cernua*
Sideoats Grama, *Bouteloua curtipendula*
Switchgrass, *Pancium virgatum*
Indiangrass, *Sorghastrum nutans*
Prairie Cordgrass, *Spartina pectinata*
Prairie Dropseed, *Sporobolus heterolepis*
Big Bluestem, *Andropogon gerardi*
Little Bluestem, *Schizachyrium scoparium*
Bottle Gentian, *Gentiana andrewsii*
Sky Blue Aster, *Aster azureus*
Silky Aster, *Aster sericeus*
Panicled Aster, *Aster lanceolatus*
Willow Aster, *Aster praealtus*



Prairie 1820
(10 million hectares)

Agriculture 1999
Croplands

Grasslands 1999
Pastures, hayfields, roadsides, rights of way, etc

Representative Current Prairie Acreage
Remnant prairie
(1,050 hectares)

Figure 14. Changes in the Illinois landscape.

FQI Skill Builder

The Floristic Quality Index (FQI) is a vegetation-based ecological calculation that can be used for area quality monitoring and assessment. FQI is based on the Coefficient of Conservatism (C), which is a numerical rating (0–10) of an individual plant species' fidelity to specific habitats and tolerance of disturbance.

Plant species that have narrow habitat requirements (fidelity to a specific area) and/or little tolerance to disturbance have a high CC rating and vice versa. FQI calculations derived from on-site vegetation data and the average *C*-values have been found to be effective indicators of area quality and are widely used.

Using data derived from specific quadrat averages, can you determine the FQI for Student Plot 16B in 2015? Let's do this one together.

STEP 1: Go to the Fermilab school data at http://eddata.fnal.gov/lasso/quadrats/study-sum.lasso.

STEP 2: Scroll to Fermilab 16B and click *Full Data*.

STEP 3: WHOA! Lots of data! Let's narrow this down. Go to *Current Data Summaries* toward the top of the page.

STEP 4: Select Lederman Science Education Center to view the plots surveyed by the 2015 summer workshop participants.

STEP 5: Count the number of native species on the list. Do you get 26?

STEP 6: Compare each species to the Prairie Plant Database by Common Name found in the *Resources* section and at http://eddata.fnal.gov/lasso/quadrats/show-plants-add.lasso. [Note the CC Rating. Did you notice that two plants, compass dock hybrid and sedge spp., are not noted with a CC rating? They are not included in the FQI calculation because they are anomalies of native plants. Reduce your total plant species by 2. Other plants do not have a CC rating because they are nonnative plants.]

STEP 7: Add the individual CC ratings and divide by 24 to determine the average C-value. 124/24 = 5.17. The square root of 24 = 4.9.

STEP 8: Calculate!

FQI = Floristic Quality Index

C = Average Coefficient of Conservation for native species (124/24 = C-value.)

N = Number of Species (in this case, 24)

FQI = (C/N) x (square root of N)

FQI = 5.17 x 4.9

FQI = 25.33

Thinking about the results . . .

1. Access the FQI Fermilab Resource for the various sites on the Fermilab campus. What do you note as the ecologists' data for 16B FQI, Average C and Species Count? When compared to the FQI Fermilab Resource, we see that this FQI is very low. How would you explain this discrepancy?

   Much more area in 16B was observed by the ecologists over the course of the blooming season. In biological science, as with all science disciplines, a key to validity and reliable data is replication—or, in this case, many observations over time. For some species within an ecosystem, evidence of plants blooming in April has dissipated by July and is all but gone by October.

2. This exercise is an authentic representation of the type of data gathered by ecologists. How does engaging in the activity help your broad view of the work of ecologists? Why are these data important?

   The average person is generally unaware of the time and expertise necessary to conduct botanical surveys. Many skills and significant patience is required to provide accurate data. The work of ecologists and citizen scientists is to natural areas, as it helps to indicate trends over time. This information is used by ecologists to indicate the health of an ecosystem and to plan needed interventions to promote the maintenance and sustainability of an area.

3. Engaging students in the work of gathering data becomes a real-world scenario as we collectively consider the ecosystem services provided by the natural areas of our region and the world. How might you use this experience to foster a deeper interest in the ecosystems near your students' homes, school or regional areas?

   Much data is needed to create a truer picture of an ecosystem. Students as citizen scientists are able to function in this role with the proper instruction. As students participate in meaningful data collection, they recognize that these are everyone's efforts —and that anyone with the commitment to learn about ecosystems can promote environmental awareness and health.

4. The NGSS MS-LS2: *Ecosystems: Interactions, Energy, and Dynamics* relationship performance expectations (PE) strive to help students answer the question: "How does a system of living and nonliving things operate to meet the needs of an organism in an ecosystem?" With this PE in mind, how can ecosystem surveys contribute to the wellbeing of individual organisms within that system?

Responses will vary. Plant diversity and the interdependent role of all the organisms in an ecosystem, coupled with critical abiotic factors, provide for success of an ecosystem. An understanding of these interrelationships and a bank of reliable data assist ecologists and citizen scientists alike to assess the condition of natural areas.

5. Using the data generated by your class, determine the FQI of your area this year. Do you think the FQI excellence numbers have different scales for different areas?

   Responses should take into consideration the variance between the natural areas through the Fermilab campus. FQI variance from ecosystem to ecosystem, for instance, prairie in Plot 16B and Plot 1, is due largely to the maturity and enrichment of Plot 1 over time. Its FQI is higher than 16B. certain plants that thrive in Plot 1 are just now making an appearance in 16B because it takes time for soil to replenish to the point that certain conservative (rare) plants to get a foothold. Comparing Plot 16B to other younger or minimally enriched plots also shows diversity advancement.

LMU Quality Metrics

Friday, March 11, 2016
10:08:36 AM

Based on survey data from 2006 till 2015

LMU	FQI	Average C	Species Count
MR SW Quad	72	4.9	216
Indian Creek Woods	71	4.6	241
MR NW Quad	66	4.9	181
Big Woods South	66	4.4	225
Big Woods	65	4.6	197
Prairie 15	64	5.0	165
MR NE Quad	62	5.0	151
Prairie 14	61	5.0	150
Wetland Mitigation	60	4.6	169
MR Savanna	57	4.2	179
Prairie 12	57	4.7	149
BNSF Prairie	55	5.2	113
Morgan's Woods	55	4.9	123
MR SE Quad	52	4.6	128
EJ&E Prairie	51	5.0	105
Prairie 17	50	4.4	131
Big Woods North	49	3.9	155
Prairie 24	49	4.3	134
Prairie 16B	49	5.1	90
Prairie 18	47	4.7	98
Prairie 16	47	4.4	114
Site 29 Woods West	47	3.8	155
Site 29 Woods East	46	4.1	124
Prairie 22	46	4.4	110
Ed Center Woods	46	4.2	123
Big Woods PS	45	4.1	123
Owl's Nest Woods	44	4.1	112
Prairie 19	43	4.2	107
Prairie 21	39	4.0	95
Arbor Day South	37	5.0	55
Big Woods A1-A2	36	4.5	64

LMU	FQI	Average C	Species Count
Girl Scout Woods	36	3.9	86
Site 29 Woods South	35	3.8	87
Bison Savanna	34	3.9	76
Prairie 23	33	4.5	53
Giese Rd Woods 5	33	3.6	86
MR West Woods	31	3.5	79
Kingnut Woods	29	3.8	58
Prairie 17 East	29	4.6	38
Giese Rd Woods 3	28	3.7	57
Site 12 Woods	27	3.8	52
Giese Rd Woods 1	25	3.2	61
Eola Rd Grassland South	24	3.1	60
Lederman Woods	24	3.8	41
Eola Rd Grassland Northwest	23	3.3	49
Eola Rd Grassland Far South	22	3.1	50
Nepese Marsh	22	3.7	35
Giese Rd Woods 2	21	3.1	45
Ed Center Pond	17	4.0	18
Giese Rd Woods 4	17	3.0	33
Miscellaneous	9	9.0	1

FQI > 65 is Very High

FQI between 51 and 65 is High

FQI between 36 and 50 is Medium

FQI between 20 and 35 is Low

Plant Species	Common Name	Family	Nat/Adv	A/B/P	Physiog	C	W	2015	2016	2017	2018
Acer negundo	box elder	Aceraceae	Native	Perennial	tree	0	-2	4			
Acer saccharinum	silver maple	Aceraceae	Native	Perennial	tree	0	-3	3			
Acer saccharum	sugar maple	Aceraceae	Native	Perennial	tree	3	3	1			
Alliaria petiolata	garlic mustard	Cruciferae	Adventive	Biennial	forb	0	0	1			
Arisaema dracontium	green dragon	Araceae	Native	Perennial	forb	7	-3	2			
Aster lateriflorus	side-flowering aster	Compositae	Native	Perennial	forb	4	-2	4			
Aster sagittifolius drummondii	drummond's aster	Compositae	Native	Perennial	forb	2	3	1			
Berberis vulgaris	European barberry	Berberidaceae	Adventive	Perennial	shrub	0	3	2			
Boehmeria cylindrica	false nettle	Urticaceae	Native	Perennial	forb	2	-5	4			
Campanula americana	tall bellflower	Campanulaceae	Native	Annual	forb	3	0	2			
Carya cordiformis	bitternut hickory	Juglandaceae	Native	Perennial	tree	7	3	3			
Celtis occidentalis	hackberry	Ulmaceae	Native	Perennial	tree	3	1	1			
Cicuta maculata	water hemlock	Umbelliferae	Native	Perennial	forb	6	-5	1			
Cinna arundinacea	common wood reed	Gramineae	Native	Perennial	grass	5	-3	4			
Cornus racemosa	gray dogwood	Cornaceae	Native	Perennial	shrub	1	-2	2p			
Cornus stolonifera	red-osier dogwood	Cornaceae	Native	Perennial	shrub	6	-3	1			
Crataegus coccinea	scarlet hawthorn	Rosaceae	Native	Perennial	tree	4	5	3			
Cryptotaenia canadensis	honewort	Umbelliferae	Native	Perennial	forb	2	0	4			
Elymus virginicus	virginia wild rye	Gramineae	Native	Perennial	grass	4	-2	3			
Euonymus atropurpureus	wahoo	Celastraceae	Native	Perennial	shrub	8	1	1p			
Eupatorium rugosum	white snakeroot	Compositae	Native	Perennial	forb	4	5	1			
Fraxinus pennsylvanica subintegerrima	green ash	Oleaceae	Native	Perennial	tree	1	0	4			
Geum canadense	wood avens	Rosaceae	Native	Perennial	forb	1	0	4			
Hystrix patula	bottlebrush grass	Gramineae	Native	Perennial	grass	5	5	1			
Juglans nigra	black walnut	Juglandaceae	Native	Perennial	tree	5	3	2			
Laportea canadensis	wood nettle	Urticaceae	Native	Perennial	forb	3	-3	1p			
Lonicera maackii	amur honeysuckle	Caprifoliaceae	Adventive	Perennial	shrub	0	5	5			
Malus pumila	apple	Rosaceae	Adventive	Perennial	tree	0	5	1			
Menispermum canadense	moonseed	Menispermaceae	Native	Perennial	vine	6	-1	3			
Morus alba	white mulberry	Moraceae	Adventive	Perennial	tree	0	0	1			
Phalaris arundinacea	reed canary grass	Gramineae	Adventive	Perennial	grass	0	-4	1p			
Pinus sylvestris	scotch pine	Pinaceae	Adventive	Perennial	tree	0	5	1			
Polygonum scandens	climbing false buckwheat	Polygonaceae	Native	Annual	vine	1	0	1			
Polygonum virginianum	woodland knotweed	Polygonaceae	Native	Perennial	forb	2	0	2			
Populus deltoides	eastern cottonwood	Salicaceae	Native	Perennial	tree	2	-1	1			
Prunella vulgaris lanceolata	self heal	Labiatae	Native	Perennial	forb	0	3	1			
Prunus serotina	wild black cherry	Rosaceae	Native	Perennial	tree	1	3	3			
Prunus virginiana	choke cherry	Rosaceae	Native	Perennial	shrub	3	3	2p			
Quercus bicolor	swamp white oak	Fagaceae	Native	Perennial	tree	6	-4	4			
Quercus macrocarpa	bur oak	Fagaceae	Native	Perennial	tree	5	1	1			
Quercus rubra	red oak	Fagaceae	Native	Perennial	tree	7	3	2			
Rhamnus cathartica	common buckthorn	Rhamnaceae	Adventive	Perennial	shrub	0	3	5			
Rhus radicans	poison ivy	Anacardiaceae	Native	Perennial	vine	2	-1	5			
Ribes americanum	wild black currant	Saxifragaceae	Native	Perennial	shrub	7	-3	3p			
Ribes missouriense	wild gooseberry	Saxifragaceae	Native	Perennial	shrub	5	5	4			
Rosa multiflora	multiflora rose	Rosaceae	Adventive	Perennial	shrub	0	3	2			
Rubus occidentalis	black raspberry	Rosaceae	Native	Perennial	shrub	2	5	2p			
Sambucus canadensis	elderberry	Caprifoliaceae	Native	Perennial	shrub	1	-2	2			
Smilax ecirrhata	upright carrion flower	Liliaceae	Native	Perennial	forb	5	5	1			
Solidago altissima	tall goldenrod	Compositae	Native	Perennial	forb	1	3	1p			
Spiranthes cernua	nodding ladies' tresses	Orchidaceae	Native	Perennial	forb	7	-2	1			
Tilia americana	american linden	Tiliaceae	Native	Perennial	tree	5	3	3			
Ulmus rubra	slippery elm	Ulmaceae	Native	Perennial	tree	4	0	4			
Verbena urticifolia	hairy white vervain	Verbenaceae	Native	Perennial	forb	5	5	1			
Viburnum opulus	European highbush cranberry	Caprifoliaceae	Adventive	Perennial	shrub	0	3	1			
Vitis riparia	riverbank grape	Vitaceae	Native	Perennial	vine	2	-2	2			
Xanthoxylum americanum	prickly ash	Rutaceae	Native	Perennial	shrub	3	5	2p			
	1 = 1–5 plants							57			
	2 = 6–25 plants							47			
	3 = 26–100 plants							10			
	4 = 101–1000 plants							3.6			
	5 = >1000 plants							**25**			
	1p = 15 patches										
	2p = 6–25 patches, etc.							0.4			
								0.8			

Surveyed by: Date:

Common Wetland Plants at Lederman Science Center Pond

Plant Species	**Common Name**	**Native**
Acorus calamus	Sweet Flag	
Apocynum cannabinum	Indian Hemp	
Asclepias incarnata	Swamp Milkweed	
Aster novae-angliae	New England Aster	
Caltha palustris	Marsh Marigold	
Carex spp.	Sedge spp.	
Eleocharis obtusa	Blunt Spike Rush	
Equisetum arvense	Horsetail	
Equisetum hyemale	Tall Scouring Rush	
Eupatorium altissimum	Tall Boneset	
Eupatorium perfoliatum	Common Boneset	
Iris virginica shrevei	Blue Flag	
Pedicularis lanceolata	Fen Betony	
Pycnanthemum virginianum	Common Mountain Mint	
Silphium perfoliatum	Cup Plant	
Solidago graminifolia	Common Grass-Leaved Goldenrod	
Typha Angustifolia	Narrow-Leaved Cattail	
Verbena hastata	Blue Vervain	
Vermonia fasciculata	Common Ironweed	

Causes and Effects of Water Chemistry

Testing for…	Desired Level	A Few Causes of Poor Levels…	A Few Problems from Poor Levels…
Temperature °C	Between 10 °C and 20 °C	Car emissions Too many buildings Cutting down trees	Low oxygen levels Disease, macroinvertebrate and fish kills Low biodiversity
Dissolved Oxygen DO	High levels	Heat Fertilizer Bird waste	Less oxygen for animals Disruption in the food web
pH Neutral 0 - 7 - 14 Acidic Basic	Close to 7	Car emission Coal burning Acid rain	Macroinvertebrate and fish kills Deformed animals
Phosphate PO_4	Low levels	Soap Sewage	Algae blooms Rotten egg smell Low oxygen levels
Nitrate NO_3	Low levels	Sewage Fertilizer Bird waste	Algae blooms Rotten egg smell Low oxygen levels
Turbidity Water Clarity	Moderate	Soil erosion Too many bottom feeders	Soil holds heat and lowers oxygen levels Blocks the sun from getting to plants
Fecal Coliform Bacteria	Low levels	Sewage Animal waste	Poisons living things

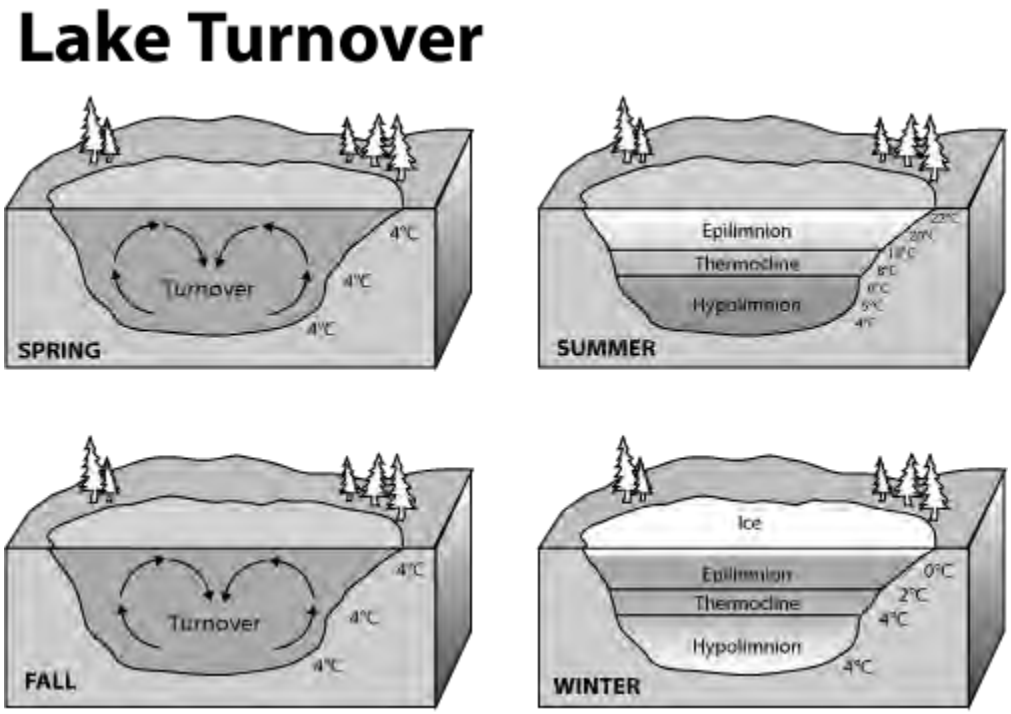
Lake/Pond Stratification and Turnover

Lakes and large, deep ponds in Northern Illinois are typically separated into three layers, defined by their temperature:

1. Epilimnion – the top layer, susceptible to wind effect
2. Metalimnion – the middle layer, with the most rapidly changing temperature region, the thermocline band
3. Hypolimnion – the bottom layer, the darkest and densest layer

In larger or deeper bodies of water, these layers are at different depth bands throughout the seasons. Shallow lakes and ponds generally have only one layer. Temperature is critical in forming the layers, or stratifications, as it defines the density of fresh water. Understanding thermal stratification is important in pond/lake management.

A common misconception is that ice at 0 °C is the densest water-form temperature. In fact, water is at its densest at about 4 °C. Notice that in all seasons, the bottom of the lake is 4 °C, thus it is the densest layer. Notice also that in ponds/lakes that form ice, the water temperature is 4 °C for a period in the spring and fall. These equalized periods can last for days or weeks depending on abiotic conditions, specifically wind and intensity of sunlight.



In spring and fall, the water temperature equalizes and becomes about the same temperature; thus, turnover occurs. Another common misconception is that the lake's

layers literally exchange places when they are actually *mixing*. As the turnover period begins, the stratification layers begin to change. The metalimnion layer thins and the differences between the densities become much closer. This layer is not at a fixed depth level as it is higher in the early spring after the ice thaws, and lower as fall approaches. The spring and fall winds hasten the turnover process and dramatic changes in water clarity and apparent water quality can occur in a matter of hours. The metalimnion region is the most rapidly changing temperature stratification region despite being quite resistant to wind mixing. The thermocline is a horizontal plane ***within*** the metalimnion related to the point of greatest water temperature change.

Typically, the most dramatic turnover is in the fall. Debris, including much organic matter, mixes throughout the water and can lead to unpleasant odors and turbidity, cloudiness, which may be perceived as an unhealthy body of water. Fish and other aquatic organisms sense this natural signal and behavior patterns change. Avid fishermen may find their luck abandons them during this period. This metalimnion region is where many game fish reside. It is richer in oxygen than warmer surface regions in the summer epilimnion but, depending on the depth of the lake, is still within the sunlight zone, which helps ensure ample food source.

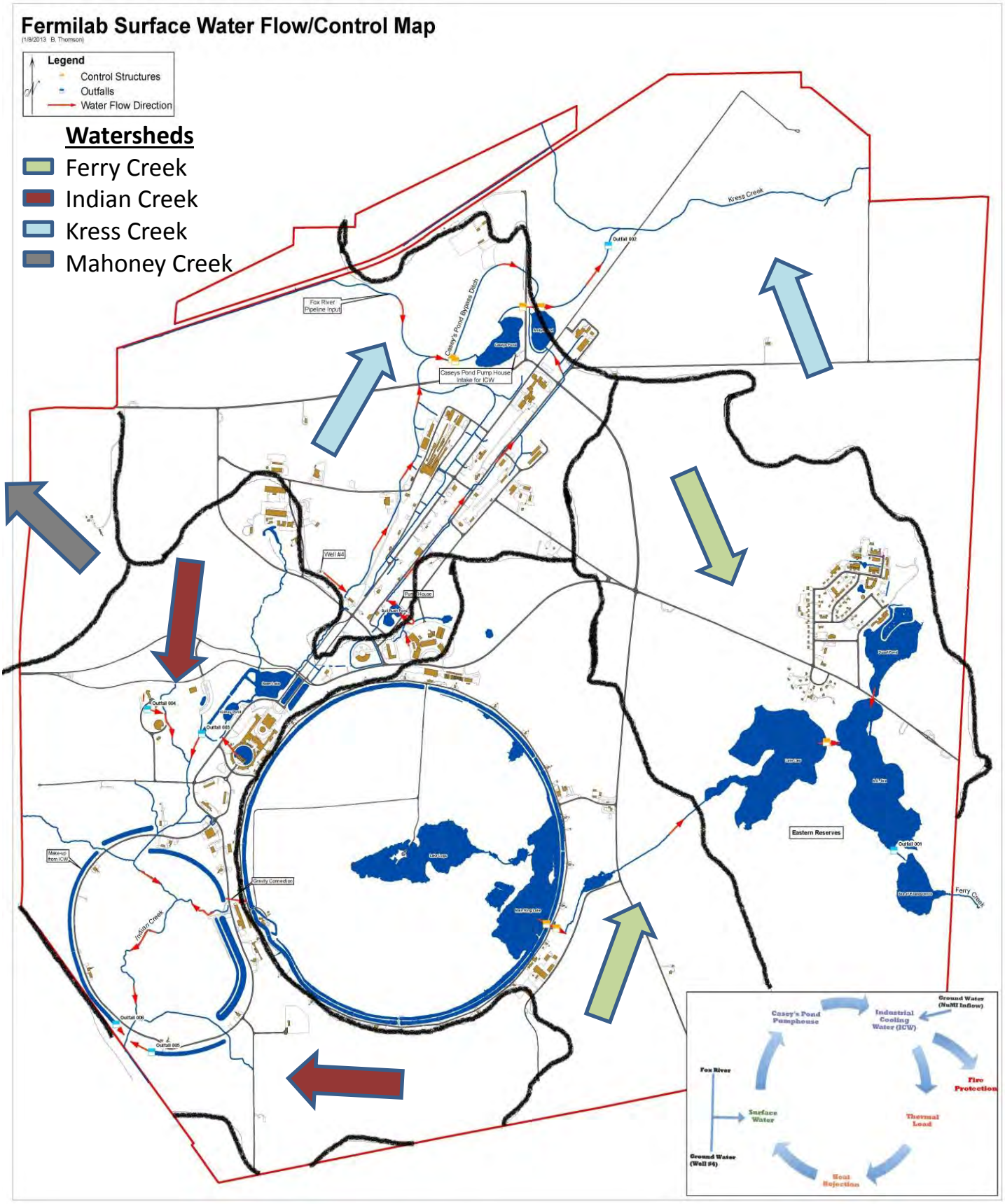
Natural resource managers may take measures to mediate potentially dangerous pond/lake conditions. Particularly harsh winter and summer seasons can overly stress organisms. For example, a body of water that becomes too warm and loses oxygen beyond a safe level can experience widespread fish kills. Aeration and introducing biodegrading bacteria (decomposing organic matter in the hypolimnion region to deepen the pond/lake) strategies are helpful but not always advised. Maintaining a natural metalimnion layer is optimum for a healthy pond/lake ecosystem.

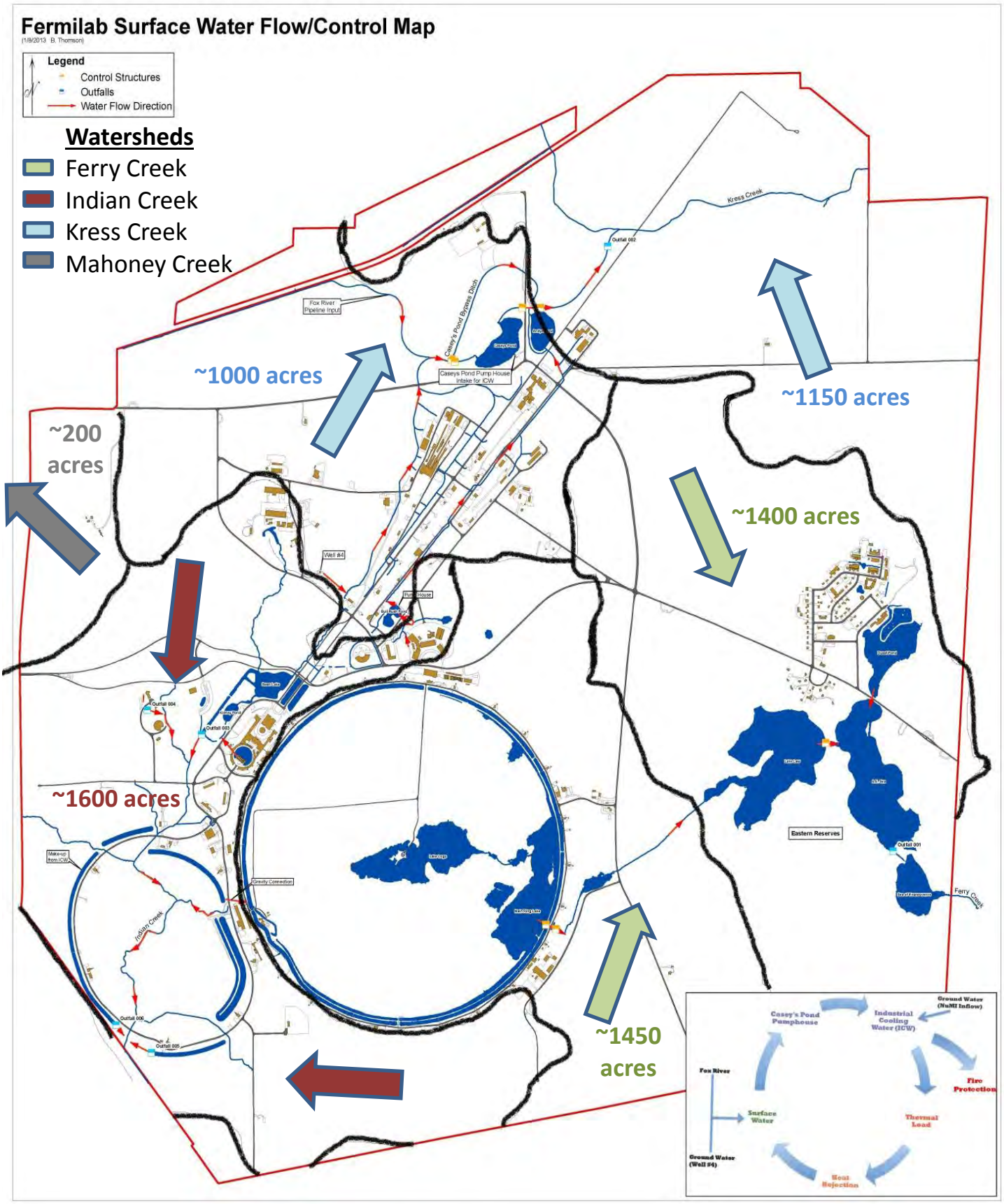
Online Demonstration:
View these rather lengthy, but highly informative videos about thermal stratification. NOTE: In Video 2 at approximately 23 minutes is a serious misstatement. Seasonally, it is not the distance from the sun, but the angle of the sun, that changes the intensity of the sun's rays.

Stan Gregory, a Ph.D. professor of fisheries and wildlife sciences at Oregon State University, uses a model lake in a laboratory to demonstrate the principles of lake stratification to his Oregon State Ecampus students. Aug 17, 2012

Video 1, 11:53 min: https://www.youtube.com/watch?v=XExQ6uaDEJQ
Video 2, 28:12 min: https://www.youtube.com/watch?v=DIT51AosbcA&feature=youtu.be

Article by Illinois Environmental Protection Agency:
http://epa.state.il.us/water/conservation/lake-notes/lake-stratification-and-mixing/lake-stratification.pdf


Fermilab Surface Water Flow/Control Map
(1/8/2013 B. Thomson)
Legend
Control Structures
Outfalls
Water Flow Direction
Watersheds
Ferry Creek
Indian Creek
Kress Creek
Mahoney Creek
Kress Creek
Outfall 002
Fox River Pipeline Input
Casey's Pond Bypass Ditch
Casey's Pond Pump House Intake for ICW
Well #4
Pump House
Outfall 004
Outfall 003
Make-up from ICW
Gravity Connection
Indian Creek
Outfall 006
Outfall 005
Eastern Reserves
Outfall 001
Ferry Creek
Casey's Pond Pumphouse
Industrial Cooling Water (ICW)
Ground Water (NuMI Inflow)
Fire Protection
Thermal Load
Heat Rejection
Ground Water (Well #4)
Surface Water
Fox River


Fermilab Surface Water Flow/Control Map
(1/8/2013 B. Thomson)
Legend
Control Structures
Outfalls
Water Flow Direction
Watersheds
Ferry Creek
Indian Creek
Kress Creek
Mahoney Creek
~1000 acres
~1150 acres
~200 acres
~1400 acres
~1600 acres
~1450 acres
Kress Creek
Outfall 002
Fox River Pipeline Input
Casey's Pond Bypass Ditch
Casey's Pond Pump House Intake for ICW
Well #4
Pump House
Outfall 004
Outfall 003
Make-up from ICW
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Industrial Cooling Water (ICW)
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Thermal Load
Heat Rejection
Ground Water (Well #4)
Surface Water
Fox River

Sampling Terrestrial Invertebrates

Topic: To compare invertebrate numbers, species, and niches of invertebrates found within the vegetative litter in the soil of the prairie and the forest (or other ecosystem).

Objectives: Students will:

- Identify soil organisms using physical characteristics.
- Analyze physical characteristics (mouthparts) to determine the niche of terrestrial invertebrates.
- Compare diversity and frequency of invertebrates of the prairie with those of the forest (or other ecosystem).
- Relate the contributions of terrestrial invertebrates to the **health of natural areas**, especially to the energy cycle.

Narrative/Background Information:
When we observe the richness of a prairie, we see a diverse array of forbs and grasses. The sounds of and sights of insects and birds moving from plant to plant are bountiful. Less obvious is the presence of the organisms known as terrestrial invertebrates existing at or below the surface of the soil. These organisms contribute to the processes required to sustain the ecosystem. The distribution of nutrients and control of biomass is part of these critical processes.

One of the most remarkable characteristics of a natural ecosystem is its capacity to sustain and maintain itself. While perfect balance is a misconception in ecology, we understand that certain key processes must be in place to help ensure the health of an ecosystem. The prairie is distinguished in that it provides a rich environment for a highly diverse and numerous community (as many as 100,000 springtails can exist in one square meter of prairie soil!) of living organisms. Many of the terrestrial invertebrates help ensure that remains of dead organisms—both plant and animal—do not accumulate. There is an inevitable piling up of materials on the prairie and forest floor that remains until the area is burned, but the work of the terrestrial invertebrates is also of critical importance.

This is true throughout different ecosystems. In streams, lakes and ponds, organic materials can smother the beds and bottoms of waterways without a means to counter the debris. The surface of the prairie and woodland floor may appear to be a lifeless carpet of natural refuse and dead leaves, but immediately below the top layer are the decaying remains of other seasons, occupied by a busy community of tiny organisms. Deeper still, the humus, dark spongy material formed from the litter, is honeycombed with passageways and burrows of insects, worms, small vertebrates such as moles and voles, and the roots of plants. It is at this level, within a fraction of a meter below the surface of the soil in prairies, forests, and other ecosystems, that the majority of decomposition takes place. Terrestrial invertebrates contribute to the decomposition of organic material produced by organisms that have lived—and died—in an ecosystem. They initially breakdown many of these items and prepare them for the microorganisms

that complete the decomposition process. Through decomposition, vital nutrients are returned to the soil. In this manner, the energy cycle is sustained as plants, through photosynthesis, capture energy from the sun and reuse these nutrients to begin the food chain anew.

Collecting terrestrial invertebrates is accomplished in a variety of ways. The Berlese method offers an inexpensive strategy with the opportunity to collect live organisms if desired. To collect living organisms, simply modify the suggested setup by tightly taping the funnel to the collecting jar and eliminating the alcohol. If live organisms are collected, return the specimens to their habitat as quickly as possible. Specimens that drop into alcohol quickly die and may be reused year after year if stored in alcohol.

The Berlese setup works by changing the conditions in which the organisms live. These organisms live beneath the surface of the soil. Therefore, they are adapted for and prefer conditions that are cooler, darker, and moister than on the surface of the soil. As the light bulb causes the litter sample to become lighter, warmer, and drier than they prefer, they will burrow deeper to escape the conditions and eventually drop from the funnel into the jar.

A familiarity with the major invertebrate phyla found on the woodland floor and the base of the prairie helps the student understand the complexities of these systems. If the sample comes from a richly organic, diverse plot, students should discover a wide variety of invertebrates. These specimens usually include herbivores (plant eaters), carnivores (animal eaters), and omnivores (consume both plants and animals). Observing and analyzing the physical characteristics of these organisms, especially the mouthparts, provide clues to the organism's niche within the ecosystem.

Materials:

- Insect Field Guide
- Access to Internet – Insect Keys
  http://www.earthlife.net/insects/orders-key.html#key
- Berlese funnel setup
- WANTED posters
- Sampling and observation equipment such as:
  - Trowels
  - Assorted bags or containers
  - Plastic Petri dishes
  - Probes (may be as simple as plastic straws cut on an angle)
  - Magnifying lenses (Reflective light or dissecting microscopes are recommended.)

Process:

1. Select the sampling sites to compare. Students will conduct a terrestrial invertebrate sampling at Fermilab, school site, or other prairie. The woodland ecosystem sampling is a pre-visit experience arranged by the teacher. (Invertebrate analysis using a Berlese funnel can be done in any habitat. If access to a woodland is not

available, two other ecosystems including the schoolyard may be substituted.) Aquatic sampling is conducted onsite using other means in the *Aquatic Diversity* investigation.

2. Provide each student team (a four-member team is suggested) with a small, defined plot to sample. Sample plots may be defined with string, small hoops or other devices that can be standardized. [NOTE: If a richly organic, on-school site is not available, consider collecting (with permission) from a nearby park, garden, etc. The area beneath a birdfeeder often yields a rich sample.]
3. Instruct the students to collect at least 50 cm^3 of leaf litter including some soil. Instruct the students to place the sample in a plastic bag or container and label the sample with the date, location, and any other pertinent data you wish to include.
4. Upon return to the classroom, set up the Berlese funnel apparatus according to the diagram. Instruct students to empty the contents of their sample bags into the funnel. Leaf litter and soil should come nearly to the top of the funnel without overflowing. (Multiple Berlese funnel setups are useful for speeding up the collection process.) The light bulb should be positioned above the material close enough to provide heat and light, but not so close that it roasts the organisms before they can escape the heat. Keep the light burning day and night for at least 24 hours. (Some setups take several days to produce specimens.)
5. Using a plastic, disposable spoon, transfer small quantities of the collected specimens to open Petri dishes. Try to distribute specimens such that not too much leaf litter also enters the dish. Fresh specimens are especially good because less dense organisms such as springtails float to the surface and are easily identified. One collection jar should provide enough material for many dishes. Replenish the alcohol as it evaporates since it preserves the specimens and, when using magnification, provides uniform light diffraction.
6. Using magnification and a probe, students investigate the material for invertebrates. Instruct students to record the number and category (herbivore, omnivore, or carnivore) for each invertebrate, and sketch the organisms they find.

Name: _____

Student Reflection: Sampling Terrestrial Invertebrates

1. What are the differences and similarities between the invertebrate populations of the prairie, wetland and the woodland (or other comparison)?

2. How do the types of invertebrates found indicate certain environmental conditions?

3. How do these invertebrates correlate with the presence of specific fauna or flora? (Life history research is helpful here.) Example: In a wooded area, fallen trees almost always guarantee pillbugs and centipedes.

4. Describe the differences between the physical characteristics of herbivorous and carnivorous terrestrial invertebrates.

5. Ecosystems are typically densely populated with an array *of* plants, millions of invertebrates representing many species, and many other animals. The plants and animals replenish themselves every year. In fact, the invertebrates may produce many generations of offspring each season. Why do these organisms, coupled with amphibians, reptiles, birds, and mammals not pile up incredibly as they die?

6. It takes energy to live. How do living organisms get this energy?

7. What questions can you pose about invertebrates, biomass, and energy transfer in these ecosystems? What measurements might you make to answer your questions?

The original tallgrass prairie prepared much of the Midwest to become one of the most prolific farmland in the world. The Department of Agriculture is interested in learning all it can about the prairie ecosystem; using the information you learned through your study of terrestrial invertebrates, prepare a report that will explain the role of these organisms in the development and sustenance of the tallgrass prairie. Provide details about the insect's adaptations for survival. Apply these concepts to invertebrates in the woodland and wetland ecosystems as well.

Teacher Page

Student Reflection Suggested Responses: Sampling Terrestrial Invertebrates

1. What are the differences and similarities between the invertebrate populations of the prairie, wetland and the woodland (or other comparison)?

   Responses will vary depending on the organisms found. Expect specificity in physical appearance and adaptations for the organisms' habitats.

2. How do the types of invertebrates found indicate certain environmental conditions?

   Responses will vary depending on the organisms found. However, since all of these invertebrates are terrestrial, some qualities may be similar. For example, many organisms such as pillbugs and centipedes live successfully in several distinct ecosystems. However, the likelihood of collecting large quantities of springtail is greater in the prairie than in the woods. Wetland areas reveal many organisms with even more diverse adaptations.

3. How do these invertebrates correlate with the presence of specific fauna or flora? (Life history research is helpful here.)

   Responses will vary. Example: In a wooded area, fallen trees almost always guarantee pillbugs and centipedes. Water-dwelling organisms such as caddisfly nymphs often are found in riffle areas under rocks.

4. Describe the differences between the physical characteristics of herbivorous and carnivorous terrestrial invertebrates.

   Expect specificity, especially in describing the mouthparts. Herbivores typically exhibit chewing mouthparts while carnivores usually are adapted for biting and/or tearing.

5. Ecosystems are typically densely populated with an array *of* plants, millions of invertebrates representing many species, and many other animals. The plants and animals replenish themselves every year. In fact, the invertebrates may produce many generations of offspring each season. Why do these organisms, coupled with amphibians, reptiles, birds, and mammals not pile up incredibly as they die?

   Terrestrial invertebrates contribute to the decomposition of organic material produced by organisms that have lived—and died—in an ecosystem. They initially break down many of these items and prepare them for the microorganisms that complete the decomposition process.

6. It takes energy to live. How do living organisms get this energy?

   The energy we use to perform life functions originated from the sun. Plants, through photosynthesis, capture energy from the sun and reuse nutrients released through decomposition of organic matter to begin the food chain. Terrestrial invertebrates contribute to the decomposition of organic material produced by organisms that have lived—and died—in an ecosystem. They initially break down many of these items and prepare them for the microorganisms that complete the decomposition process. Through decomposition, vital nutrients are returned to the soil.

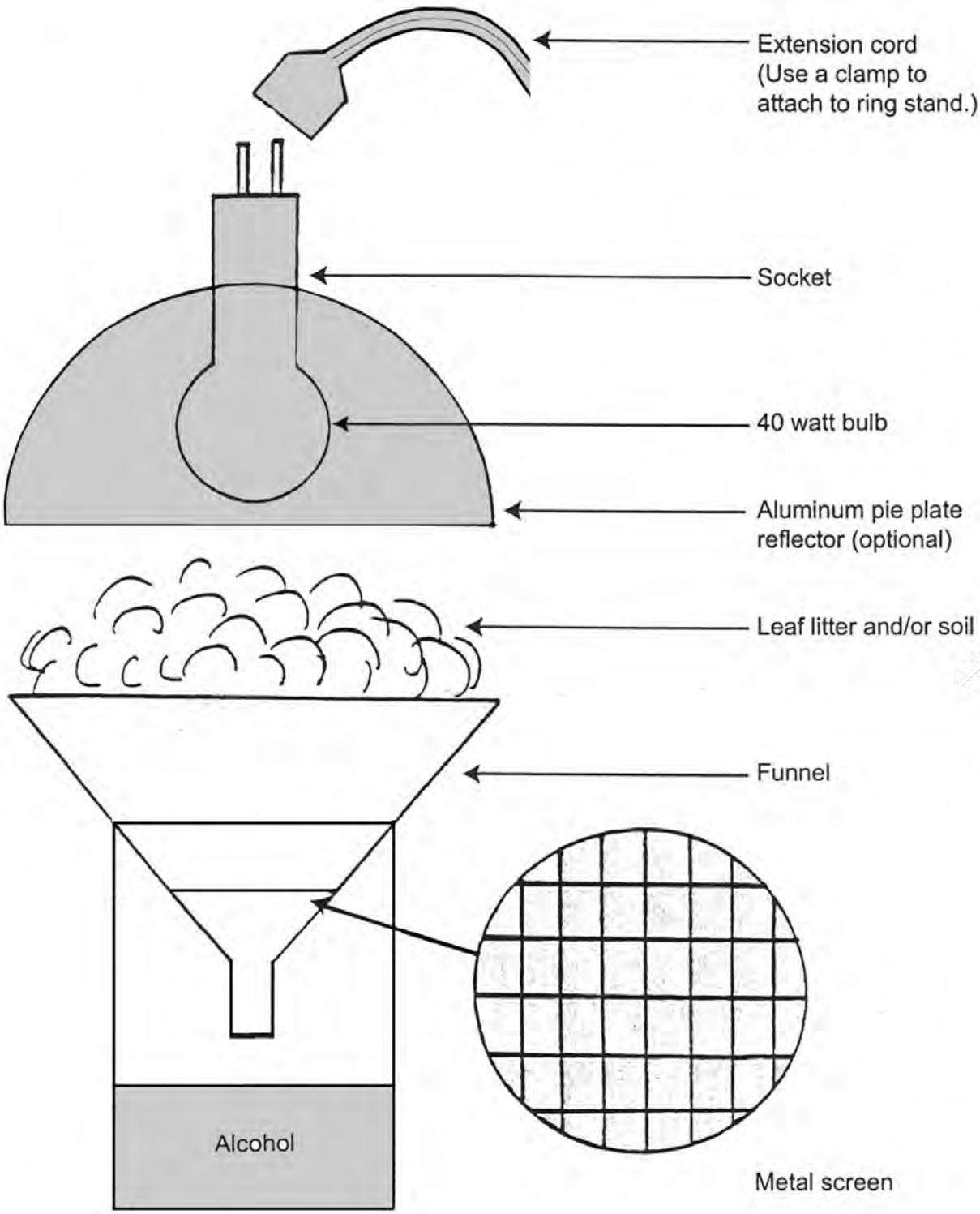
7. What questions can you pose about invertebrates, biomass, and energy transfer in these ecosystems? What measurements might you make to answer your questions?

   Responses will vary. Expect specificity.

The original tallgrass prairie prepared much of the Midwest to become one of the most prolific farmland in the world. The Department of Agriculture is interested in learning all it can about the prairie ecosystem; using the information you learned through your study of terrestrial invertebrates, prepare a report that will explain the role of these organisms in the development and sustenance of the tallgrass prairie. Provide details about the invertebrates' adaptations for survival. Apply these concepts to invertebrates in the woodland and wetland ecosystems as well.

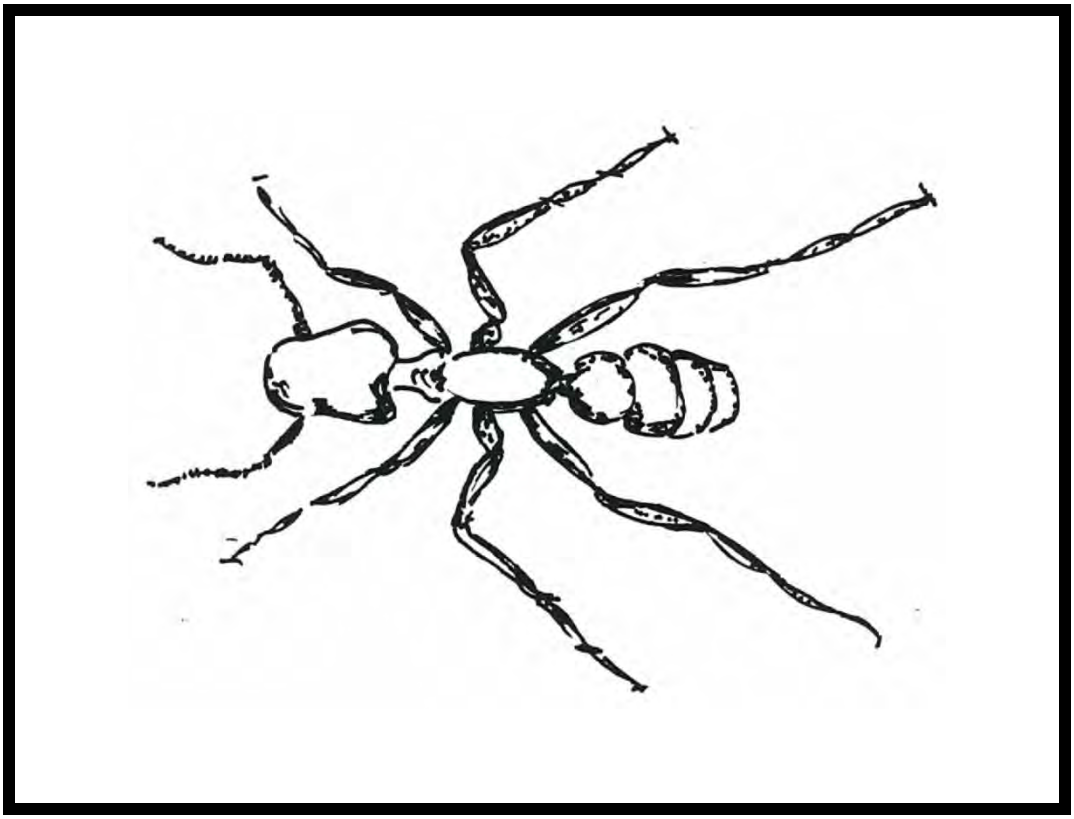
Expect a degree of sophistication as determined by the teacher and communicated to the student prior to assigning this task.

Berlese Apparatus



WANTED

For Being an Omnivore



Ant

This organism has been known to eat:

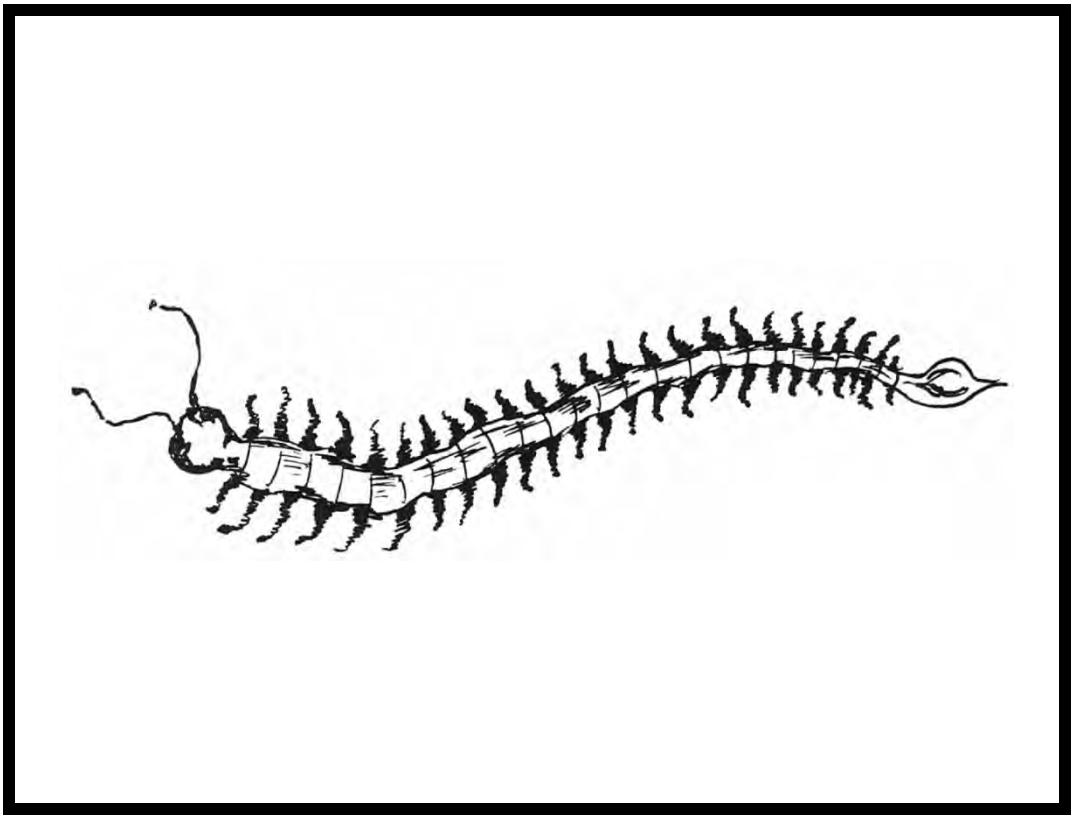
Plants, animals, and fungus.

Classification:

Kingdom.....Animalia
Phylum.....Arthropoda
Class.....Insecta
Order.....Hymenoptera
Family .....Formicidae

WANTED

For Being a
Predator, Carnivore



Centipede

This organism has been known to eat:

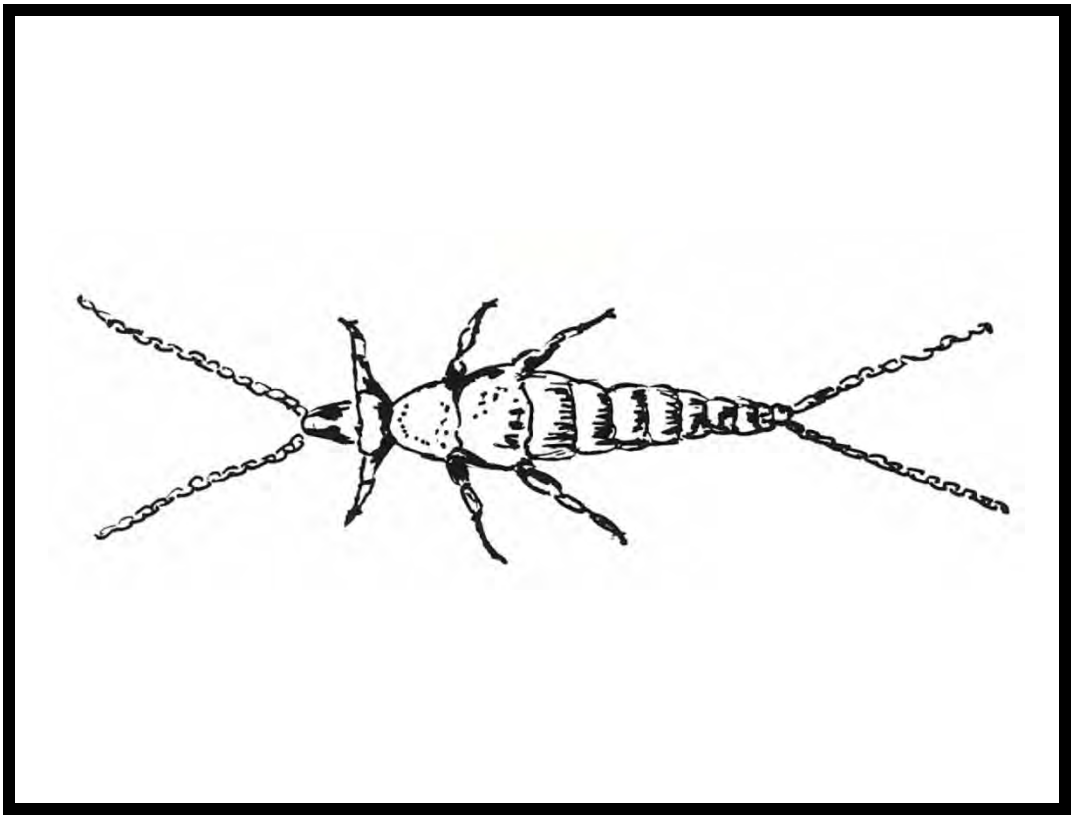
Insects

Classification:

Kingdom.....Animalia
Phylum.....Arthropoda
Class.....Chilopoda

WANTED

For Being a Herbivore



Dipluran

This organism has been known to eat:

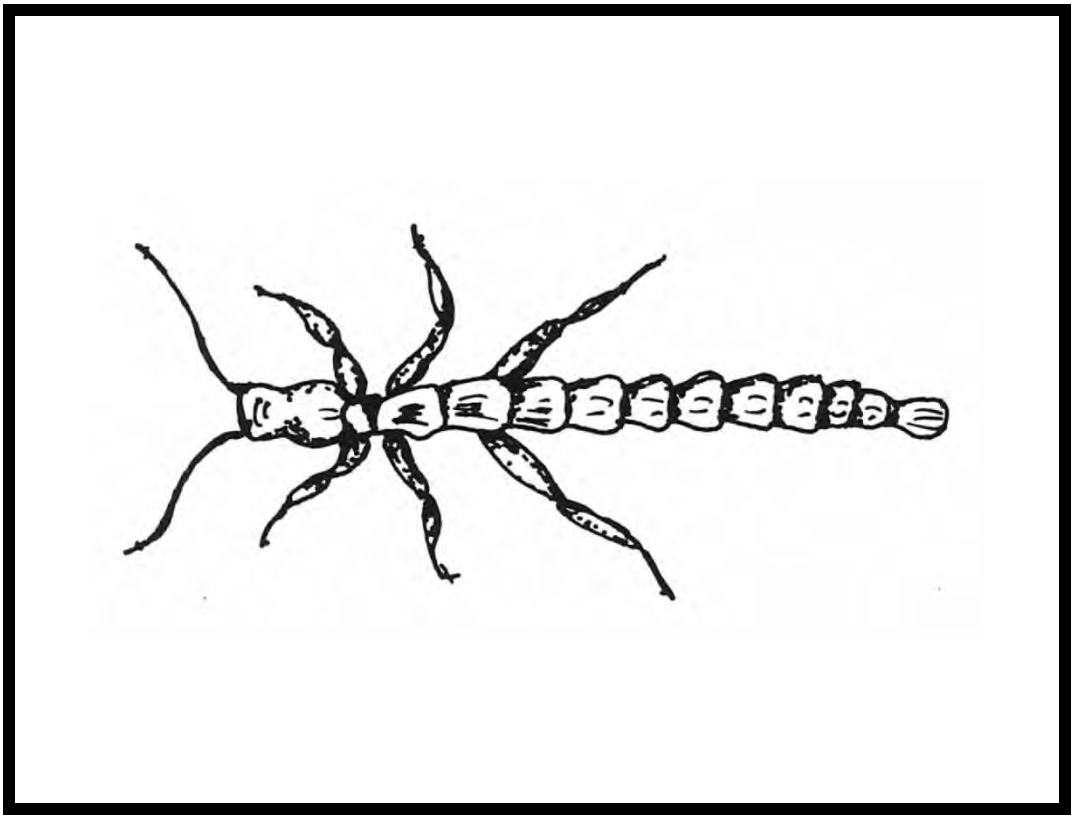
Plant material

Classification:

Kingdom.....Animalia
Phylum.....Arthropoda
Class.....Insecta
Order.....Diplura

WANTED

For Being a Herbivore



Dipluran

This organism has been known to eat:

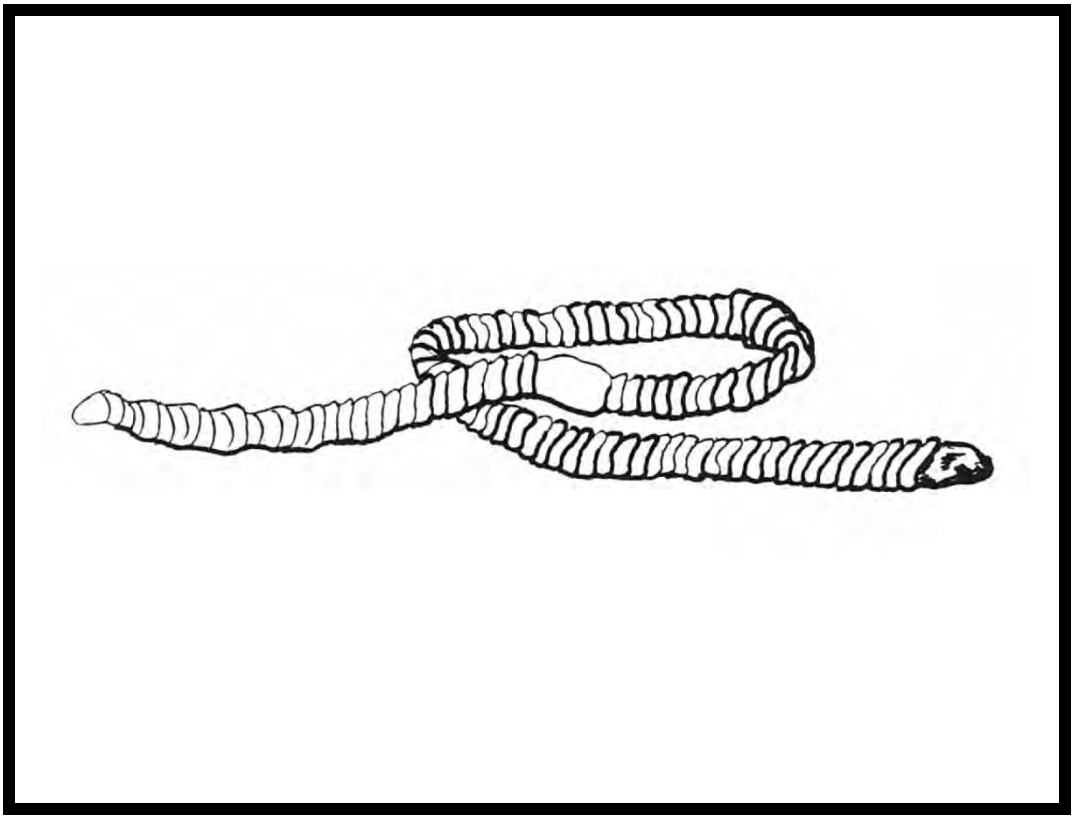
Plant material

Classification:

Kingdom.....Animalia
Phylum.....Arthropoda
Class.....Insecta
Order.....Diplura

WANTED

For Being a Herbivore



Earthworm

This organism has been known to eat:

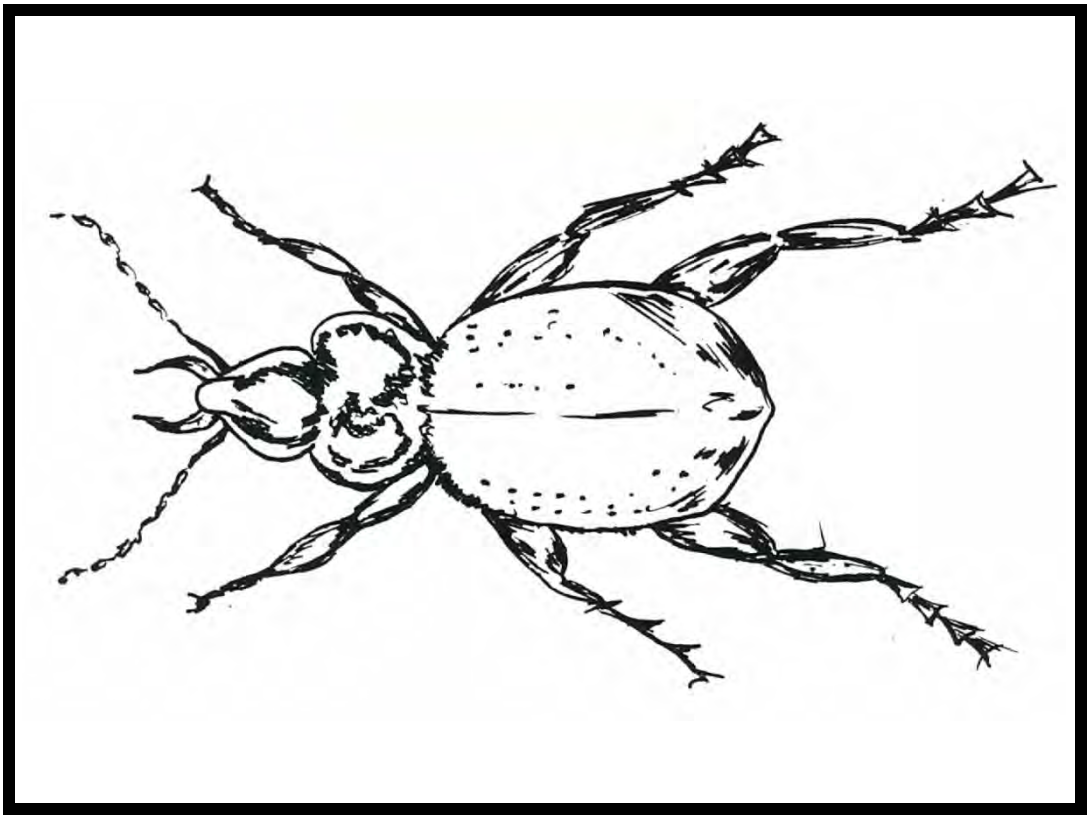
Plant material

Classification:

Kingdom.....Animalia
Phylum.....Annelida

WANTED

For Being a
Predator, Carnivore



Ground Beetle

This organism has been known to eat:

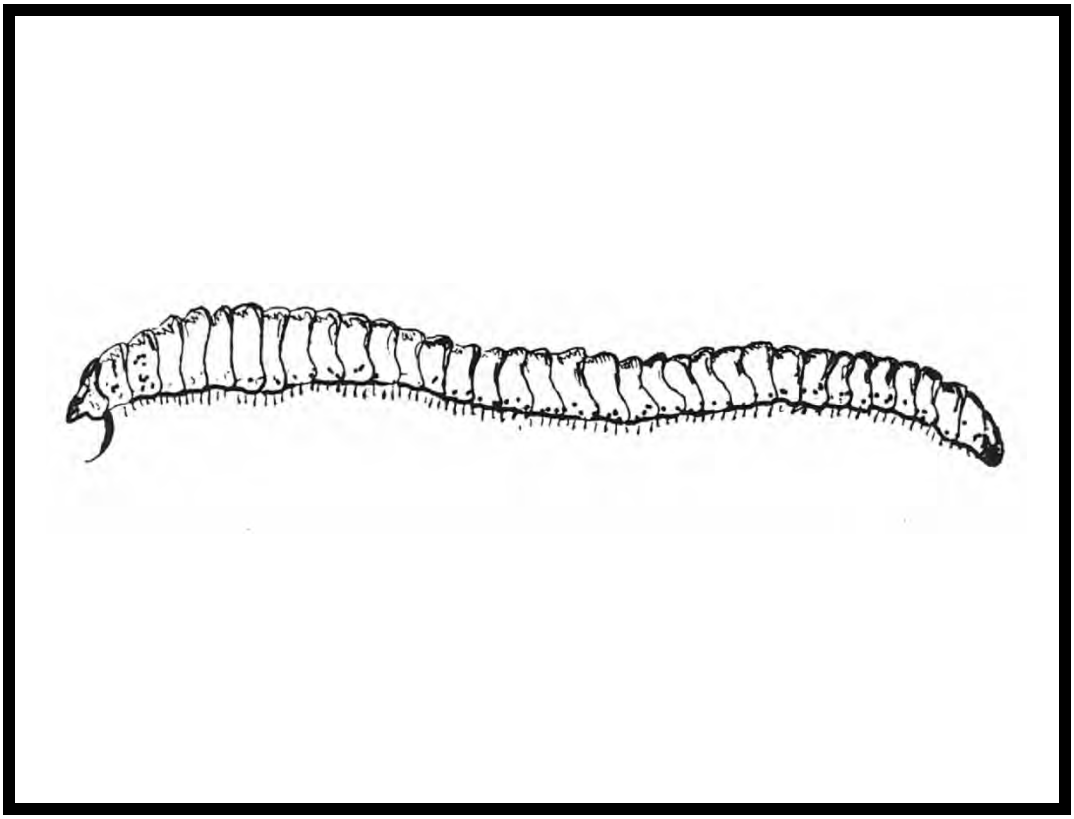
Small insects

Classification:

Kingdom.....Animalia
Phylum.....Arthropoda
Class.....Insecta
Order.....Coleoptera
Family .....Carbidae

WANTED

For Being a Herbivore



Millipede

This organism has been known to eat:

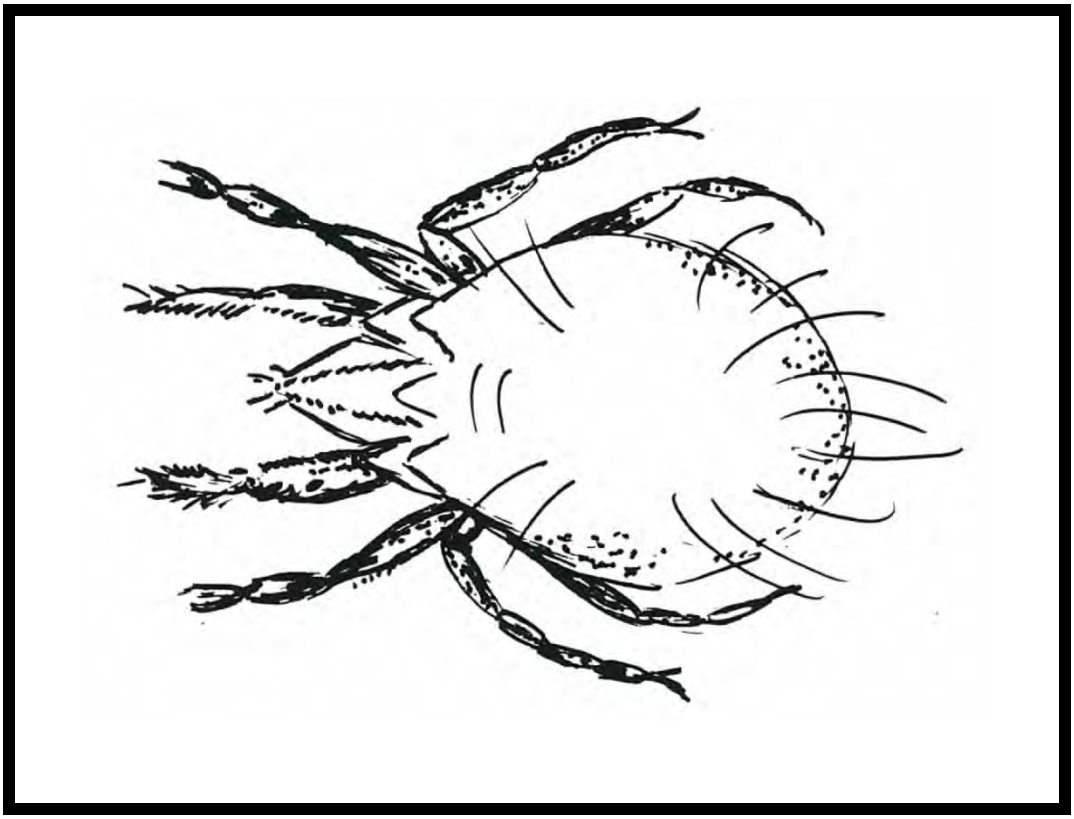
Plant material

Classification:

Kingdom.....Animalia
Phylum.....Arthropoda
Class.....Diploda

WANTED

For Being a/an
Predator, Carnivore, Omnivore, Parasite, Scavenger, Herbivore



Mite

This organism has been known to eat:

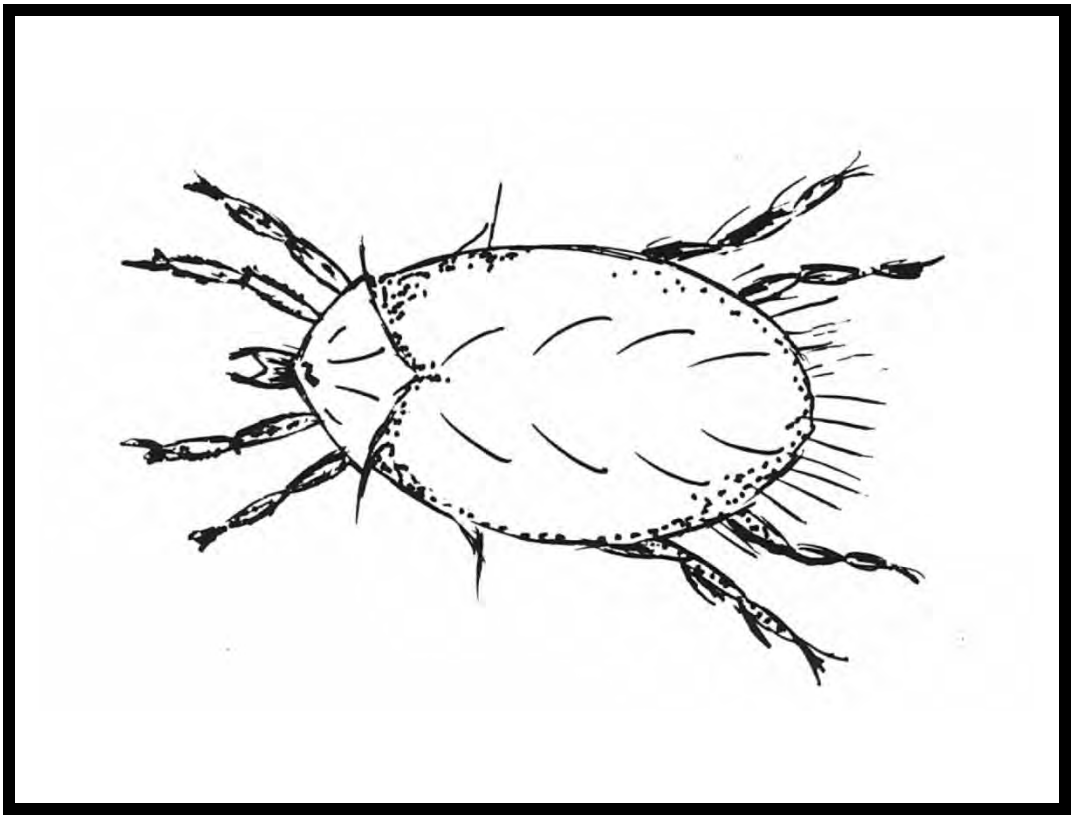
Most anything, depending on the species: small insects, plants, as parasites on larger animals including man.

Classification:

Kingdom.....Animalia
Phylum.....Arthropoda
Class.....Arachnida
Order.....Acari

WANTED

For Being a/an
Predator, Carnivore, Omnivore, Parasite, Scavenger, Herbivore



Mite

This organism has been known to eat:

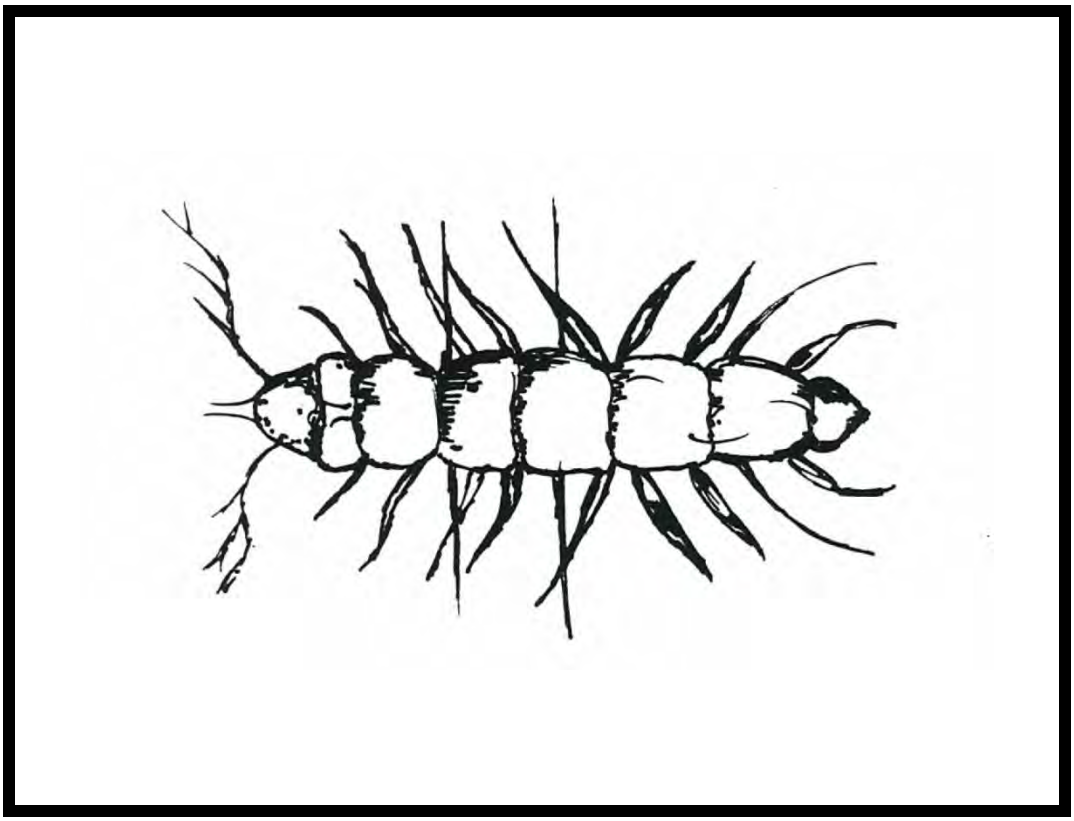
Most anything, depending on the species: small insects, plants, as parasites on larger animals including man.

Classification:

Kingdom.....Animalia
Phylum.....Arthropoda
Class.....Arachnida
Order.....Acari

WANTED

For Being a Herbivore



Pauropod

This organism has been known to eat:

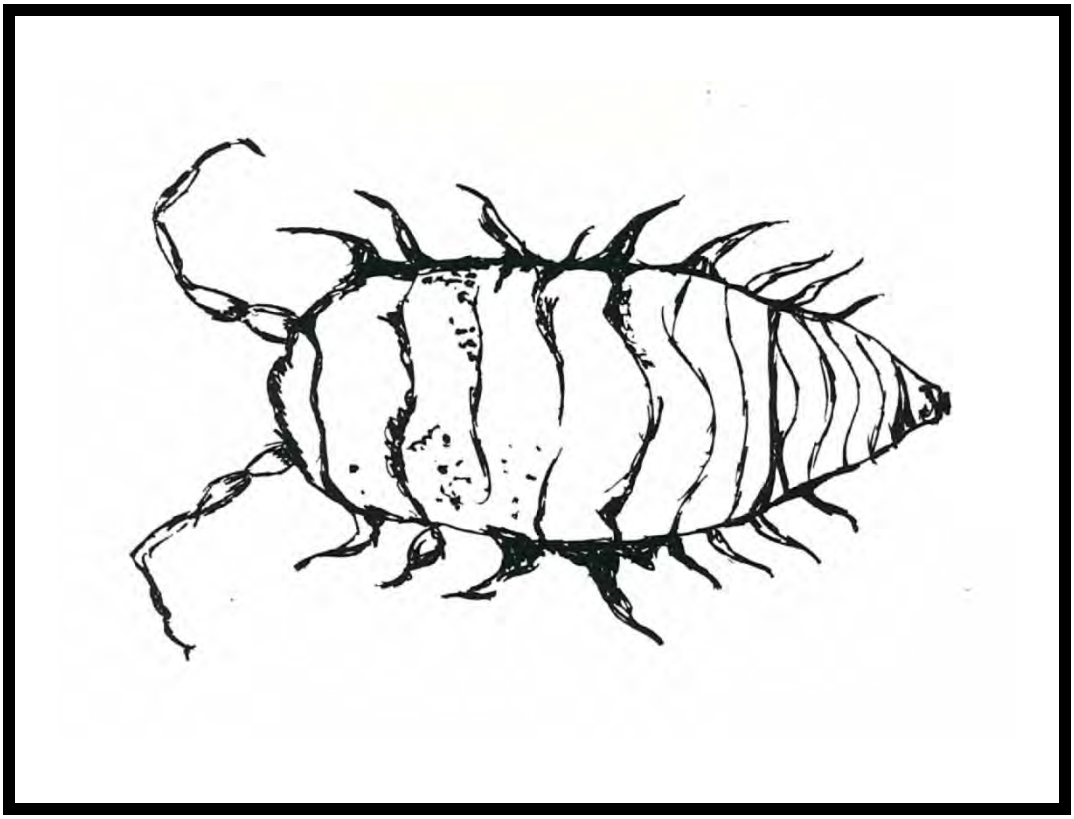
Plant material

Classification:

Kingdom.....Animalia
Phylum.....Arthropoda
Class.....Pauropda

WANTED

For Being a Herbivore



Pillbug, Sowbug

This organism has been known to eat:

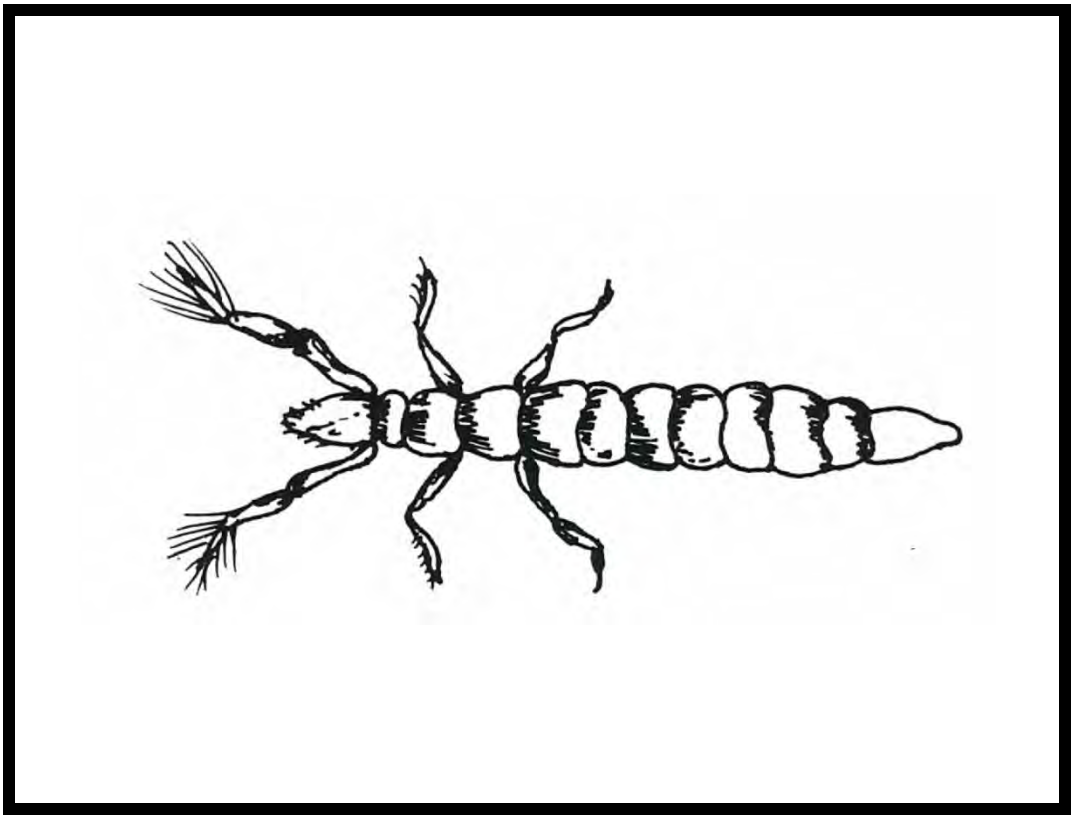
Plant material

Classification:

Kingdom.....Animalia
Phylum.....Arthropoda
Class.....Crustacea
Order.....Isopoda

WANTED

For Being a Scavenger



Proturan

This organism has been known to eat:

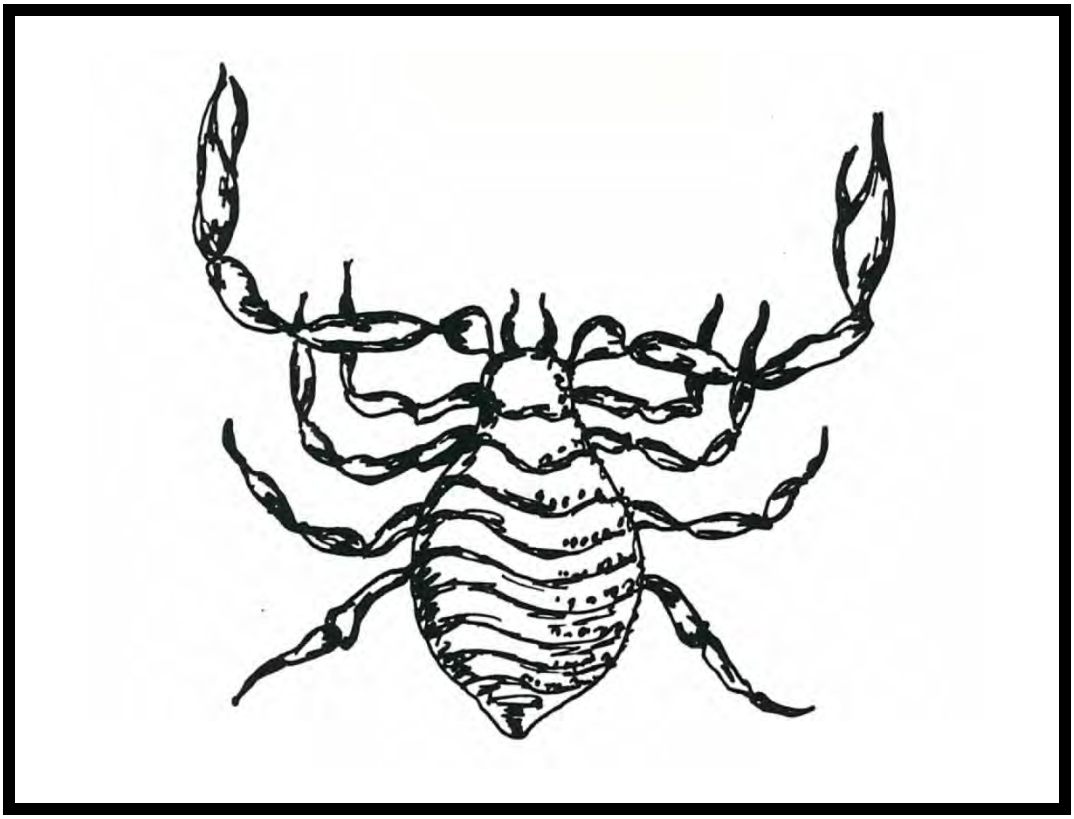
Decaying plant and animal material.

Classification:

Kingdom.....Animalia
Phylum.....Arthropoda
Class.....Insecta
Order.....Protura

WANTED

For Being a
Predator, Carnivore



Pseudoscorpian

This organism has been known to eat:

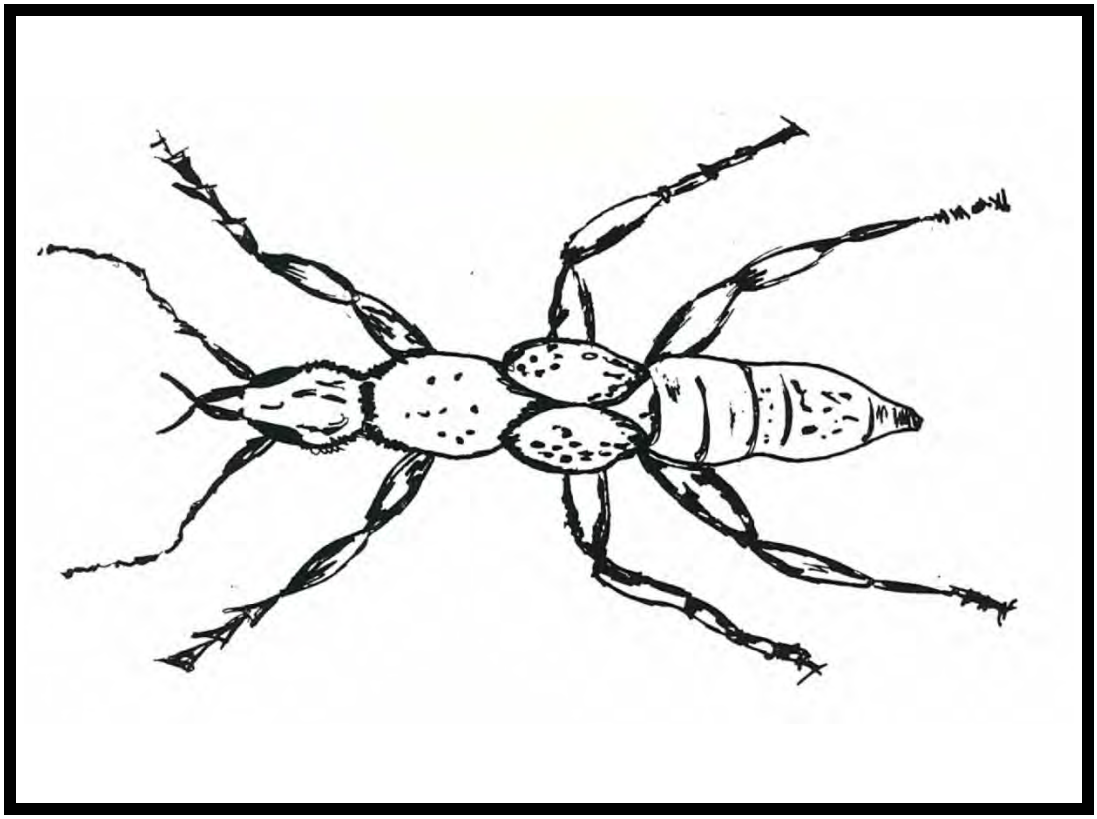
Very small insects, such as springtails.

Classification:

Kingdom.....Animalia
Phylum.....Arthropoda
Class.....Arachnida
Order.....Pseudoscorpionida

WANTED

For Being a
Predator, Carnivore



Rove Beetle

This organism has been known to eat:

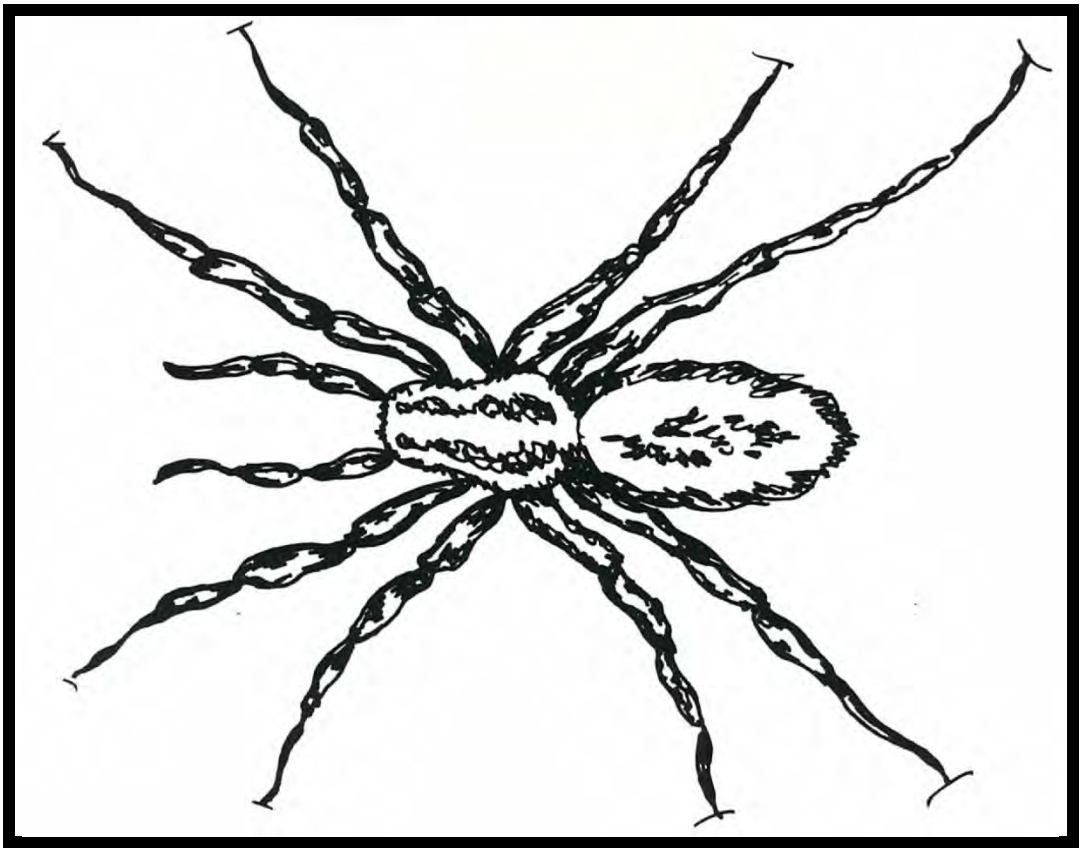
Small insects

Classification:

Kingdom.....Animalia
Phylum.....Arthropoda
Class.....Insecta
Order.....Coleoptera
Family .....Staphylinidae

WANTED

For Being a
Predator, Carnivore



Spider

This organism has been known to eat:

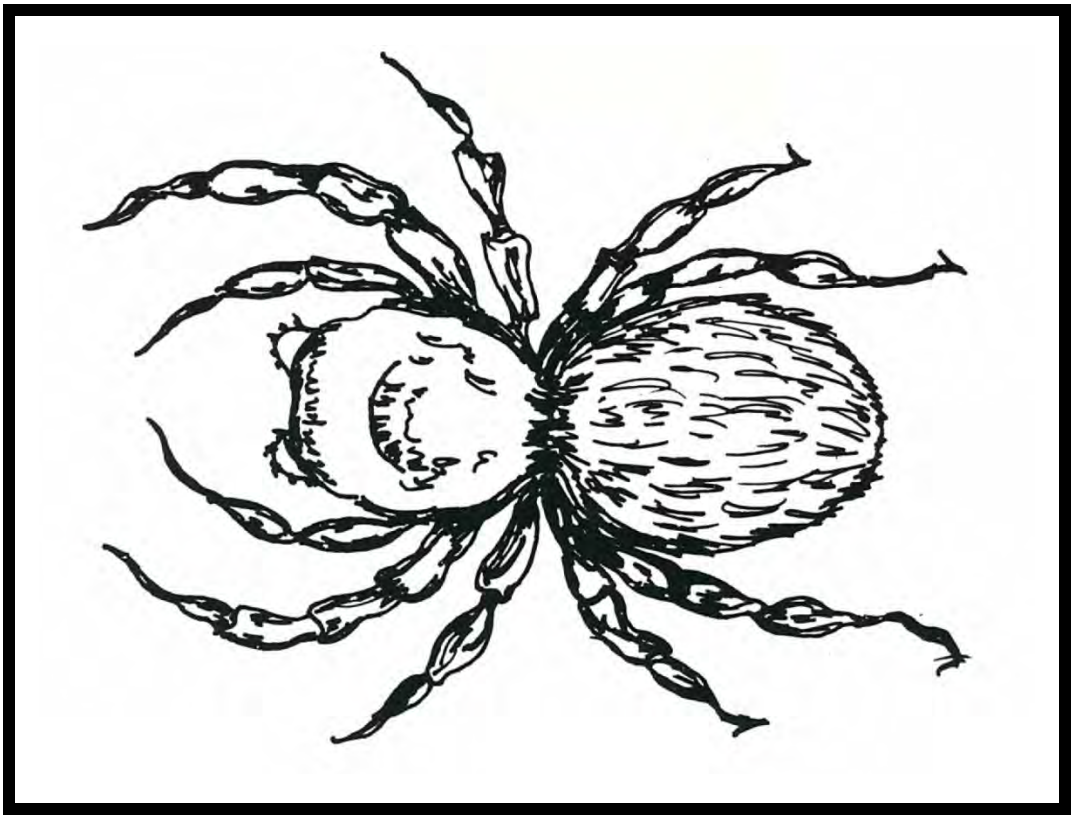
Small insects

Classification:

Kingdom.....Animalia
Phylum.....Arthropoda
Class.....Arachnida
Order.....Araneida

WANTED

For Being a
Predator, Carnivore



Spider

This organism has been known to eat:

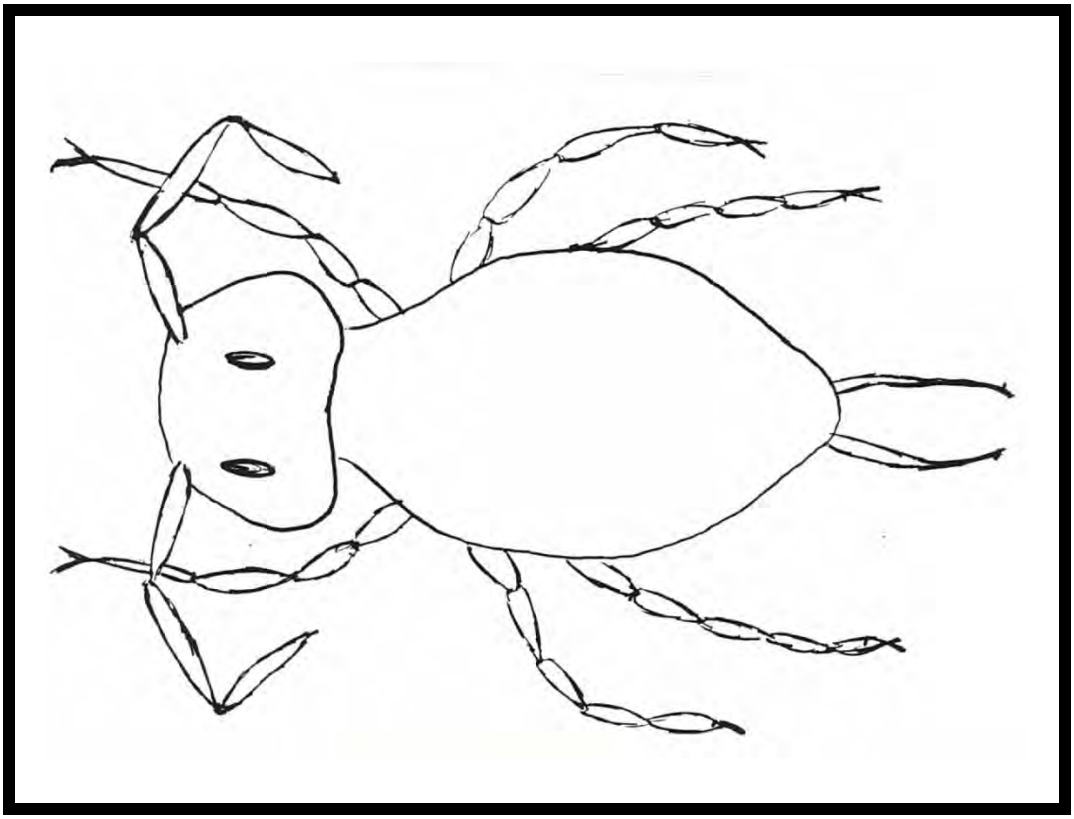
Small insects

Classification:

Kingdom.....Animalia
Phylum.....Arthropoda
Class.....Arachnida
Order.....Araneida

WANTED

For Being a Scavenger



Springtail

This organism has been known to eat:

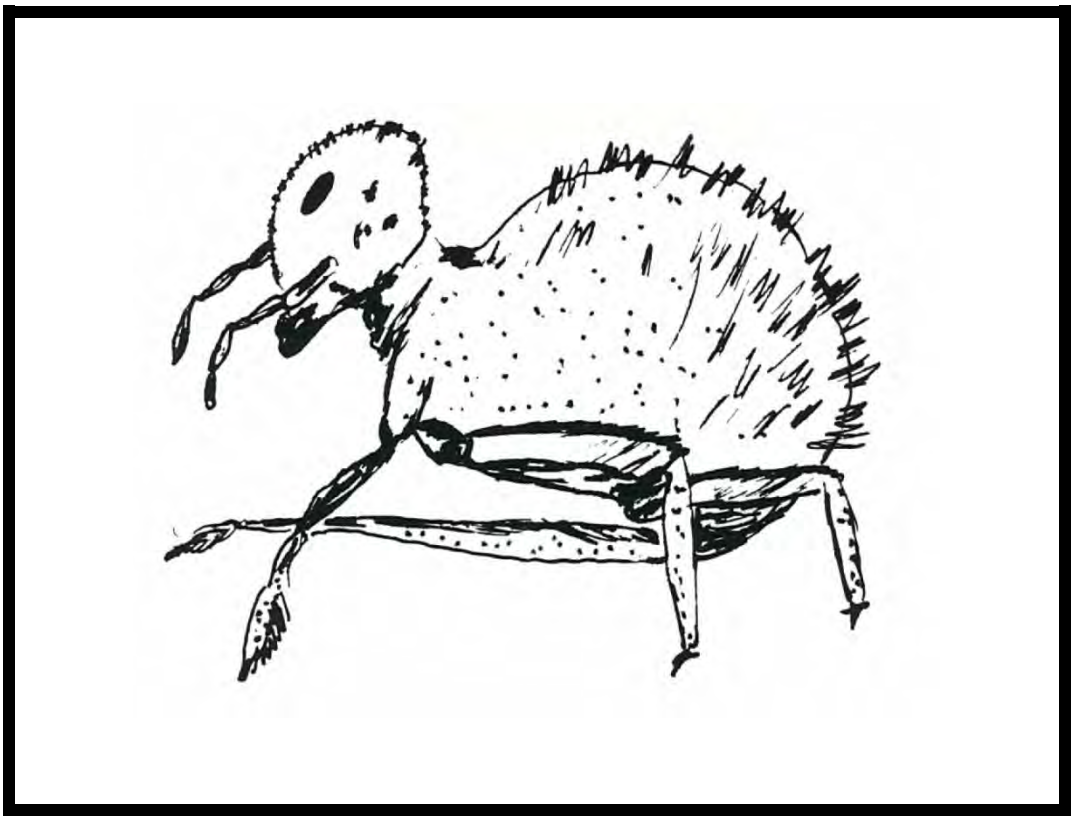
Decaying plant and animal material, fungus, feces and bacteria.

Classification:

Kingdom.....Animalia
Phylum.....Arthropoda
Class.....Insecta
Order.....Collembola

WANTED

For Being a Scavenger



Springtail

This organism has been known to eat:

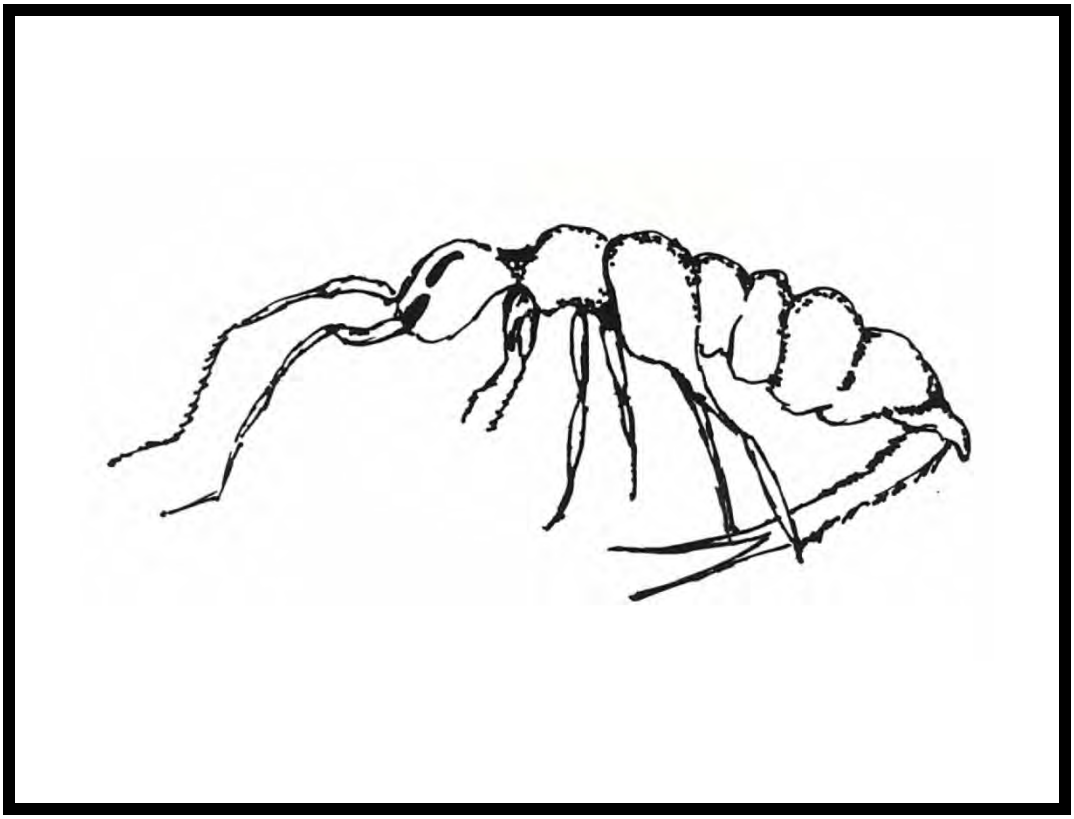
Decaying plant and animal material, fungus, feces and bacteria.

Classification:

Kingdom.....Animalia
Phylum.....Arthropoda
Class.....Insecta
Order.....Collembola

WANTED

For Being a Scavenger



Springtail

This organism has been known to eat:

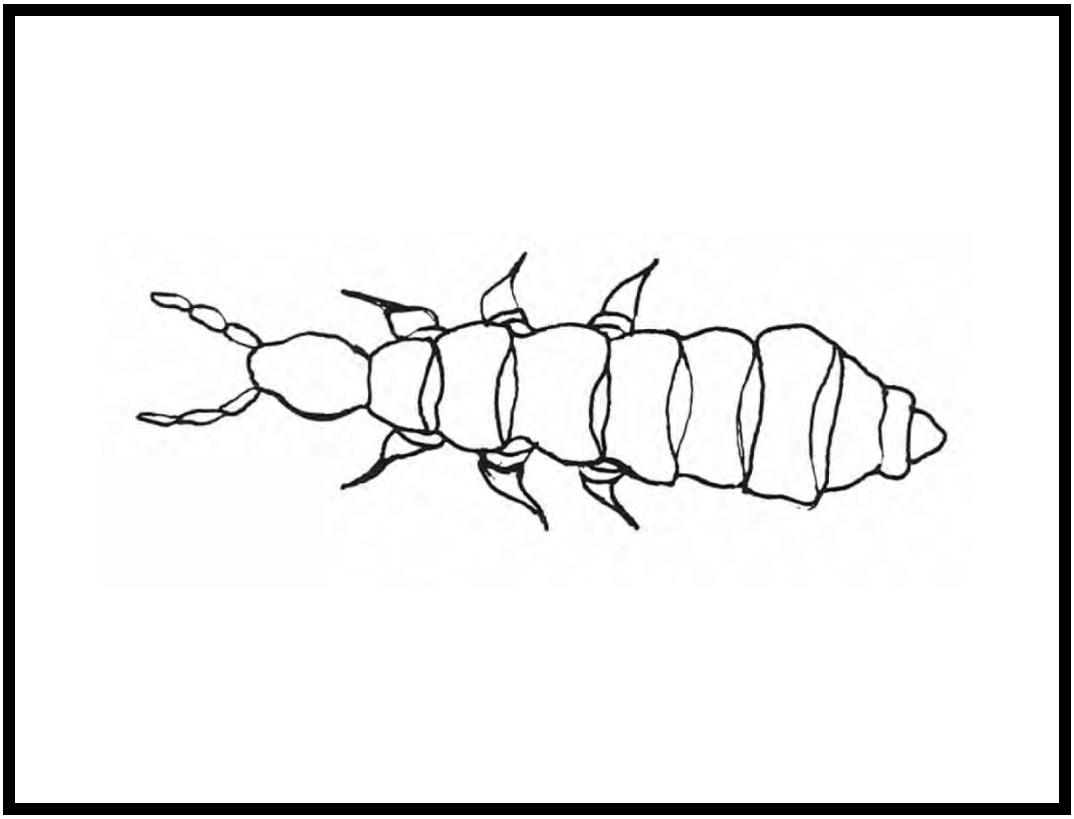
Decaying plant and animal material, fungus, feces and bacteria.

Classification:

Kingdom.....Animalia
Phylum.....Arthropoda
Class.....Insecta
Order.....Collembola

WANTED

For Being a Scavenger



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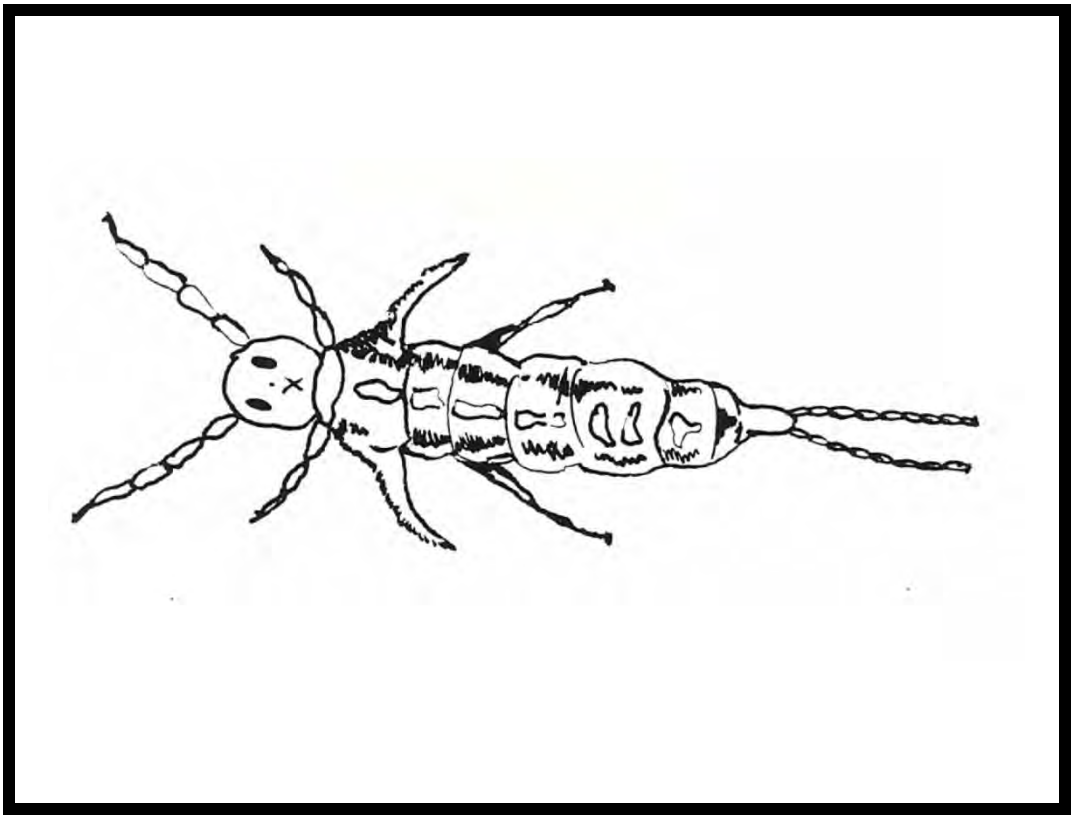
WANTED

For Being a Scavenger



Springtail

This organism has been known to eat:

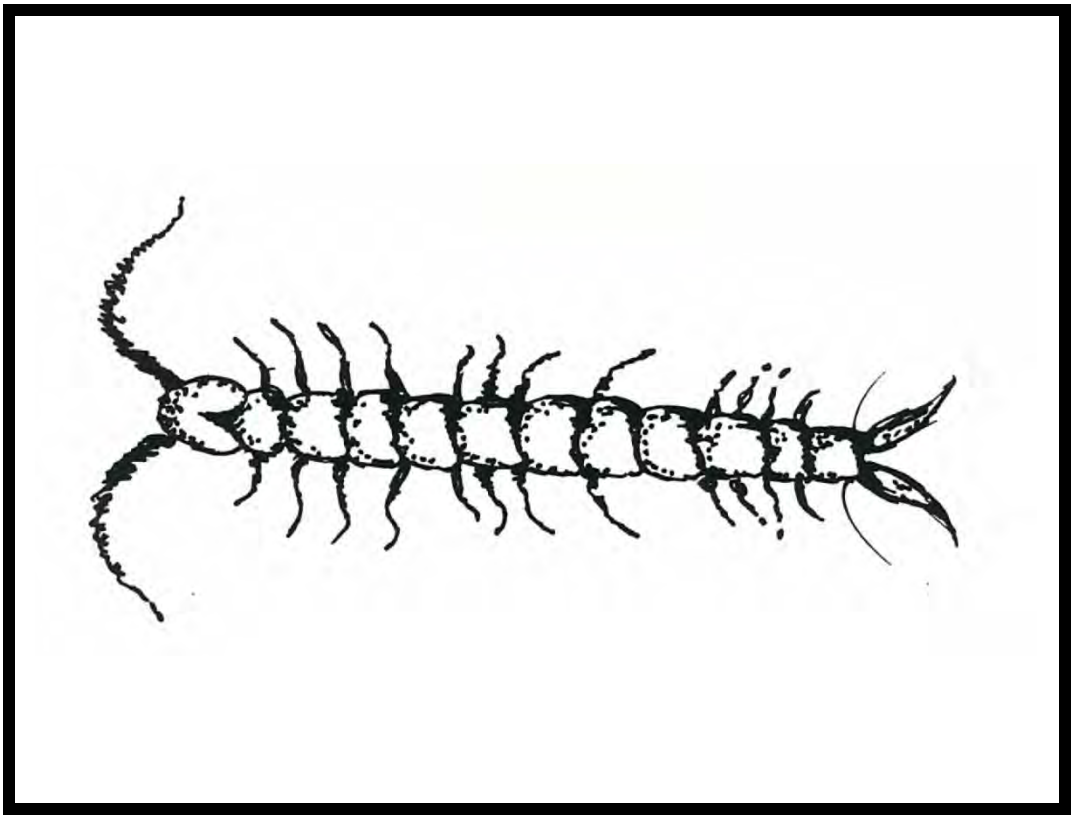
Decaying plant and animal material, fungus, feces and bacteria.

Classification:

Kingdom.....Animalia
Phylum.....Arthropoda
Class.....Insecta
Order.....Collembola

WANTED

For Being a Herbivore



Symphylan

This organism has been known to eat:

Plant material

Classification:

Kingdom.....Animalia
Phylum.....Arthropoda
Class.....Symphyla

What is Symbiosis?

Symbiosis is a unique relationship between two or more species that live within close proximity. Symbiosis takes many forms but is generally divided into three classes:

- Commensalism – when one organism is benefited and the other is neither hurt nor helped
- Mutualism – Win-Win! Both organisms benefit from the relationship.
- Parasitism – The host (victim) is harmed by the parasite, sometimes resulting in the death of the host.

Commensalism: The bison and cowbird are examples of commensalism. The bison is neither helped nor hindered by the cowbird, but the cowbird benefits greatly from the bison. As the bison moves about the grassland areas, insects are kicked up or disturbed, revealing their location and providing easy meals for the cowbird. It is not unusual to see many cowbirds following bison or cattle during daylight hours.

Mutualism: A classic example of mutualism is the WIN-WIN relationship between bumblebees and forbs (showy flowering plants). The flowering plants require pollination to reproduce; the bumblebees need the flowers as a food source. Other organisms serve as pollinators, but are not necessarily in a mutualistic relationship.

Parasitism: Common parasitic relationships include a warm-blooded host and such parasitic organisms as mosquitoes, lice and ticks. Higher-level organisms can also be parasites. The cowbird is considered a parasite in its relationship with certain other birds in a subcategory of parasitism known as kleptoparasites. The cowbird does not build its own nest. Rather, the female lays an egg in the nest of another bird, allowing that bird to raise her young at the expense of her own. If the nesting bird recognizes the offending egg and moves it from the nest, the seemingly vindictive cowbird is known to destroy the remaining eggs.

Within any ecosystem, all types of symbiotic interrelationships are critically prevalent on the microscopic level as well. An example of mutualism is mycorrhizae, relationships that develop between fungi and plants, providing nutrients for both plant roots and fungi. The digestive systems of organisms are often dependent on bacteria to assist in digestion. Symbiotic relationships have formed via evolution since the first living organisms, bacteria, emerged. Bacteria play a crucial role in reproduction, nourishment and even protection within populations of other organisms with whom they have co-evolved for hundreds of millions of years.

Some interactions and relationships are long lasting, having remained much the same for millennia, but others are still emerging. As we recognize the changes that constantly take place within ecosystems, we also recognize that organisms are constantly adapting to new conditions. If conditions change faster than the organism(s) can adapt, the species can suffer to the point of extinction. Awareness of these unique relationships help to ensure ongoing symbiosis in the natural world.

Ecosystem Services – Student Resource

Ecosystem Services: the important benefits for human beings that arise from healthy functioning ecosystems (Costanza)

Research with your team any of the broad benefits of ecosystem services, such as:

- Gas regulation (production of oxygen and carbon dioxide needed for photosynthesis and respiration)
- Climate regulation (Transpiration by plants helps regulate temperature and relative humidity.)
- Disturbance regulation (storm protection/flood control/erosion buffer)
- Water regulation (natural filtration and flood control; water cycle)
- Erosion control/sediment retention (Root systems hold soil in place; plants block wind.)
- Soil formation (Decomposition/Detritus processing add nutrients to form rich, organic soil.)
- Nutrient cycling (storage, nutrient cycling, biochemical breakdown)
- Waste treatment (recovery of mobile nutrients and removal of xenic/toxic substances; natural areas offer filtration mechanisms to keep the environment clean.)
- Pollination (fertilization of plants essential to life on Earth)
- Biological control (trophic dynamic relationships/keystone species; food chains/food webs)
- Refugia (habitat for migration/visiting species)
- Food production (Native plants and animals are food/medicine sources; commercial farming)
- Raw materials (biofuels; hemp (fiber); multitudes of uses for native plants and animals)
- Genetic resources (medicine; restoration/gene pools; improved crops)
- Recreation (What's not to love about playing/hiking/camping/fishing . . .?)
- Culture (revival of Native American uses of natural area flora and fauna for crafts, medicine, dyes, fine art, musical instruments, etc.)

EXTRA! EXTRA!! READ ALL ABOUT IT!!!

Dateline: Washington, DC

April 29, 2016

The Bison is Poised to Become the U.S. National Mammal!

Move over, bald eagle; there's a new kid in town! Of course it does not have the ability to soar through the air, but the recovery story of the American bison is every bit as impressive as our national bird, the beloved bald eagle. Congress passed a bill designating the bison as the national mammal. The bill needs only the signature of the President to become law.

Congress selected the bison for many reasons, including:

- First species on the brink of extinction to be rescued, nurtured for procreation and reintroduced to the land it once roamed. An estimated 160,000 bison now live on public and private land throughout the U.S. and Canada.
- Sacred animal of many Native American tribes. American Indians worshiped the bison and used bison products for trade. They harvested only what they needed for food, clothing and shelter. Nothing from the bison was left unused. Bones were made into tools, horns to cups or receptacles, hide to shelter or clothing, even the skull became headdresses or bowls. The bison was and is revered.
- Ecological importance. Healthy grasslands and prairies benefit from grazing. While overgrazing is not an advantage, bison are adapted to grazing on the Great Plains. Returning bison to native grasslands is mutually beneficial.
- Bison is a commercially successful food source. Lean meat, rich in protein and other nutrients, bison meat is a healthier alternative to beef.
- Wildlife Conservation Society president Cristián Samper calls the bison "an icon that represents the highest ideals of America: unity, resilience and healthy landscapes and communities."

What IS a bison? First, it is NOT a buffalo, which is an animal indigenous to Southeast Asia. The bison, an undulate (hoofed mammal), is native to North America. The male is larger than the female and can be considerably heavier. With immense heads and front quarters, the bison is formidable. At Fermilab, double wire fences, the inside fence electrified, ensures that the bison herd can be viewed by visitors in safety.

Bison are herbivores and once roamed the Great Plains in massive herds estimated in the tens of millions. They have thick, shaggy brown coats with a down-like under layer in the winter. When the weather warms in the spring, bison can be seen rubbing on trees or stakes to loosen and shed that insulation and reveal their lighter summer coats.

Bison calves, usually born in April and May, are generally reddish, sometimes appearing to have curly hair. They nurse until the next calf is born, typically the next

spring. Mating takes place usually in August or September. With a gestation period of 285 days, bison cows carry their babies about the same length of time as humans. Within three years, bison are sexually mature but younger bulls are frequently dismissed if older bulls are present.

In the wild, bison have a typical life expectancy of 15 years, but in captivity with optimum conditions like the herd enjoys at Fermilab, the age span moves to 25 years and beyond.

	Bull (male)	Cow (female)	Calf (young)
Height	Up to 6 feet at the shoulder	Up to 5 feet at the shoulder	24–30 inches at the shoulder
Length	7 feet long	5–7 feet long	3 feet long
Weight	900–2000 lbs.	Up to 900 lbs.	50–75 lbs.
Color	Dark brown	Dark brown	Light reddish-brown
FNAL Quantity	2	15	12

Quantity facts are from 2016.

Bison are social—in the wild—often living in herds of 60 or more per band (cows and calves). Bulls typically separate from the herd from late fall until spring, gathering with the cows and calves from time to time.

Bison gestation takes nine months; most calves are born in the spring.

Bison can run at full speed up to 30–40 mph.

It is said, “Never turn your back on a bison.”

Photo: Reidar Hahn

There is a myth surrounding the bison herd at Fermilab. It’s been said that the bison on site function like the legendary canary in the mineshaft, providing forewarning to workers of unsafe conditions. *Fermilab bison are not living Geiger counters to warn off radioactivity*. They are on the Fermilab site to carry on the tradition of connections with prairie heritage begun by the lab’s first director, Robert Wilson. Wilson brought the first bison, a bull and four cows, to Fermilab in 1969; 21 more head were added in 1971. The current herd is descended from those animals.

This herd is self-sustaining. The lineage is genetically superb, with verification that these animals are truly purebred *Bison bison*. When the herd’s numbers begin to climb, a bison auction is held. Because of the excellent care and genetics, Fermilab bison draw top dollar.

For more information about bison, follow the Resource links to:

American Bison Status Survey and Conservation Guidelines 2010, International Union for Conservation of Nature.

Bison Conservation Initiative Bison Conservation Genetics Workshop: Report and Recommendations. Natural Resource Report NPS/NRPC/BRMD/NRR—2010/257.

Ecology Resources

Adaptations – Set 2
National Geographic
http://education.nationalgeographic.org/encyclopedia/adaptation/

Aquatic – Set 1
Aquatic macroinvertebrates nature guide
http://fieldguides.fieldmuseum.org/sites/default/files/rapid-color-guides-pdfs/macro_id_cards_2015_v2.pdf

Birds
Identify feathers of birds.
https://www.fws.gov/lab/featheratlas/

Bison – Sets 1 & 2
The Genetic Purity and Diversity of the Fermilab Bison Herd
http://news.fnal.gov/2016/01/the-genetic-purity-and-diversity-of-the-fermilab-bison-herd/

American Bison Report
https://drive.google.com/open?id=0B_J2m_A8wSzKalRuYzg0Q3J6TEE

Bison Genetics Report
https://www.nature.nps.gov/biology/documents/Bison_Genetics_Report.pdf

How may climate change affect bison?
http://blog.nature.org/science/2016/03/16/incredible-shrinking-bison-unexpected-impact-climate-change-warming-diet/?src=e.nature.loc_b1&lu=1801363&autologin=trueThe

Positive Effects of Bison-Free Grazing
http://woodsandprairie.blogspot.com/2016/07/what-would-bison-do.html
Posted by Stephen Packard, Strategies for Stewards, photos of bison-grazed land at Nachusa Grasslands, Lee County, in North Central Illinois, reveal how diversity is helped by bison grazing.

Botany – Sets 1–3
Prairie Root Systems
http://proof.nationalgeographic.com/2015/10/15/digging-deep-reveals-the-intricate-world-of-roots/

Planting Native Plants
http://www.dnr.illinois.gov/education/Pages/PlantListMaintain.aspx
http://www.dnr.illinois.gov/education/Pages/PlantLists.aspx

Master Gardener Manual: Basic Botany, Physiology and Environmental Effects on Plant Growth
http://cals.arizona.edu/pubs/garden/mg/botany/

Weed Field Guide
https://drive.google.com/open?id=0B_J2m_A8wSzKT2x5b2RQUmVfbkk

Seedling ID Guide for Native Prairie Plants
http://www.nrcs.usda.gov/Internet/FSE_PLANTMATERIALS/publications/mopmcpu6313.pdf

Climate Change/Genetics – Set 1
EPA: Climate Change Is Happening
https://www3.epa.gov/climatechange/basics/

NASA: Climate Change and Global Warming
http://climate.nasa.gov/

Shrinking Bison
http://blog.nature.org/science/2016/03/16/incredible-shrinking-bison-unexpected-impact-climate-change-warming-diet/?src=e.nature.loc_b1&lu=1801363&autologin=true

Citizen Science – Set 1
The Xerces Society is a nonprofit organization that protects wildlife through the conservation of invertebrates and their habitat. For over forty years, the Society has been at the forefront of invertebrate protection worldwide, harnessing the knowledge of scientists and the enthusiasm of citizens to implement conservation programs.
http://www.xerces.org/

Citizen Scientist Site: Bumblebee Watch
http://www.bumblebeewatch.org/

Citizen Science Project Ideas – Scientific American:
http://www.scientificamerican.com/citizen-science/

National Wildlife Federation: What is a Citizen Naturalist?
https://www.nwf.org/Wildlife/Wildlife-Conservation/Citizen-Science.aspx

Ecosystem Services – Sets 1–3
The value of the world's ecosystem services, R. Costanza et al., 1997.
http://www.esd.ornl.gov/benefits_conference/nature_paper.pdf

Changes in the global value of ecosystem services, R. Costanza et al., 2014.
http://www.sciencedirect.com/science/article/pii/S0959378014000685

National Wildlife Federation: What are Ecosystem Services?
http://www.nwf.org/Wildlife/Wildlife-Conservation/Ecosystem-Services.aspx

actionbioscience offers another interpretation of ecosystem services.
http://www.actionbioscience.org/environment/esa.html

A global initiative focused on making nature's values visible.
http://www.teebweb.org/resources/ecosystem-services/

List of ecosystem services for students' use can be found in the *Resources* section.

Books:
Tercek, Mark R. and Adams, Jonathan S. *Nature's Fortune: How Business and Society Thrive by Investing in Nature*. Paperback, August 6, 2015.
http://www.amazon.com/Natures-Fortune-Business-Society-Investing/dp/1610916956/ref=sr_1_1?ie=UTF8&qid=1446754422&sr=8-1&keywords=natures+fortune

Tallamy, Douglas W. *Bringing Nature Home: How You Can Sustain Wildlife with Native Plants, Updated and Expanded.* Timber Press: Portland and London, April 1, 2009.
https://www.amazon.com/Bringing-Nature-Home-Wildlife-Expanded/dp/0881929921

Fermilab Resources – Sets 1–3
Fermilab Ecology

- Prairie: http://sustainability.fnal.gov/ecology/prairie/index.html
- Wildlife (birds, butterflies, bison, etc.): http://sustainability.fnal.gov/ecology/wildlife/index.html
- Ecological Land Management Committee: http://sustainability.fnal.gov/ecology/elm/index.html
- Fermilab Natural Areas: http://www.fermilabnaturalareas.org/
- National Environmental Research Park: http://sustainability.fnal.gov/ecology/park/index.html
- Conservation: http://sustainability.fnal.gov/ecology/conservation/index.html

Fermilab E&E Prairie Data Summaries

- http://eddata.fnal.gov/lasso/quadrats/display2015.html
- http://eddata.fnal.gov/lasso/quadrats/display-dataset-full.lasso?-KeyValue=165
- http://eddata.fnal.gov/lasso/quadrats/display-dataset-plants.lasso?-KeyValue=165

Odonata (dragonflies/damselflies) found at Fermi

- http://sustainability.fnal.gov/ecology/wildlife/dflies.html

Smallville Prairie

- http://ed.fnal.gov/help/prairie/4prairie/index.html

Floristic Quality Index – Set 1
FQI – Swink and Wilhelm:
https://theprairieecologist.files.wordpress.com/2011/10/plotwise-fqi-description-short.pdf

Fermilab FQI sites (Resources)

Food Webs – Set 3
Idaho Public Broadcasting offers this basic page, ideal for the delayed reader.
http://idahoptv.org/sciencetrek/topics/food_chain/facts.cfm

National Geographic – Food Chains and Webs
http://education.nationalgeographic.org/encyclopedia/food-web/

USDA: Soil Food Web
http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/soils/health/biology/?cid=nrcs142p2_053868

Illinois History
Illinois Conservation Timeline Up to 1996
http://www.dnr.illinois.gov/education/Documents/timelineto1996.pdf

INSECTS
Bumblebees – Sets 1 & 3
National Wildlife Federation
Excellent article about gardening for bumblebees and other pollinators.
http://www.nwf.org/News-and-Magazines/National-Wildlife/Gardening/Archives/2009/The-Buzz-on-Native-Pollinators.aspx

National Wildlife Foundation
Bumblebees are in trouble! How can we help? Ideas for gardeners to help sustain the bumblebee populations. Read the National Wildlife Federation article, *The Buzz about Bumble Bees* at http://www.nwf.org/News-and-Magazines/National-Wildlife/Gardening/Archives/2014/Bumblebees.aspx.

Keep our bumblebee populations healthy. http://blog.nwf.org/2014/04/5-facts-about-bumble-bees-and-how-to-help-them/

Videos:
How do bumblebees fly?
Watch bumblebees fly. Almost always overfly closer meadows. Once they find their patch, they go back and forth—in BEE lines. 3:18 min.
https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0ahUKEwi28a-hg8zPAhUi7oMKHfIWB0MQtwIIHDAA&url=https%3A%2F%2Fwww.youtube.com%2Fwatch%3Fv=W2YEzY8tzMU&usg=AFQjCNHmTFIDw16oZTaHvMHrFcfDTOkrOw&sig2=x4PQDHG-75O2vzcrZUMLfg&bvm=bv.135h

How do bumblebees fly? Embedded in an article, this 47-second video shows the motion of the bumblebee's wings during flight.
http://www.dailymail.co.uk/sciencetech/article-2402226/Video-shows-bumblebees-fly-The-creatures-muscles-oscillate-spontaneously.html - ixzz472WaWz84

How do bumblebees fly? This short video (3:11 min.) offers a scientific explanation for the mystery of how bumblebees fly using aerodynamic principles of lift. Smoke is used to demonstrate how this works. Amazing!
https://www.youtube.com/watch?feature=player_embedded&v=JMB6tVmkRhE

Earth Rangers ask: Why do we need bumblebees? Aimed for upper elementary but good basic information.
https://www.youtube.com/watch?feature=player_embedded&v=6CxCTyxRFh0

Colony Collapse Disorder – Honey Bees. While not bumblebees, this video is well done. (Stop before the end as there are several commercials.)
https://www.youtube.com/watch?v=GqA42M4RtxE

Description of how a bee becomes a queen.
https://www.youtube.com/watch?v=m_SlH3Uwslc

Dragonflies and Damselflies
Odonata (dragonflies/damselflies) found at Fermi
http://sustainability.fnal.gov/ecology/wildlife/dflies.html

Make your own insect sweep nets.
https://www.bing.com/videos/search?q=insect+sweep+net&&view=detail&mid=E20ECB1626C562D8693FE20ECB1626C562D8693F&FORM=VRDGAR

Land Management
What is land management?
https://docs.google.com/document/d/1MlyeetRqAaBiL1KnMLj1w30XJo7HhqQV1CpPslKCg2Q/edit

- Fermilab: Past, Present and Future Intro (Resources)
- Fermilab Land Management (Field Research)
- Lake Stratification (Resources)
- Habitat Communities of the Fermilab Site (Introduction)
- Fermilab's primary watersheds (Resources)

Conservation Reserve Program (CRP)
http://www.fsa.usda.gov/programs-and-services/conservation-programs/conservation-reserve-program/

Book:
Helzer, Chris. *The Ecology and Management of Prairies in the Central United States,* University of Iowa Press. Iowa City, Iowa, 2010.

Nutrient Cycling (See also Food Chains and Webs.) – Set 3
Ecology Education Consulting – Could a molecule once in a dinosaur now be in you?
http://www.ecologyedu.com/education_resources/nutrient_cycling_in_an_ecosystem.html

Sustainable Sanitation and Water Management – Comprehensive article with excellent diagrams.
http://www.sswm.info/category/concept/nutrient-cycle

Photosynthesis – Set 3
Activity Idea 1
Carolina Biological Supply – Using Aquatic Plants to Demonstrate Photosynthesis
http://www.carolina.com/teacher-resources/Interactive/photosynthesis-cellular-respiration/tr10764.tr?s_cid=em_ccphoto_201511&utm_source=bronto&utm_medium=email&utm_term=Try+the+Activity&utm_content=11/23/2015&utm_campaign=2015+-+Content+Connection

Activity Idea 2
Science and Plants for Schools – Bubbling Cabomba pondweed
http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&uact=8&ved=0ahUKEwiM8OjciczPAhUEaD4KHefTCQUQFgglMAE&url=http%3A%2F%2Fww

w.saps.org.uk%2Fsecondary%2Fteaching-resources%2F190-using-cabomba-to-demonstrate-oxygen-evolution-in-the

NASA: Seeing Photosynthesis from Space
http://www.nasa.gov/content/goddard/seeing-photosynthesis-from-space-nasa-scientists-use-satellites-to-measure-plant-health/ - .VyKVQIQrKUk

Pollination – Sets 1–3
Amazing video footage of birds, bats, butterflies, honey bees and bumblebees as pollinators. 4:18 min.
https://www.youtube.com/watch?feature=player_embedded&v=MQiszdkOwuU

TED Talk – The Beauty of Pollination. Louis Schwartzberg. 7:40 min. Includes the previous footage with intro by the filmmaker, including co-evolution of plants and pollinators.
https://www.youtube.com/watch?feature=player_embedded&v=eqsXc_aefKI

Featured Videos
Yellowstone Wolves
http://www.filmsforaction.org/watch/how-wolves-change-rivers/

Hawk and squirrel
https://www.youtube.com/v/XBEyCr5AoIs

Seasonal Videos:
Winter is coming… 3:46 min.
http://www.youtube.com/embed/fdSVp9GFeS4?autoplay=1&rel=0

Beautiful Nature, Spring – 6:37 min.
https://www.youtube.com/watch?v=XhHCcH7hyqo

Amazing Nature, Summer – 4:30 min.
https://www.youtube.com/watch?v=imVIGxbHxEo

Autumn Nature Walk, British Natural History Museum – narrated 6:33 min.
https://www.youtube.com/watch?v=u4pkpG5QqXo

General Interest for Educators
NGSS and Common Core Links
http://ngss.nsta.org/making-connections-common-core.aspx

What Makes an Essential Question?
http://www.ascd.org/publications/books/109004/chapters/What-Makes-a-Question-Essential%A2.aspx

Related Links:
Why it makes you feel better to walk in the woods
http://www.childrenandnature.org/2016/02/04/why-a-walk-in-the-woods-really-does-help-your-body-and-your-soul/?utm_source=Children+%26+Nature+Network+News+%26+Updates&utm_campai

gn=34dd0ff70b-
RSS_EMAIL_CAMPAIGN&utm_medium=email&utm_term=0_e0808fca17

Glossary

Abiotic: a nonliving factor in an environment; e.g., rock, water, temperature.

Abundance: an ecological concept referring to the relative representation of a species in a particular ecosystem.

Adaptation: a change or the process of change by which an organism or species becomes better suited to its environment.

Amphibian: an animal that typically lives in an aquatic habitat breathing by gills when it is young, and primarily in a terrestrial habitat breathing by lungs and through moist glandular skin as an adult, e.g., frog.

Animal Community: animals of various species living within a certain habitat, each occupying a specific position in this particular environment, directly parallel and related to plant communities.

Annual Plant: a plant that completes its life cycle from seedling to mature seed-bearing plant during a single-growing season and then dies.

Aquatic: growing, living in, or frequenting water.

Aquifer: an underground layer of sand and rock that holds water.

Arachnida: class of arthropods, characteristics include six pair of appendages; the first two are chelicerae and the rest are legs and two distinct body regions; group includes ticks, spiders, harvestmen, mites, and pseudoscorpions.

Arthropoda: phylum of invertebrates; characteristics include segmented bodies, paired segmented appendages, bilateral symmetry, a chitinous exoskeleton, an open circulatory system, excretion usually by means of Malpighian tubules, respiration by means of gills or tracheae and spiracles and an anterior nerve cord.

Assumption: to take something for granted.

Backfire: a fire burning into the wind.

Bacteria: one-celled microorganisms which have no chlorophyll; some are decomposers which break down once-living material.

Berlese Funnel: apparatus designed to separate invertebrates from leaf litter.

Biennial Plant: a plant that lives for two growing seasons, producing only leaves during the first season, flowers and seeds during the second.

Biodegradable: the quality of a substance that makes it possible for aerobic bacteria and other microorganisms to break the substance down into simpler compounds; some man-made substances, such as plastics and certain synthetic chemicals (PCB's, DDT), which do not break down easily into simpler compounds, are considered non-biodegradable.

Biodiversity: biological diversity or the variety of life in the world or in a particular habitat or ecosystem.

Biologist: a person who studies living organisms and their relationships to one another.

Biome: a large geographic area with somewhat uniform climatic conditions; a complex of communities characterized by a distinctive type of vegetation and maintained under the climatic conditions of the region; a community of living organisms of a single major ecological region.

Biosphere: the part of the Earth's crust, water, and atmosphere where living organisms can subsist.

Biotic Community: commonly the living organisms in the given community; it includes all plant and animal life within the community; the nonliving parts are considered the abiotic parts of the community.

Bird: an animal that maintains a constant body temperature, has adaptation for flight such as feathers and hollow bones, and lays eggs.

Brainstorm: a sudden idea.

Breeding: a series of complex behavioral interactive patterns from courtship to rearing of young necessary for the continuation of a species.

Broadleaf: the term describing a plant with wide-bladed leaves; non-grasses or sedges.

Canopy: a layer formed by the leaves and branches of the forest's tallest trees.

Carnivore: an animal that eats meat; also an insect or meat-eating plant.

Carrion: dead and putrefying flesh; scavengers consume carrion.

Categorizing: to arrange in specific groups.

Characteristics: a distinguishing feature or quality of something.

Chilopoda: class of arthropods; characteristics include elongated, flattened bodies with each body segment bearing a single pair of legs; there are typically 15 or more pairs of

legs; the last two pairs project to the rear; members of this group are commonly called centipedes.

Chlorophyll: the green pigment that is found in all green plant that absorbs the sunlight needed for photosynthesis; during photosynthesis the leaves release oxygen that becomes part of the air that we and other animals breathe.

Chrysalis: pupa (encasement) form of a butterfly or moth as larva changes to adult form.

Circumference (of a tree): the distance around a tree's trunk, usually measured 4.5 ft. (1.4 m) above the ground, and is approximated to the nearest inch (2.5 cm.).

Class: forming a group because of common attributes, characteristics, qualities, or traits.

Classification: to sort things in groups or classes based on common characteristics.

Clay: fine-grained natural rock or soil material that combines one or more clay minerals with traces of metal oxides and organic matter.

Climax Community: the final stage of plant or animal succession when environmental conditions have been stable long enough for an area to develop a semi-permanent biome; for example, rock crumbles and pioneering plants begin to grow in the sandy soil; as they add mulch and humus, other plants follow—from grasses to shrubs to pine forest; if climatic conditions and soil types are appropriate, the climax species could be the pine forest; animal types would follow this pattern of succession, ending perhaps with squirrels, porcupines, and Steller's jays as climax species.

Community: an association of organisms—plant and animal—each occupying a certain position or ecological niche, inhabiting a common environment, and interacting with each other; all the plants and animals in a particular habitat are bound together by food chains and other interrelations.

Competition: when two or more organisms have the potential for using the same resource; may be inter- or intra-specific.

Complete Metamorphosis: changes undergone in lower classes of animals; the four stages include egg, larva, pupa and adult.

Conservation: the wise and intelligent use or protection of natural resources; ethical use and protection of valuable resources such as trees, minerals, wildlife, water and others; it focuses on maintaining the natural world in order to protect the sources of resources**.** (See "preservation.")

Control Group: in an experiment, the group which is like the treated, or experimental group in all regards except that it is not subject to the test conditions; it is used as a method of measuring the change in the experimental group or factor.

Consumer: the first part of an ecosystem is the nonliving substance; the second part consists of those organisms, which are called “producers,” or food makers; part three of this system is called the “consumer” because it utilizes the producer for its food; it may, in turn, be used as food by a secondary consumer; a rabbit is a primary consumer; a fox would be a secondary consumer.

Critical Attributes: characteristics of organisms that are the most easily used in identification.

Crustacea: a class of arthropods that usually lives in water and breathes through gills; crustaceans have an exoskeleton, paired jointed limbs, two pairs of antennae, and a jointed body; crabs, lobsters, shrimp, and barnacles belong to this class (also freshwater crayfish, Daphnia, Cyclops, and others).

Cycles: periods in which a round of regularly recurring events are completed.

Data: a group of facts or statistics, especially the numerical results of experiments.

Debearding: process by which “beard” or awn is removed from grass seeds.

Deciduous: referring to trees that shed their leaves annually; regarding animal teeth, most commonly called “milk teeth,” which are shed at some time.

Decomposer: those organisms (bacteria, fungi) that convert dead organic materials into inorganic materials; a plant or animal that feeds on dead materials and causes its mechanical or chemical breakdown.

Decomposition/Decay: the breakdown of organic material due to the digestive action of microorganisms such as molds, bacteria and yeasts.

Dependent Variable: what is measured in an experiment and whose value is determined by other variables (the variable that is manipulated while others remain constant).

Description: a statement that creates a visual of something with words.

Dichotomous Key: a key that is used to identify a plant or animal; each stage of the key presents descriptions of two distinguishing characters, with a direction to another stage in the key, until the species is identified.

Diplopoda: class of arthropods; characteristics include wormlike, cylindrical bodies composed of diplosegments, each bearing two pairs of legs; members of this group are commonly called millipedes.

Dispersal: the scattering of living things or their seeds within a given area or over the earth; seeds, for example, are often adapted for dispersal.

Disturbance: a temporary change in environmental conditions that causes a pronounced change in an ecosystem (examples: hurricane, beetle outbreak, or logging).

Diurnal: active by daylight; the opposite of nocturnal.

Diversity: richness plus abundance; the total number of species and how common they are in the community or ecosystem variety; the general health of an ecosystem is sometimes assessed by its diversity.

Dormancy: a period of inactivity in plants or plant seeds usually associated with winter.

Drought: extreme shortage of rainfall compared to the normal rain expected for an area.

Ecological Niche: the role played by an organism in a biological community; its food preferences, requirements for shelter, special behaviors, and the timing of its activities (e.g., nocturnal or diurnal); the ecological niche of an organism has little to do with where it is found but much more to do with its function or role, e.g., predator, decomposer, and with how it performs that function.

Ecologist: a scientist who studies the interrelationships of living things to one another and their environment.

Ecology: the study of the relation of organisms or groups of organisms to their environment; or the science of the interrelation between living organisms and their environment.

Ecosystem: a natural unit that includes living and nonliving parts interacting to produce a system in which the exchange of materials between the living and nonliving parts follows closed paths; all living things and their environment in an area of any size linked together by energy and nutrient flow.

Ecosystem Services: direct and indirect contributions of ecosystems to human well-being; what nature provides for free to humans.

Ecotone: the intermediate area between two vegetative sites; this area typically supports more diverse and prolific examples of wildlife.

Edge Effect: the effect of an abrupt transition between two quite different adjoining ecological communities on the numbers and kinds of organisms in the marginal habitat; edge effects can be quite detrimental to small, isolated, fragmented habitat.

Endangered: a species that is in danger of extinction throughout all or a significant portion of its range.

Energy: the capacity for action; in food chain terms, the fuel for living organisms.

Entomologist: a scientist who studies insects.

Environment: the total of all of the surrounding—air, water, vegetation, human element, wildlife—that has influence on existence, including physical, biological, and all other factors; the surroundings of a plant or animal including other plants and animals, climate, and location.

Estimate: an approximate opinion or calculation of something.

Eutrophication: the process by which a body of water becomes enriched in dissolved nutrients (e.g., phosphates) that stimulate the growth of aquatic plant life usually resulting in the depletion of dissolved oxygen; nutrients in the water promote the growth of algae and weeds that die and decay; the bacteria and other organisms involved in the decaying process use the oxygen needed by other aquatic animals; when runoff containing fertilizer, dirt and decaying plant matter carries nutrients from the land into the lake or pond, the natural eutrophication process is accelerated and, depending on the degree of eutrophication, aquatic animal life can be destroyed.

Evaporation: the removal of a liquid from something by converting the liquid to a gas or vapor.

Evolution: the process by which changes in living things happens over time.

Experimental Group: the group or factor in an experiment that is subjected to the test conditions.

Extinction: the condition of having been removed from existence.

Family: a group of similar organisms; the fifth level in the seven levels of classification used to organize plants and animals.

Flammable: easily burned or ignited.

Flora: the plants of a certain site or region.

Flora: the plants of a certain site or region.

Food Chain: the transfer of food energy through a network of primary producers and consumers; for example, a green plant, a leaf-eating insect, and an insect-eating bird would form a simple food chain; any one species is usually represented in several or many food chains.

Food Web: an interlocking pattern of food chains.

Food Pyramid: the symbolic representation of the amount of food mass necessary to support the top level of consumers in a food chain.

Forb: broad-leafed, annual or perennial, herbaceous flowering plants.

Forest: a complex community of plants and animals in which trees are the most conspicuous members.

Forest Floor: the layer of decomposing material that covers the soil in a forest.

Fungi: any group of thallophytes, including molds, mildews, mushrooms, etc.; these organisms act as decomposers in a community.

Fungicide: a pesticide used to control fungi.

Genetic: referring to heredity of, relating to, or involving genes.

Genus: a subdivision of families; the generic first part of a scientific name, usually consisting of more than one species.

Germination: the act of sprouting and beginning growth.

Glaciation: the moving, grinding action of glaciers.

Grassland: a vegetative community in which grasses are the most conspicuous members.

Greenhouse Gases: gases that pollute the air and cause the warming of the Earth's atmosphere.

Habitat: the arrangement of food, water, shelter and space suitable to animals' needs; it is the "life range" which must include food and water, as well as escape cover, winter cover, cover to rear young, and even cover in which to play.

Hardwood: a deciduous or broadleaf tree; the wood from such trees.

Head Fire: a fire burning with the wind.

Herb: any flowering plant or fern that has a soft, rather than woody, stem.

Herbicide: pesticide used to kill unwanted plants.

Herbivore: an animal that eats plants.

Humus: organic matter in soil.

Hybridize: when two separate species reproduce (examples: red oak and black oak or prairie dock and compass plant).

Hypothermia: a state of dangerously low body temperature.

Incomplete Metamorphosis: changes undergone in lower classes of animals; the three stages include egg, nymph and adult.

Independent Variable: a variable in an experiment whose value determines the value of other variables.

Indigenous: a naturally occurring species.

Inorganic: compounds that do not contain carbon, often referring to nonliving material.

Insectivore: an animal that eats insects; certain birds, such as swallows, are insectivores.

Interaction: the relationship of one organism to another; the action of one population affecting the growth or death rate of another population; one population may eat members of the other population, compete for food, excrete harmful wastes, or otherwise interfere with the other population; some interactions are positive, some negative, and some are completely neutral.

Interdependence: interrelationships of wildlife with one another and with the various elements of their environment.

Invade: to enter, to encroach upon, to spread over into.

Invasive Species: plants, animals, or pathogens that are non-native (or alien) to the ecosystem under consideration and whose introduction causes or is likely to cause harm.

Invertebrate: an organism without a backbone. More than 90 percent of all living animal organisms are invertebrates.

Kingdom: the first level of classification of organisms.

Larva: an immature state that most insects and some water animals pass through after hatching from an egg and before becoming a pupa; usually distinct in form from its adult

counterpart; a moth or butterfly larva is a caterpillar; a fly larva is a maggot; a frog or toad larva is a tadpole.

Legume: nitrogen-fixing plants; the group of plants that includes beans, peas, alfalfa and some prairie plants; bacteria is associated with the roots of legumes and are able to fix atmospheric nitrogen into a form usable by plants.

Lichen: algae and fungus growing together in a symbiotic relationship.

Life Cycle: the continuous sequence of change undergone by an organism from one primary form to the development of the same form again.

Limiting Factor: influences, shelter, space, disease, predation, climatic condition, pollution, hunting, poaching, and accidents; when one or more of these exceeds the limit of tolerance of that animal, population of the animals or species, it then becomes a limiting factor; the factor then directly affects the well-being of that animal and may result in the animal's death; limiting factors may result from causes in nature as well as human activities.

Loam: a rich soil of clay, sand and organic matter.

Loess: clay or loam forming deposits along a river valley.

Mammal: animals that are able to regulate their body temperature, have hair and produce milk to feed their young.

Metamorphosis: changes undergone in the body structure of lower classes of animals; incomplete: egg, nymph and adult; complete: egg, larva, pupa and adult.

Microhabitat: a localized, small environment.

Microorganism: an organism microscopic in size, observable only through a microscope.

Migration: travel that occurs in seasonal cycles; example: monarch butterfly.

Molting: a growth adaptation in an animal life during which old skin splits and is discarded; examples: snakes, crayfish and monarch larva.

Monoculture: growing only one type of plant crop; this is very efficient for farming but extremely unstable because of the lack of diversity.

Moraine: a mass of earth, sand and rocks left by glaciers.

Natural Selection: adaptive change over time; a process in nature resulting in the survival and perpetuation of only those forms of plant and animal life having certain favorable characteristics that enable them to adapt best to a specific environment.

Niche: See “ecological niche.”

Nitrogen Fixation: The conversion of elemental nitrogen from the atmosphere to organic combinations or to forms readily utilizable in biological processes; normally carried out by bacteria, living symbiotically in legumes or by free-living soil bacteria.

Nocturnal: active by night; the opposite of diurnal.

Nonrenewable Resource: nonliving resources such as rocks and minerals; resources which do not regenerate themselves; once used these resources cannot be replaced, at least not in this geological age; examples: petroleum, coal, copper and gold.

Observation: the skill of observing and noticing.

Omnivore: an animal that eats both plant and animal materials.

Order: the fourth specific group of organisms in biological classification.

Organic Matter: chemical compounds of carbon combined with other chemical elements and generally manufactured in the life processes of plants and animals; most are a source of food for bacteria and usually combustible; organic compounds were once part of a living thing and biodegradable.

Organism: a living thing; a form of life composed of mutually dependent parts that maintain various vital processes.

Owl Pellet: the compacted mass of undigested hair, teeth, scales, feathers, insect skeletons and bone regurgitated by the owl after feeding.

Parts Per Million (ppm): in liquid measure, refers to mg/L or milligrams per liter.

Percolation: the filtering of water through soil.

Perennial: a plant that lives for several years and usually produces seeds each year.

Percentage: a rate or proportion per hundred.

Pesticide: any chemical used to kill unwanted organisms; includes insecticides, herbicides, and fungicides.

Perspective: one’s ideas and view on information, relationships and relevant data.

Photosynthesis: the process in which leaves use carbon dioxide from the air, water from the roots, and the sun's energy (in the form of sunlight) to make glucose (simple carbohydrates).

Phenology: timing in relation to biological activities such as plant life cycles or seasonal changes.

Phylum: the second organizational level in the seven levels of biological classification.

Pioneer Plants: the first plants to colonize bedrock and begin conversion to soil; examples: lichens and mosses.

Pollinator: an organism (often an insect) that facilitates the transfer of pollen from stamen to pistil.

Pollution: harmful substances deposited in the air or water or land leading to a state of dirtiness, impurity, unhealthiness or hazard.

Pond: a body of fresh water smaller than a lake.

Population: the number of individuals of a particular species in a defined area.

Prairie: a grassland community, specifically in North America.

Predaceous: a predatory animal that kills and eats other animals.

Predation: the act of preying upon.

Predator: an animal that kills and eats other animals.

Prescribed Burning: the planned application of fire to natural fuels with the intent to confine the burning to a predetermined area.

Preservation: protection that emphasizes non-consumptive uses including no direct use by humans; contrasted by conservation which emphasizes both consumptive and non-consumptive values and uses. (See "conservation.")

Prey: animals that are killed and eaten by other animals.

Primary Producers: green plants that are able to manufacture food from simple organic substances using energy from the sun.

Propagation: in plants, the production of more plants by seeds or vegetative division.

Quadrat: a sample plot of an area, usually square.

Range: the limits to which variation is possible.

Rare: referring to wildlife species not presently in danger, but of concern because of low numbers.

Recovery Plan: a plan devised by a study team to re-establish or increase the population of an endangered or threatened species that has been reduced or eliminated in a specific area; recovery plans identify the factors that have diminished the animal and its habitat and work toward reducing those negative impacts; recovery teams have been assigned to study many listed endangered and threatened species with hopes of increasing their numbers enough to take them off the lists.

Recycling: using again and again as in stored food energy being returned to the soil through decomposition and used by plants as nutrients.

Renewable Resource: living resources, such as plants and animals, which have the capacity to renew themselves when conditions for survival are favorable. (See "nonrenewable resources.")

Reptile: animal that cannot regulate own body temperature; have an outer covering of scales and are usually egg laying.

Resource: a portion of an environment upon which people have placed or assigned a value, or see as being available for use.

Respiration: the sum total of the physical and chemical processes in an organism by which oxygen is conveyed to tissues and cells; the oxidation products, carbon dioxide and water, are emitted.

Sand: loose, gritty grains of disintegrated rock.

Savannah: a distinct ecosystem; a grassland characterized by scattered trees without canopy closure and plants that tolerate sun and shade.

Scarification: the process of making small scratches or punctures in the surface; in the case of prairie management, in the surface of thick seed coatings.

Scavenger: an organism that habitually feeds on refuse or carrion; a coyote is a part-time scavenger while a dermestid beetle is a full-time scavenger.

Scientific Name (also known as species name): made up of three parts: the genus (generic name), specific epithet (specific name), and authority (who named the species).

Secchi Disk: a black and white disk used to measure turbidity (sediment suspended in water); using a calibrated rope, the disk is lowered into the water to a depth at which the color variation cannot be seen because of the cloudiness of the water.
Sediment: material that settles to the bottom of a liquid; mineral or organic material deposited by natural forces such as wind, water, and glaciers.

Shelter: cover from the elements for natal activity, to travel in, for breeding, for bedding, etc.; varies depending on the species.

Silt: very small particles of soil or rock.

Soil: an incredibly complex sub-surface environment; the surface layer of earth supporting life.

Soil Aggregates: many small soil particles held together in a clump.

Species: a population of individuals that are more or less alike and that are able to breed and produce fertile offspring under natural conditions; a category of biological classification immediately below the genus or subgenus.

Species Name (also known as scientific name): made up of the genus, specific epithet and authority.

Species Richness: total number of species in a given area.

Stomata: one of the minute openings in the epidermis of a plant organ (as a leaf) through which gaseous interchange takes place; *also***:** the opening with its associated cellular structures.

Stratification: the process of subjecting seeds to cold temperatures to break dormancy.

Succession: the orderly, gradual, and continuous replacement of one plant or animal by another.

Sustainability: not being harmful to the environment or depleting natural resources; the use of natural resources in a way that assures their continuing availability to future.

Symbiosis: a close living relationship between organisms.

Thatch: non-living plant matter.

Threatened: nearly endangered of extinction.

Till: mineral portion of soil transported to its location by a glacier.

Trait: a distinguishing characteristic or quality.

Transpiration: the release of water vapor through the stomata of a plant.

Tree: a woody plant with a single main stem (trunk) and a more or less distinct crown of leaves.

Trophic Interactions: interactions between different levels of the food web.

Trophic Level: each of several hierarchical levels in an ecosystem, comprising organisms that share the same function in the food chain and the same nutritional relationship to the primary sources of energy.

Turbidity: describes the suspended or stirred up particles of sediment in a liquid; turbid waters are cloudy and contain a lot of suspended particles.

Understory: the layer of plants growing under another layer of plants; examples: grasses, weeds and brush under forest trees.

Variable: something that a scientist changes during the course of an experiment.

Variation: change in condition, character or degree.

Vegetation: the mass of plants that covers a given area.

Viability: the ability of a thing to maintain itself; potential for survival.

Water Cycle: the movement of water through the ecosystem; including, evaporation, condensation and precipitation.

Weather: the state of the atmosphere with respect to wind, precipitation, temperature, cloud cover, humidity and pressure.

Weed: a plant out of place; any undesired, uncultivated plant, especially one growing up in profusion and crowding out a desired plant; plants not native to America.

Wetlands: a land area that is saturated with water, either permanently or seasonally, such that it takes on the characteristics of a distinct ecosystem; distinct soils and plants (e.g., marsh, bog, floodplain forest).

Wind Dispersal: moving seeds from the parent plant by means of wind.

Woodland: a forest community with some level of canopy openness.