Bundling Performance Expectations for Ecology NGSS-Aligned Units

http://www.state.nj.us/education/modelcurriculum/sci/biou1.pdf
http://brinzaengineering.weebly.com/the-raccoon-mystery (how a tree gets its mass)
http://brinzaengineering.weebly.com/the-raccoon-mystery/previous/2

Phenomena: mechanism that drives student learning across all 3 dimensions (SEP, CCC, DCI)

- Thread that can go through an entire unit
- Phenomena does not always need to be phenomenal

Dimension 1: Science and Engineering Practices (SEP)

Science and engineering practices are the same behaviors that scientists use to answer questions and engineers use to solve problems in the real world.

NGSS Science and Engineering Practices:

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Dimension 2: Crosscutting Concepts (CCC)

Crosscutting concepts are those concepts that apply across all scientific disciplines. They provide students with an organizational framework based on behavior and function that connects ideas from different scientific disciplines. For example, students can see how energy and matter are essential to understanding Life Sciences, but also for understanding Physical Science, Earth Science, and Engineering.

NGSS Crosscutting Concepts:

1. Patterns
2. Cause and effect
3. Scale, Proportion, and Quantity
4. Systems and System Models
5. Energy and Matter
6. Structure and Function
7. Stability and Change

Dimension 3: Disciplinary Core Ideas (DCI)

Disciplinary Core Ideas form the basis of what most educators would consider STEM "content knowledge," also known as scientific facts.

These core ideas are grouped into four content domains:

1. Physical sciences
2. Life sciences
3. Earth sciences
4. Engineering, technology and application of science

Unit 1: Matter and Energy Transformations in Ecosystem (instructional time: 20 days)

In this unit of study, students construct explanations for the role of energy in the cycling of matter in organisms and ecosystems. They apply *mathematical concepts* to *develop evidence to support explanations* of the interactions of photosynthesis and cellular respiration, and they will *develop models to communicate these explanations*. Students also understand organism's interactions with each other and their physical environment and how organisms obtain resources. Students utilize the crosscutting concepts of matter and energy and systems, and systems models to make sense of ecosystem dynamics. Students are expected to use students *construct explanations* for the role of energy in cycling of matter in organisms and ecosystems. They *apply mathematical concepts* to *develop evidence to support explanations* as they demonstrate their understanding of the disciplinary core ideas.

Crosscutting Concepts (CCC):

1. **Matter and Energy**: Tracking energy and matter flows, into, out of, and within systems helps one understand their system's behavior.
2. **Systems and System Models**: A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems.

Performance Expectations (PE): *set learning goals for students but do not describe how students get there*

- **Performance Expectation LS1-5 - Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.** [Clarification Statement: Emphasis is on illustrating inputs and outputs of matter and the transfer and transformation of energy in photosynthesis by plants and other photosynthesizing organisms. Examples of models could include diagrams, chemical equations, and conceptual models.] [*Assessment Boundary: Assessment does not include specific biochemical steps.*]
    - **Disciplinary Core Idea (DCI) - LS1.C: Organization for Matter and Energy Flow in Organisms**
        - The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen. (HS-LS1-5)
        - *How do organisms obtain and use the matter and energy they need to live and grow?*
        - Sustaining life requires substantial energy and matter inputs. The complex structural organization of organisms accommodates the capture, transformation, transport, release, and elimination of the matter and energy needed to sustain them. As matter and energy flow through different organizational levels—cells, tissues, organs, organisms, populations, communities, and ecosystems—of living systems, chemical elements are recombined in different ways to form different products. The result of these chemical reactions is that energy is transferred from one system of interacting molecules to another.
        - In most cases, the energy needed for life is ultimately derived from the sun through photosynthesis (although in some ecologically important cases, energy is derived from reactions involving inorganic chemicals in the absence of sunlight—e.g., chemosynthesis). Plants, algae (including phytoplankton), and other energy-fixing microorganisms use sunlight, water, and carbon dioxide to facilitate photosynthesis, which stores energy, forms plant matter, releases oxygen, and maintains plants' activities. Plants and algae—being the resource base for animals, the animals that feed on animals, and the decomposers—are energy-fixing organisms that sustain the rest of the food web.
    - ***By the end of grade 8.*** *Plants, algae (including phytoplankton), and many microorganisms use the energy from light to make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen. These sugars can be used immediately or stored for growth or later use. Animals obtain food from eating plants or eating other animals. Within individual organisms, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, to support growth, or to release energy. In most animals and plants, oxygen reacts with carbon-containing*

molecules (sugars) to provide energy and produce carbon dioxide; anaerobic bacteria achieve their energy needs in other chemical processes that do not require oxygen.

  - ***By the end of grade 12.*** *The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen. The sugar molecules thus formed contain carbon, hydrogen, and oxygen; their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used for example to form new cells. As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. For example, aerobic (in the presence of oxygen) cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. Anaerobic (without oxygen) cellular respiration follows a different and less efficient chemical pathway to provide energy in cells. Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy loss to the surrounding environment. Matter and energy are conserved in each change. This is true of all biological systems, from individual cells to ecosystems.*

- **Performance Expectation LS2-3 - Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions.** [Clarification Statement: Emphasis is on conceptual understanding of the role of aerobic and anaerobic respiration in different environments.] [*Assessment Boundary: Assessment does not include the specific chemical processes of either aerobic or anaerobic respiration.*]
  - **Disciplinary Core Idea (DCI) - LS2.B: Cycles of Matter and Energy Transfer in Ecosystems**
    - Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes. (HS-LS2-3)
    - *How do matter and energy move through an ecosystem?*
    - The cycling of matter and the flow of energy within ecosystems occur through interactions among different organisms and between organisms and the physical environment. All living systems need matter and energy. Matter fuels the energy-releasing chemical reactions that provide energy for life functions and provides the material for growth and repair of tissue. Energy from light is needed for plants because the chemical reaction that produces plant matter from air and water requires an energy input to occur. Animals acquire matter from food, that is, from plants or other animals. The chemical elements that make up the molecules of organisms pass through food webs and the environment and are combined and recombined in different ways. At each level in a food web, some matter provides energy for life functions, some is stored in newly made structures, and much is discarded to the surrounding environment. Only a small fraction of the matter consumed at one level is captured by the next level up. As matter cycles and energy flows through living systems and between living systems and the physical environment, matter and energy are conserved in each change.
    - The carbon cycle provides an example of matter cycling and energy flow in ecosystems. Photosynthesis, digestion of plant matter, respiration, and decomposition are important components of the carbon cycle, in which carbon is exchanged between the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes.
  - ***By the end of grade 8.*** *Food webs are models that demonstrate how matter and energy is transferred between producers (generally plants and other organisms that engage in photosynthesis), consumers, and decomposers as the three groups interact—primarily for food—within an ecosystem. Transfers of matter into and out of the physical environment occur at every level—for example, when molecules from food react with oxygen captured from the environment, the carbon dioxide and water thus produced are transferred back to the*

environment, and ultimately so are waste products, such as fecal material. Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem.

   - ***By the end of grade 12.*** *Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes. Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward, to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels of a food web, and there is a limit to the number of organisms that an ecosystem can sustain.The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil and are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved; some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. Competition among species is ultimately competition for the matter and energy needed for life. Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged between the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes.*

- **Performance Expectation: LS2-4 - Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.** [Clarification Statement: Emphasis is on using a mathematical model of stored energy in biomass to describe the transfer of energy from one trophic level to another and that matter and energy are conserved as matter cycles and energy flows through ecosystems. Emphasis is on atoms and molecules such as carbon, oxygen, hydrogen and nitrogen being conserved as they move through an ecosystem.] [*Assessment Boundary: Assessment is limited to proportional reasoning to describe the cycling of matter and flow of energy.*]
   - **Disciplinary Core Idea - LS2.B: Cycles of Matter and Energy Transfer in Ecosystem**
      - Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward, to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels of a food web. Some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved. (HS-LS2-4)
      - *How do matter and energy move through an ecosystem?*
      - The cycling of matter and the flow of energy within ecosystems occur through interactions among different organisms and between organisms and the physical environment. All living systems need matter and energy. Matter fuels the energy-releasing chemical reactions that provide energy for life functions and provides the material for growth and repair of tissue. Energy from light is needed for plants because the chemical reaction that produces plant matter from air and water requires an energy input to occur. Animals acquire matter from food, that is, from plants or other animals. The chemical elements that make up the molecules of organisms pass through food webs and the environment and are combined and recombined in different ways. At each level in a food web, some matter provides energy for life functions, some is stored in newly made structures, and much is discarded to the surrounding environment. Only a small fraction of the matter consumed at one level is captured by the next level up. As matter cycles and energy flows through living systems and between living systems and the physical environment, matter and energy are conserved in each change.
      - The carbon cycle provides an example of matter cycling and energy flow in ecosystems. Photosynthesis, digestion of plant matter, respiration, and

decomposition are important components of the carbon cycle, in which carbon is exchanged between the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes.

  - ***By the end of grade 8.*** *Food webs are models that demonstrate how matter and energy is transferred between producers (generally plants and other organisms that engage in photosynthesis), consumers, and decomposers as the three groups interact—primarily for food—within an ecosystem. Transfers of matter into and out of the physical environment occur at every level—for example, when molecules from food react with oxygen captured from the environment, the carbon dioxide and water thus produced are transferred back to the environment, and ultimately so are waste products, such as fecal material. Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem.*
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- **Performance Expectation: LS2-5 - Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.** [Clarification Statement: Examples of models could include simulations and mathematical models.] [*Assessment Boundary: Assessment does not include the specific chemical steps of photosynthesis and respiration.*]
  - **Disciplinary Core Idea - LS2.B: Cycles of Matter and Energy Transfer in Ecosystem**
    - Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes. (HS-LS2-5)
    - *How do matter and energy move through an ecosystem?*
    - The cycling of matter and the flow of energy within ecosystems occur through interactions among different organisms and between organisms and the physical environment. All living systems need matter and energy. Matter fuels the energy-releasing chemical reactions that provide energy for life functions and provides the material for growth and repair of tissue. Energy from light is needed for plants because the chemical reaction that produces plant matter from air and water requires an energy input to occur. Animals acquire matter from food, that is, from plants or other animals. The chemical elements that make up the molecules of organisms pass through food webs and the environment and are combined and recombined in different ways. At each level in a food web, some matter provides energy for life functions, some is stored in newly made structures, and much is discarded to the surrounding environment. Only a small fraction of the matter consumed at one level is captured by the next level up. As matter cycles and energy flows through living systems and between living systems and the physical environment, matter and energy are conserved in each change.

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    - ***By the end of grade 12.*** *A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability, anthropogenic changes (induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species.*

Unit 2: Interdependent Relationships in Ecosystems (instruction days: 20 days)

In this unit of study, students formulate answers to the question **"how and why do organisms interact with each other (biotic factors) and their environment (abiotic factors), and what affects these interactions?"**

Secondary ideas include the interdependent relationships in ecosystems; dynamics of ecosystems; and functioning, resilience, and social interactions, including group behavior. Students use mathematical reasoning and models to make sense of carrying capacity, factors affecting biodiversity and populations, the cycling of matter and flow of energy through systems. The crosscutting concepts of scale, proportion, and quantity, and stability and change are called out as organizing concepts for disciplinary core ideas. Students are expected to use mathematical reasoning and models to demonstrate proficiency with disciplinary core ideas.

Cross Cutting Concepts (CCC):

1. Scale, Proportion, and Quantity: In considering phenomena, it is critical to recognize what is relevant at different size, time, and energy scales, and to recognize proportional relationships between different quantities as scales change.
2. Stability and Change: For both designed and natural systems, conditions that affect stability and factors that control rates of change are critical elements to consider and understand.

Exemplar

Driving question for the unit: What is happening between the badger and its environment.

This unit started with a video of badger road kill. Although it seems like a small 2 minute video, there was a lot of questions and that the video generated.

The badger was found at the side of the road. The road is a man-made structure, as opposed to a natural structure. Therefore, anthropogenic activities are important in the ecosystem. The anthropogenic changes include habitat destruction, pollution, invasive species, overexploitation of resources (such as over-fishing our oceans), climate change (it's real!). Some examples are organisms that have been challenged if there is a lack of habitat due to habitat destruction or fragmentation of habitats due to roads cutting through animal ranges. On the other hand, even though invasive species can decimate indigenous populations, as we learned in the shopping cart activity, sometimes an indigenous species that was less prevalent in an area can take off if the invasive species is a a new food resource that other organisms can't use.

The time-lapse video showed in some detail what happened to the badger. The badger was decomposing and being used as a food source for other organisms. This illustrated how the badger was part of the food web and the ecosystem. For example, visible organisms such as flies and crows were seen feeding on the carcass of the badger until there was only fur, bones and small amounts of flesh left over. Invisible organisms that cannot be seen with the naked eye included aerobic and anaerobic bacteria (which will be described later in the essay), Additionally, the website/ecosystem activity demonstrated that abiotic factors were also important. For example, sun and humid weather would increase the rate of decomposition. From the time-lapse in the video, we ascertained that the decomposition occurred within a period of 2 weeks. It was summer, green plants were present, If it were winter, the decomposition would have taken longer, since the cold would have acted to preserve the carcass.

After examining the role of the badger as more or less as a food source in the ecosystem and working up (from organism → population → community → ecosystem), there was the question of what actually happened to the badger. It was getting smaller, but what exactly happened to it? Other organisms were feeding from the badger carcass, but what was the badger made of? A similar activity describing levels of organization within the badger helped answer this questions. Working backwards, the badger (from large to small) consisted of badger → organ systems → organs → tissues → cells → organelles → molecules → atoms.

Now that we know about the levels of organization in a badger, did this organization hold true for other organisms? We watched a video of pig decomposition. From the evidence gleaned from the video, there are definite patterns between the pig and the badger. They both decomposed in essentially the same manner. There were some differences, some man-made, some environmental. For example, larger animals could not feed off the pig because it was contained within an enclosure that did not allow large organisms to enter. Also, there appeared to be a lot more insect activity. From the evidence provided, we decided that most organisms have a 'universal' structure.

In both cases, the animal seemed to expand and contract. At first we didn't understand the contractions, especially since the visible organisms were eating the carcass and making it smaller. Another activity helped answer that question. From our last unit (evolution), we know that bacteria are everywhere even though we can't see them. We hypothesized that the bacteria are metabolizing and that the products of metabolism include carbon dioxide and/or other gases that are causing the animal to expand. To show this was the case, we took a sample of rotting meat, swabbed it and touched the swab to an agar dish. Within a few day, the agar was teeming with different colonies of bacteria. To show that the growth wasn't coming directly from the rotting meat, we 'sterilized' the meat by washing it in alcohol, and then swabbed into onto a different agar dish. No bacteria grew on the plate. It was concluded that bacteria is also responsible for a great deal of decomposition, although it is not seeable with the naked eye.

Even though we saw that the carcass was getting smaller, and it was evident that matter from the badger and pig carcass was being moved to the organisms that was feeding it, we were curious as to what exactly was being transferred. How do other organisms actually use the organisms? Do they use the matter directly, or do they turn it into other forms of energy? For example, in middle school we learned that plants can use solar energy to grow and animals use cellular respiration and that carbon dioxide is a product of cellular respiration But is this true for all organisms? To answer those questions, we did a series of related experiments.

To show if organisms use matter directly, or have to change it to another form, we performed an experiment We used yeast and sugar. We set up fermentation tubes. The first tube contained yeast and water, the second tube contained yeast and a sugar solution. Nothing happened in the yeast and water tube, but in the tube that contained yeast and sugar, many carbon dioxide bubbles were formed, showing that cellular respiration was occurring. After a long while, the sugar solution was tested for the decrease in the concentration of sugar with time, using a sugar test strip, and there was a decrease in the amount of sugar in the solution. This provided evidence that the sugar was being changed into something else, that carbon dioxide was a product. Therefore, since sugar is matter it is being changed into something else that the cell can use. We theorized this change of matter was being converted to energy that the yeast could use.

An offshoot of the above activity led us back to levels of organization, where we re-examined atoms→ elements→ macromolecules. Using sugar as our model, we determined that organisms are organic because they contain carbon, oxygen (and hydrogen) and that these three elements can be combined in many ways to form many different kinds of molecules.

We are unsure where the key component lab fits into the unit. Originally it was included as a way to link energy and matter. However, after talking to our colleagues from middle school, the students should have a fairly sound understanding of conversion of matter to energy during the processes of cellular respiration and photosynthesis.

The first experiment we did was to put either a snail or elodea (a plant) in separate test tubes filled with water and bromothymol blue (BTB), a pH indicator. At a neutral pH, the water is blue, in an acidic environment, BTB is yellow Since carbon dioxide in solution is acidic, carbon dioxide will turn the solution yellow. The water/BTB solution with the snail turned yellow, while the water/BTB solution with the elodea remained blue. Therefore, it was concluded that animals respire, and carbon dioxide is a product. Cellular respiration was occurring. We also put the elodea in an acidic solution (since we respire, we blew into the test tube containing BTB and water, and turned the solution yellow (further evidence of cell respiration!). We put the elodea in the test tube and it eventually turned blue, showing that the plant is using the carbon dioxide. That led us to several other questions. What is the role of carbon in the environment? This led us to the carbon cycle. We also wanted to know what the relationship between photosynthesis and cell respiration and the carbon cycle. Another question we wanted to address was if all organisms used the same type of cell respiration, and if plants ever used cell respiration.

To determine if all organisms use the same type of cell respiration, we did an experiment using clothespins. In one scenario we opened and closed the clothes pin for 30 seconds with a 2 minute break during activity (3 cycles), In the other scenario, we opened and closed the clothes pin for 90 seconds without a break. After the end of the 90 seconds, everyone's arms were sore. This led us to think that there is more than one type of cell respiration, and the students on the track team explained how our muscles can undergo a kind of respiration called lactic acid fermentation when the muscles run out of oxygen. We concluded that there is anaerobic and aerobic respiration, respiration without and with oxygen, respectively.

Another question we had from the BTB activity was the role of cell respiration and photosynthesis in the carbon cycle. We made models of the carbon cycle that included plants, which we determined use carbon dioxide and animals that produce carbon dioxide. This fit in well with the idea of a cycle, and it also fit in with the equation of cell respiration and photosynthesis ('reciprocal' processes that we also discovered during the BTB experiments.)

At this point, we decided we wanted to determine the role of carbon dioxide in photosynthesis. We know that plants use it because of the BTB experiment (yellow BTB solution turns blue after a plant has been introduced into the solution). We discovered that carbon dioxide is the source of carbon that is needed to make macromolecules from researching the role of carbon dioxide and studying van Helmont's experiment that the mass of a tree does not come directly from the soil, but from water, and from other experiments, carbon dioxide.

Our final model of the carbon cycle included photosynthesis, cell respiration, carbon in the atmosphere in the form of carbon dioxide, in organisms in different organic molecules, in abiotic reservoirs such as fossil fuels. When we burn fossil fuels, we increase the level of carbon dioxide in the atmosphere, which we linked to global warming and the impact of humans in the environment (anthropogenic factors).

At the end of this unit, we were able to link organisms to the environment, determine that different organisms are able to utilize different kinds of energy, and can 'change' one type of energy to another, link all of the above components as players in the carbon cycle, and even include the role of man in the environment.

Energy and Matter (CCC)

Blue Font: teacher generated questions
Green Font: student generated questions

DCI: disciplinary core idea linked to lesson
Green highlight: Assessment

Pink Font: student activities
Red Font: link to previous knowledge

Tan Font: What have students figured out at this point?

Phenomenon: badger road kill video https://youtu.be/E93rNE5F-LE

1. Human activity → why did I hit the badger?
    a. Teacher Generated Prompts:
        i. Think about what you see and what you think is going on here.
        ii. Consider what is going on with the badger itself as well as how the badger fits into the environment.
    b. Students should relate to personal experience.
        i. Students should be able to relate the video to their lives - seeing road kill examples like deer, squirrel, turkey, etc.
    c. Teacher Generated Questions:
        i. How are other animals in ecosystem related?
        ii. What sort of questions do you have?
    d. Possible Student Generated Questions:
        i. Anticipated questions
            1. Q's about animals eating the badger
            2. Q's about what is happening to the carcass
            3. Q's about what happens to the meat
            4. Q's about the time it takes
            5. Q's about how the badger died
        ii. Possible categories to group questions
            1. Food
            2. Habitats/systems
            3. Bacteria
            4. Human impact

Students will construct an *initial model individually*→ students will draw a diagram or explanation of what happened to the badger

2. Systems: the badger part of a larger system → ecosystem that contains flies, birds, bacteria, among other organisms (plants) and other components (rock, soil, sun, water).
    a. Levels of organization from ecosystem to organism.
    b. Possible student generated questions
        i. Where is the badger in the system?
        ii. What is a system?
        iii. What are interacting parts of a system?
    c. Activity: provide students with cards for a food web/ecosystem based on the badger. In a small group have them make relationships between components of the ecosystem.

d. Activity: Key Component Lab using organisms from food web/ecosystem based on the badger to gain an understanding of the interactions and what is being transferred in each interaction
e. Possible Student Generated Questions:
    i. What do the beans represent?
    ii. What is being transferred from one organism to another during consumption?
    iii. Why were producers able to collect more beans after each encounter?

DCI: levels of organization and flow of energy and cycling of matter
DCI: Energy is transformed from one system to another.
DCI: Competition among species is ultimately competition for matter and energy needed for life.
DCI: Only a small fraction of matter consumed is transferred upwards on a food web.
DCI: At each link of an ecosystem, matter and energy are conserved.
DCI: Ecosystems have complex interactions.
DCI: Plants or algae form the lowest level of the food web.
DCI: The transferred matter produces growth and releases energy at the next level of the food chain.
DCI: Some matter is stored in newly made structures.
DCI: There are limits to the number of organisms that an ecosystem can sustain.

Students will generate a model in small groups (HOPEFULLY THEY WILL ADD ENERGY)

Students should have figured out that energy flows through a system and that producers are important for functional ecosystems.

3. Review the badger video and guide students to study the badger as a system in and of itself.
    a. Possible Student generated questions:
        i. What is the badger made of?
        ii. What are the different parts of the badger?
    b. Activity: similar to above by providing students cards from atoms to organisms. In a small group have them place levels of organization in the correct order.
        i. **Go over levels of organization from atoms (element) → molecule → organelle → cell → tissue → organ → organ system → organism**
        ii. **Teacher should include a discussion of hydrocarbon backbones, macromolecules, and the different types of macromolecules.**
    c. Teacher generated questions:
        i. How does this help us figure out what is going on with the badger?
        ii. What should we do next to help figure out what is going on with the badger?

DCI: Sugar molecules contain atoms (C, H, O)

DCI: Hydrocarbon backbones can be used to make other macromolecules.
DCI: The chemical elements that make up the molecules of organisms pass through food webs.
DCI: As molecules of organisms pass into the ecosystem, they are combined and recombined in different ways.

Allow students to add to or edit their small group models (do not let them redo their models, only add or edit)

Students should have figured out that organisms are made up of smaller components and that some of those components are important for food (All organisms take in matter and rearrange the atoms in chemical reactions).

4. **Students will now watch the pig decomposition video**
   https://www.youtube.com/watch?v=eUA0l1DWz9E&feature=youtu.be

   a. Encourage students to look at patterns: similarities and differences between the decomposition of the badger and the pig in the 2 videos.
   b. Possible Student Generated Questions:
      i. Why is the badger and it getting "bigger" or "breathing'?
      ii. Why are there more flie in the pig decomposition?
      iii. Why are there birds in the pig decomposition?
      iv. What is happening with the fur?
      v. Is there anything going on that is not visible?
   c. Link to previous evolution unit. Is there anything going on during the process that the student can't see? *Hopefully the students should have remembered that they made bacterial cultures from the environment in the evolution unit.*
   d. Activity: rotting meat and bromothymol blue (BTB), a pH indicator. Turns yellow if acidic. If there is carbon dioxide being produced from the bacteria on the rotting meat, the BTB will turn blue.
   e. Possible Student Generated Questions:
      i. Why is the color changing?
      ii. What process is occurring?
      iii. What molecules are involved?
      iv. Is meat still alive? *If students generate this question, the meat can be cultured after it is 'sterilized' by dipping in alcohol, then the meat can be touched to an agar plate.*
   f. Teacher generated questions:
      i. How does this help us figure out what is going on with the badger?
      ii. What should we do next to help figure out what is going on with the badger?

Important! make sure students recognize the link between the rotting meat and food/carbon for cellular respiration.

Students should have figured out that bacteria are eating the meat and that they are using the carbon compounds in the meat for food.

5. **The above should then segue into cell respiration** (students have knowledge of carbon dioxide from grade 8) **from the rotting meat activity. From the activity, they should know that carbon dioxide and water condensation (rotting meat put in a covered glass jar will have water condensed on the side of the jar), and then realize these are the products of cell respiration.**
   a. Hopefully this will lead to student generated questions regarding reactants in the process of cellular respiration and linking to levels of organization.
   b. Possible Student Generated Questions:
      i. What process is causing the BTB change?
      ii. What are the reactants of cell respiration?
      iii. Where do the reactants come from?
      iv. What is in the meat?
   c. **Go back over the cell and the relationship between the mitochondrion and cellular respiration.** *From grade 8, the students know the cell wall, cell membrane, nucleus, mitochondrion, chloroplast.*

DCI: Aerobic respiration (in presence of oxygen) to help break down food molecules.
DCI: Chemical elements recombine in different ways to form different products.
DCI: Oxygen and glucose provide energy for cells.

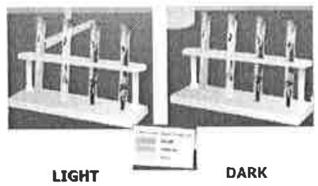
6. Video on Earth before oxygen was present
   a. Possible Student Generated Questions
      i. Why was there no oxygen present on Earth?
      ii. Where did the oxygen come from?

7. DEMO: YEAST IN FERMENTATION TUBES TO ILLUSTRATE ANAEROBIC RESPIRATION and guide students to recognize the difference between aerobic and anaerobic respiration. USE SUGAR AND WATER AS A CONTROL
   a. Possible Student Generated Questions:
      i. What is different about the rotting meat demo and the yeast fermentation demo? (with and without oxygen)
      ii. Why are gas bubbles being generated in sugar and not in water?
   b. Teacher generated questions:
      i. How does this help us figure out what is going on with the badger?
      ii. What should we do next to help figure out what is going on with the badger?

DCI: Anaerobic (without oxygen) is less efficient than aerobic but still provides energy to cells.

Students should have figured out from activity: cellular respiration is the process by which the matter in food (sugars, fats) reacts chemically with other compounds, rearranging the matter.

8. Demo: Elodea, Snails, and BTB. **This will help to connect cell respiration, photosynthesis and the carbon cycle.**



- Possible Student Generated Questions:

    Why did the snail BTB will go from blue→ yellow?
    Why did the elodea BTB go from yellow→ blue?
    What is causing this?
    Where did molecules come from?
    What are the molecules?

May need to show some videos of different wavelengths and plant growth.

Students should have figured out from activity: photosynthesis and cellular respiration are reciprocal processes. Photosynthesis uses CO2 and cellular respiration uses O2.

9. DEMO: AIR BUBBLES COMING FROM ELODEA

DCI: the process of photosynthesis converts light energy to stored chemical energy.
DCI: photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes.

10. WHOLE GROUP DISCUSSION: make sure all students have a full understanding of the similarities and differences between photosynthesis and cell respiration (including rearrangement of atoms), which will allow us to move into the carbon cycle. Emphasis should be on the idea that carbon cycles through the ecosystem and that CR and PS are part of that process.

DCI: Photosynthesis and cellular respiration are important components of the carbon cycle.

After the previous units and the demo, the students should come to understand that carbon dioxide and water are products of cellular respiration and that carbon dioxide is used during photosynthesis. This can then move the students into the direction of the carbon cycle.

Students should have figured out from activity: photosynthesis captures energy in sunlight to create chemical products (carbohydrates) that can be used as food in cellular respiration.

11. Activity: with their recently acquired knowledge, have the students work in small groups and make a model of the carbon cycle, then go back into a large class discussion in the format of a circle. Link back to anthropogenic activity with sinks of fossil fuels.

c. Teacher generated questions:
    i. How does this help us figure out what is going on with the badger?
    ii. What should we do next to help figure out what is going on with the badger?

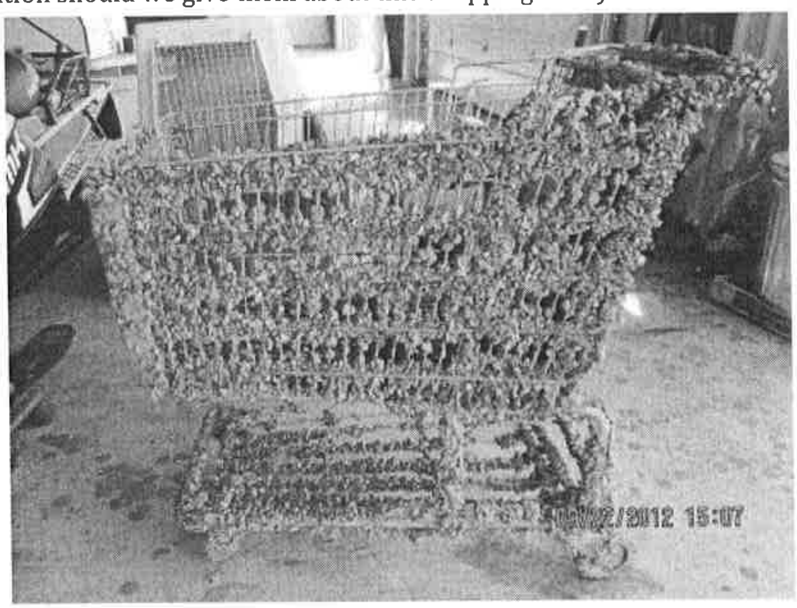
12. Carbon cycle and systems check in.
Activity: Reading on van Helmot's experiment?

d. Teacher Generated Question: How do organisms relate to the carbon cycle?
e. Possible Student Generated Questions:
    i. What is the relationship between plants and animals in a system?
    ii. How do plants and animals use carbon dioxide differently? Same?
    iii. Do plants need to undergo cellular respiration since they make their own food?
    iv. Can plants always make their own food?

DCI: Carbon in the carbon cycle is exchanged between the biosphere, atmosphere, oceans, and geospheres through chemical, physical, and geological processes.

Students should have figured out from this reading that the carbon that forms plants comes from CO2 in the air and that accounts for the mass of plants.

13. Activity: Students will view the image below and generate the questions they have. **(what sort of information should we give them about this shopping cart?)**



Possible Student Generated Questions:

f. Student generated questions:
    i. What are those things on the shopping cart?
    ii. Where was the shopping cart before this photo?
    iii. Where did those things on the cart come from?

iv. Is this a rusted shopping cart?

v.

g. Teacher generated questions:

i. What would happen if we added humans to activity (system)?

ii. What role do humans play in this system?

iii. How does this help us figure out what is going on with the badger?

iv. CAN THEN MOVE INTO ANTHROPOGENIC ACTIVITIES that are linked to DCIs

h. What should we do next to help figure out what is going on with the badger? **Repeat steps D and E - SHOULD BE PUT IN THE BACK OF ALL OF THE SECTIONS TO GO BACK TO THE ANCHORING PHENOMENON AND PREVIOUSLY LEARNED SECTIONS.**

14.

Performance Assessment:

1. Invasive Species:Kudzu
2. Give background
3. Description of native ecosystem
4. Graph of # of species before and after invasion of Kudzu
5. Assessment questions

i. What patterns do you see in the species data?

1. Model system before and after Kudzu invasion

ii. Why did animals population "A" decrease?

iii. How did the flow of energy change within the ecosystem when Kudzu was introduced?

1. Out compete other plants
2. Some animal populations increased
3. Some animal populations increased (natural selection)