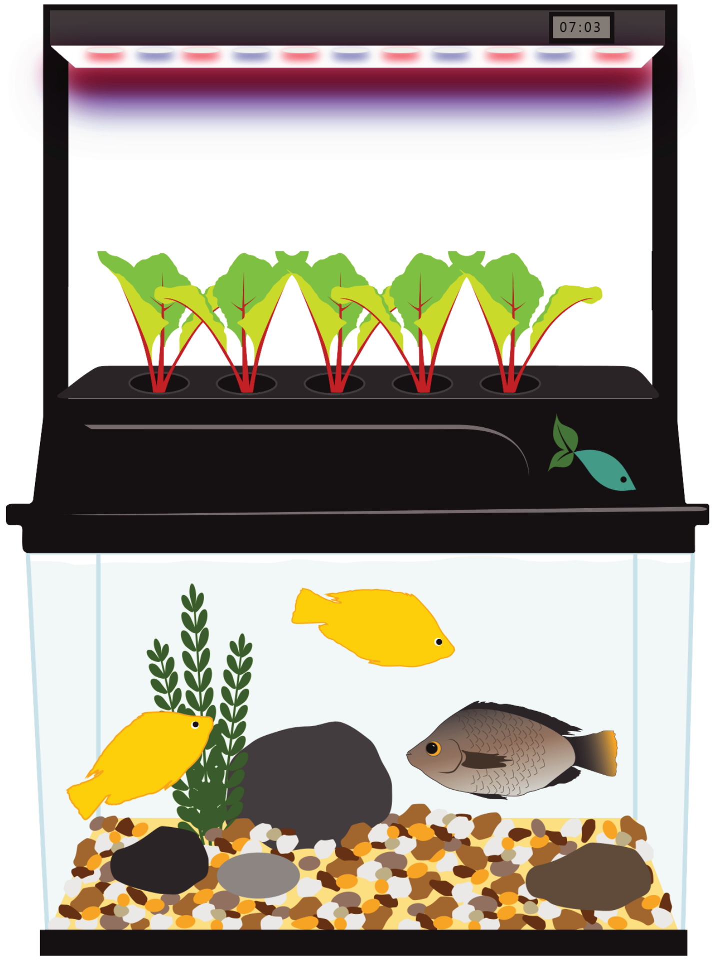
ECOLIFE aquaponics®

9-12

ECO-CYCLE CURRICULUM

What is the ECO-Cycle Aquaponics Kit™?



The ECO-Cycle Aquaponics Kit™ provides students and teachers with an interactive, hands-on tool for learning. The kit may be used to demonstrate concepts such as:

- **Plant and animal anatomy**
- **Photosynthesis and respiration**
- **Living systems**
- **The Nitrogen Cycle**
- **The role of bacteria in ecology**
- **The function of water in ecology**
- **The science of sustainable agriculture**
- **Climate change and ecological issues**

and many others, all while caring for fish and plants, germinating seeds, and harvesting vegetables.

The curriculum is designed around the ECO-Cycle. Once it is assembled and running (see assembly instructions included with the kit), the following lessons may be implemented.

ACTIVITY #1: NITROGEN CYCLE

NGSS: HS-LS1-7, HS-LS2-4

OBJECTIVE:
This lab gives students a hands-on approach to the Nitrogen Cycle. Students will observe the daily changes in different nitrogen compounds in their ECO-Cycle. After the initial set up of the kit, the levels of three nitrogen compounds (ammonia, nitrite and nitrate) fluctuate as nitrifying bacteria begin to colonize the system and the process of nitrification occurs. These levels will eventually stabilize as bacteria become established in the aquarium. This activity will require three - four weeks of daily testing. (The tests only take a few minutes.)

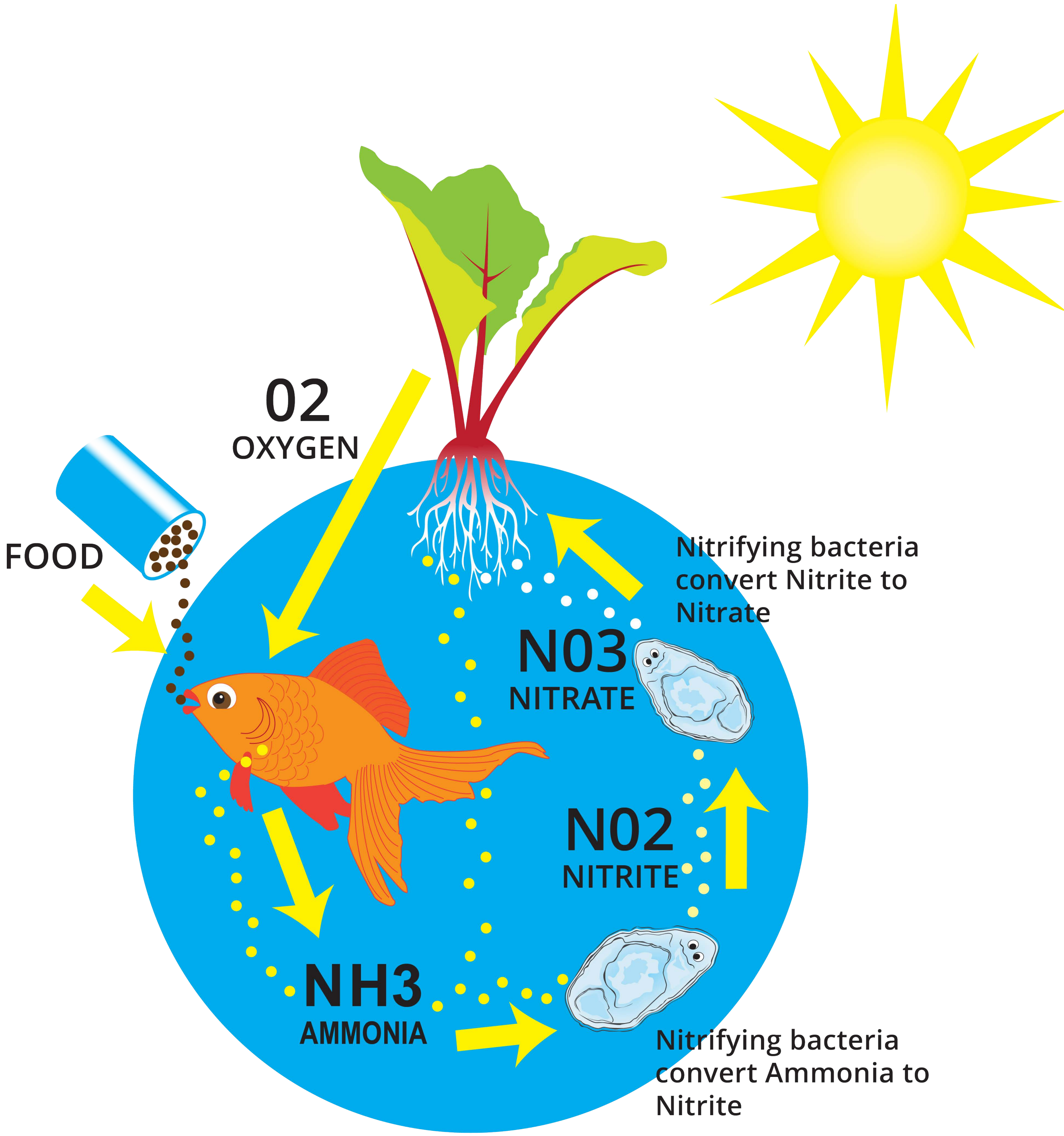
BUILDING BACKGROUND:
In order to survive, all forms of life must have nitrogen (N). The air has a significant amount of nitrogen (approximately 75%) in the form of N2 (chemical formula for Nitrogen gas). The problem with N2 is most life forms can't use nitrogen in that form. Plants get their nitrogen in a fixed form such as nitrate ions, ammonia, or urea. Animals get their nitrogen from plants or from animals that have eaten plants.

Nitrogen in the air is fixed in a couple of ways but for this discussion we will only talk about how bacteria help to make nitrogen available to plants. Some of these bacteria are found in soil and in water, and some are associated with legumes and other nitrogen fixing plants.

Through their roots, plants can take up some forms of nitrogen such as ammonia-nitrogen, but most plants get nitrogen that has been further processed by nitrifying bacteria.

FOR THE TEACHER:
Aquaponics uses this information and is an excellent resource for teaching the Nitrogen Cycle. A very simplified explanation starts in the setup. First, fish in an operating aquarium are fed. Second, fish excrete ammonia and solid waste that is converted by bacteria in the system to ammonia. Even low levels of ammonia are toxic to fish. If ammonia builds up in the tank, the fish may die. Third, beneficial nitrifying bacteria convert the ammonia to less toxic nitrate, which is readily absorbed by the plants growing in the grow tray. By cycling the ammonia and nitrate filled water to the plants, the plants remove these forms of the nitrogen from the water, and use them to grow. Fourth, the water then filters down through the grow tray and returns to the tank, giving the fish fresh clean water to live in.

The Nitrogen Cycle



MATERIALS:

- ECO-Cycle Aquaponic Kit
- Plants
- Live fish (recommended goldfish or small tropical fish)
- Pencils
- Paper
- pH Test Strips
- API Freshwater Master Test Kit

PURPOSE:

To test, observe, and record daily changes in the amounts of three nitrogen compounds as they relate to the nitrogen cycle in a newly setup aquarium.

To test, observe, and record daily changes in the pH of a newly setup aquarium.

To understand how bacteria can clean the water by consuming and converting toxic compounds into less toxic forms.

ACTION:

Procedure - Day 1

Prior to adding fish to the system, use your test kit to measure the levels of ammonia (NH3), nitrite (NO2), and nitrate (NO3-) in the tank and record the amounts in your table.

Add fish to the system. It is always best to start with just 2-3 small and hardy goldfish. Once the initial cycle is stable, add a few more and continue to add fish incrementally until you have an adequate bioload for the system. This is usually 15–20 total inches of fish for a twenty gallon tank.

Measure NH3, NO2, NO3, and pH levels of the water that the fish came in, record on your table.

Procedure - Day 2

Measure NH3, NO2, NO3, and pH levels of the ECO-Cycle aquarium water and record on your table.

Repeat the four tests every day for the next three or four weeks. Make sure to run the tests at the same time daily, before the fish are fed. The initial cycle will be completed when ammonia (NH3) and nitrite (NO2) levels are both at zero.

Data Table – Test Results

Time	Date	Ammonia Level	Nitrite Level	Nitrate Level	pH Level
Day 1					
Day 2					
Day 3					
Etc.					

ACTIVITY #2: THE NITROGEN CYCLE SKIT

NGSS: HS-ESS3-3

OBJECTIVE:
Students will be taught to identify the different parts of the Nitrogen Cycle. Students will also learn and understand the importance of a balanced system. Students will interpret data and draw conclusions.

KEY WORDS:
Consumers, producers, nitrates, bacteria, air, soil, nitrogen fixation, plants, animals.

MATERIALS:
Paper, pencils

ACTION:

Introduction: Class discussion – Offer different scenarios that are examples of imbalanced systems. For example, ask students to predict what would happen if the cafeteria could only produce 300 lunches daily and there were 375 students to feed.

Conclude: That this system is imbalanced because there is not enough for everyone and ask them how to fix this problem? Teachers will see what students know by leading the group discussion. Students will think of problems with different scenarios and talk about solutions. Teachers will introduce an illustration of the Nitrogen Cycle.

Explore: Divide the class into three equal groups: fish, bacteria, and plants.

Have students act out as the teacher reads the following story:

As the sun comes up on a beautiful spring day, the fish become active and head out looking for breakfast. They swim around each other looking for a tasty treat to gobble. They happily eat their food and leave behind waste. The fish, now full, look for a place to rest. The bacteria are also hungry! They enter the fish waste and look for their favorite food called nitrogen. Notice nothing is wasted in nature, everything is recycled! So the bacteria leave behind nitrates (a form of nitrogen plants can use). Now the plants can eat thanks to the work of bacteria. The plants thirstily drink up the nutrients left by bacteria, the sun shines and the plants produce new leaves. The leaves contain nitrogen that has been changed into a protein that animals and humans can use, and just in time for the fish that are ready to eat again.

(Repeat the story at least twice – each time the story is told represents one system). Students will then draw a representation of the Nitrogen Cycle.

***Elaborate*:** Repeat the activity with unequal groups. Students will write down their findings from observing the story with unequal groups.

FURTHER DISCUSSION:
Students will summarize what they have learned in a few complete sentences. Call upon students to reflect on what they learned and share their findings with the classroom. Ask the students how we can make sure our environment stays balanced for all life as found in the ECO-Cycle Aquaponics Kit.

ACTIVITY #3: NITROGEN CYCLE COLLAGE

NGSS: HS-ESS2-6

OBJECTIVE:
To introduce how aquaponics works and the importance of the Nitrogen Cycle.

MATERIALS:
- Construction or poster paper (11″ x 17″)
- Magazines
- Scissors
- Glue
- Markers

BUILDING BACKGROUND:
Nitrogen is a key component in plant growth, being an essential macro-nutrient needed by all plants to grow. There are terms to know when discussing the Nitrogen Cycle. In this activity, students will use vocabulary to create a picture and vocabulary diagram of the Nitrogen Cycle as it relates to aquaponics.

TERMS TO KNOW AND REMEMBER:

- Ammonia: NH_3
- Decompose
- Nitrates NO_3
- Nitrites: NO_2
- Fish
- Plant
- Water
- Light

1. Have students look through magazines for pictures of plants (especially with roots attached), fish, light and other symbolic images that could represent the parts found in the Nitrogen Cycle. If students have trouble finding pictures, teachers can consider using clip art from the computer. Encourage students to be creative when searching for pictures and don't give up after one magazine.

2. Students should decide on a shape or series of shapes for their diagram. Ideas range from circles and squares, like a flow chart, to drawing a simple aquarium shape with a spot for plants on top (refer to the ECO-Cycle for ideas or encourage students to think of some geometry projects they have worked on in the past).

3. Using magazine pictures, have students glue pictures to represent the different parts of the Nitrogen Cycle.

4. Ask students to complete their diagram with other shapes, colors and arrows to map out the Nitrogen Cycle. Remind students to double check that arrows point to the next correct step in the cycle.

ACTIVITY #4: N WHAT?

NGSS: HS-LS2-4:

OBJECTIVE:
To introduce the Nitrogen Cycle found in both the ECO-Cycle and outside environment in relation with animals and plants. This is a fun and exciting way to help students understand the periodic table of elements.

QUESTIONS FOR DISCUSSION:
What is the symbiotic relationship between animals in the environment and fish in the ECO-Cycle that help plants to grow? Which elements do you think are

important in the growth of plants both inside our kit or out in our garden beds? Most fertilizers are made of 3 important elements N, P, K, however are these the only elements or nutrients needed in our soil and can you identify these elements?

MATERIALS:
Periodic Table of Elements, Nitrogen Cycle chart

BUILDING BACKGROUND:
Nitrogen is crucial for life on Earth and is a component in all amino acids. Nitrogen is essential for many processes and in plants much of the nitrogen is used in chlorophyll which is essential for photosynthesis and further growth of the plant itself. The process of the Nitrogen Cycle isn't much different in aquaponics than in traditional agriculture.

VOCABULARY:

- NH3 Ammonia: Found in both fish waste and in animal waste and is necessary in the contribution to the Nitrogen Cycle.
- NO2 Nitrite: Bacteria will convert the ammonia into this much needed form of Nitrogen for your system. Nitrite is harmful to fish and should be monitored closely.
- NO3 Nitrate: Primarily used for fertilizers in agriculture because it is soluble.

ACTION:
Have the students study their periodic table of elements and begin to search for the different names of elements that we find in our ECO-Cycle and also in our outside garden. Students should search for other important elements needed for plants to grow.

SWIMMING DEEPER:
Students can adopt an element and go deeper into learning and studying the importance of this element.

- Ask the students to write a short essay about their findings and the importance of their chosen element.
- Ask would we be able to survive with or without such an element?

Periodic Table of Elements

hydrogen 1 H 1.0079																	helium 2 He 4.0026
lithium 3 Li 6.941	beryllium 4 Be 9.0122												boron 5 B 10.811	carbon 6 C 12.011	nitrogen 7 N 14.007	oxygen 8 O 15.999	fluorine 9 F 18.998	neon 10 Ne 20.180
sodium 11 Na 22.990	magnesium 12 Mg 24.305												aluminium 13 Al 26.982	silicon 14 Si 28.086	phosphorus 15 P 30.974	sulfur 16 S 32.065	chlorine 17 Cl 35.453	argon 18 Ar 39.948
potassium 19 K 39.098	calcium 20 Ca 40.078		scandium 21 Sc 44.956	titanium 22 Ti 47.867	vanadium 23 V 50.942	chromium 24 Cr 51.996	manganese 25 Mn 54.938	iron 26 Fe 55.845	cobalt 27 Co 58.933	nickel 28 Ni 58.693	copper 29 Cu 63.546	zinc 30 Zn 65.39	gallium 31 Ga 69.723	germanium 32 Ge 72.61	arsenic 33 As 74.922	selenium 34 Se 78.96	bromine 35 Br 79.904	krypton 36 Kr 83.80
rubidium 37 Rb 85.468	strontium 38 Sr 87.62		yttrium 39 Y 88.906	zirconium 40 Zr 91.224	niobium 41 Nb 92.906	molybdenum 42 Mo 95.94	technetium 43 Tc [98]	ruthenium 44 Ru 101.07	rhodium 45 Rh 102.91	palladium 46 Pd 106.42	silver 47 Ag 107.87	cadmium 48 Cd 112.41	indium 49 In 114.82	tin 50 Sn 118.71	antimony 51 Sb 121.76	tellurium 52 Te 127.60	iodine 53 I 126.90	xenon 54 Xe 131.29
caesium 55 Cs 132.91	barium 56 Ba 137.33	57-70 *	lutetium 71 Lu 174.97	hafnium 72 Hf 178.49	tantalum 73 Ta 180.95	tungsten 74 W 183.84	rhenium 75 Re 186.21	osmium 76 Os 190.23	iridium 77 Ir 192.22	platinum 78 Pt 195.08	gold 79 Au 196.97	mercury 80 Hg 200.59	thallium 81 Tl 204.38	lead 82 Pb 207.2	bismuth 83 Bi 208.98	polonium 84 Po [209]	astatine 85 At [210]	radon 86 Rn [222]
francium 87 Fr [223]	radium 88 Ra [226]	89-102 **	lawrencium 103 Lr [262]	rutherfordium 104 Rf [261]	dubnium 105 Db [262]	seaborgium 106 Sg [266]	bohrium 107 Bh [264]	hassium 108 Hs [269]	meitnerium 109 Mt [268]	ununnilium 110 Uun [271]	unununium 111 Uuu [272]	ununbium 112 Uub [277]		ununquadium 114 Uuq [289]			

*Lanthanide series	lanthanum 57 La 138.91	cerium 58 Ce 140.12	praseodymium 59 Pr 140.91	neodymium 60 Nd 144.24	promethium 61 Pm [145]	samarium 62 Sm 150.36	europium 63 Eu 151.96	gadolinium 64 Gd 157.25	terbium 65 Tb 158.93	dysprosium 66 Dy 162.50	holmium 67 Ho 164.93	erbium 68 Er 167.26	thulium 69 Tm 168.93	ytterbium 70 Yb 173.04
**Actinide series	actinium 89 Ac [227]	thorium 90 Th 232.04	protactinium 91 Pa 231.04	uranium 92 U 238.03	neptunium 93 Np [237]	plutonium 94 Pu [244]	americium 95 Am [243]	curium 96 Cm [247]	berkelium 97 Bk [247]	californium 98 Cf [251]	einsteinium 99 Es [252]	fermium 100 Fm [257]	mendelevium 101 Md [258]	nobelium 102 No [259]

ACTIVITY #5: THE AQUAPONIC BRACELET

NGSS: HS-LS1-7; HS-LS2-1; HS-ESS3-3

OBJECTIVE:
Students use aquaponic verbiage combined with art to replicate the action of the ECO-Cycle.

MATERIALS:

- Leather or nylon string,
- 4 plastic beads per student (yellow, green, blue, white, black, brown, orange)

ACTION:
Students observe the cycle, receive materials, design their bracelet, and then write an explanation. Students will put the beads on the string in the order of the action that occurs in the ECO-Cycle.

The order of the beads is important and represents the sequence of action in the ECO-Cycle. Place the beads on a leather string in the following order: yellow, green, blue, white, black, brown, and orange. The beads on this environmental bracelet can go around the bracelet twice to represent cycling twice.

- Sun shining down on growing plants
- Plants in the water using sun for food
- Water in the system
- Oxygen produced by plants through photosynthesis
- Fish that use the oxygen to breathe and grow
- Waste produced by the fish
- Bacteria which helps convert waste to nitrogen

FURTHER DISCUSSION:
What do you think would happen if you decided to change the sequence of colors on your bracelet? Would this adversely change how the ECO-Cycle works? What would happen if you removed a color in the bracelet? How would that change the action in your ECO-Cycle?

CLASS DISCUSSION:
Have students reflect on food webs and the importance of a symbiotic relationship between fish, plants, water, food, and light within the ECO-Cycle. Have students write a paragraph of their understanding and the effect this has on sustaining human populations.

The famous naturalist 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 mean to the class? Ask the students write a paragraph explaining their understanding.

SWIMMING DEEPER:
Teachers should demonstrate to students how to make these bracelets and use questions provided for a Think-Pair-Share discussion activity. Ask students to write out their own instructions on how to make an aquaponics bracelet. Work with another class on campus and have an older group of students work with a younger group of students teaching them how to make a bracelet and explaining what each bead represents.

ACTIVITY #4: PLANTS AND LIGHT

NGSS: HS-LS1-5

OBJECTIVE:
Students learn early on that all plants need the sun in order to grow and produce their own food. In this lesson, students will gain an understanding of the how grow lights in the ECO-Cycle take place of the sun. Since these lamps act in a similar fashion of the sun, the students will observe that plants grow towards light.

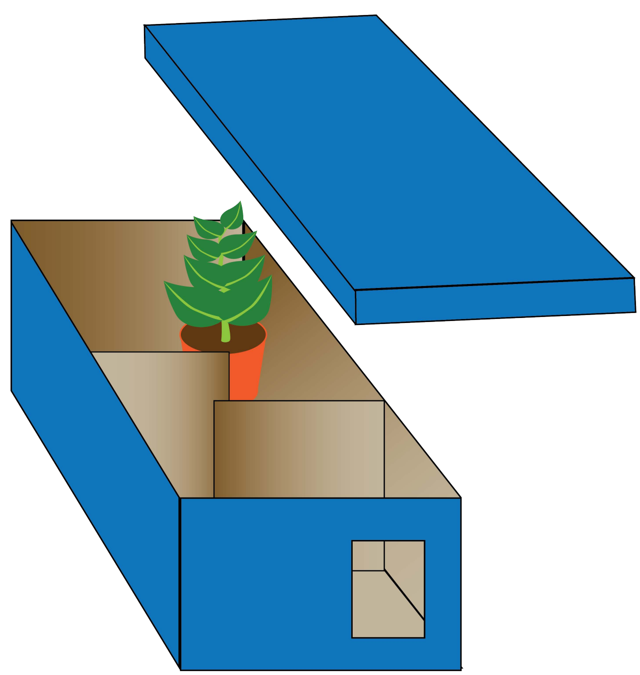
MATERIALS NEEDED:

- Scissors
- Large shoebox
- Heavy cardboard box
- Masking tape
- Small potted ivy plant

FURTHER DISCUSSION:
Plants need sunlight to survive. If something is blocking the light, how will a plant respond?

ACTION:
Cut a hole in one end of a shoebox. Cut two dividers from the cardboard as tall as the shoebox but an inch shorter than its width. Tape the dividers upright along the inside of the box. The first divider should be attached to the same side as the hole that was cut into the box in step 1.

The other divider should be on the other side. Put your plant in the end of the box opposite the hole. Put the lid on the box and turn the hole toward bright sunlight.



OBSERVE:
Every three or four days, remove the lid to water your plant and observe its growth. Do this for several weeks.

WRAP UP:

- ➢ How does the plant change after a few weeks?
- ➢ How does it get the light it needs?
- ➢ How might this be similar to what happens on a forest floor?

SWIMMING DEEPER:
Divide students into groups and ask them to try different size boxes, different types of plants, different color lining paper in the boxes, multiple light holes, different size light holes, etc.

Once all groups have created their different growing boxes, have all students write a hypothesis for all boxes. After a designated number of weeks and checking boxes regularly, have students assess the different growing patterns in the different boxes and compare the outcomes to their hypothesis.

At the conclusion, ask students to write a conclusion about each box that includes a tie in to the original hypothesis.

ACTIVITY #6: 'LEAF' IT BE! MATH IN SCIENCE

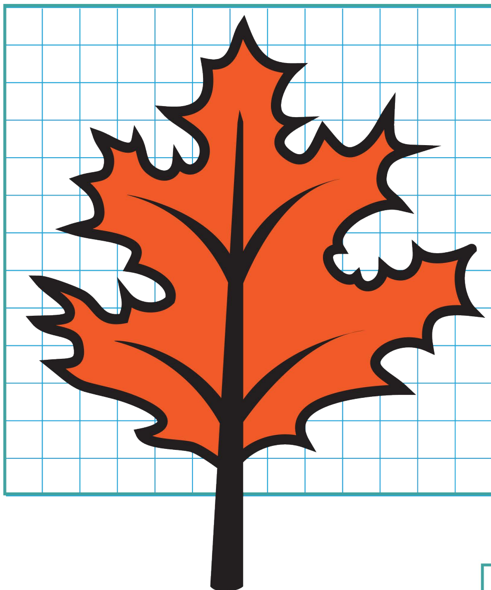
NGSS: HS-LS2-4

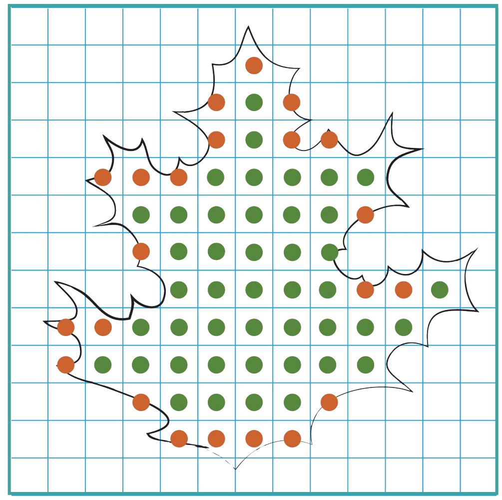
OBJECTIVE:
Have your students learn and understand how to find the area of an irregular shape. Students may have already learned and understood how to find the area of a regular shape such as a rectangular (maybe a garden bed in your school garden) or the shape of the ECO-Cycle fish tank. Perhaps it is a square bed, but students will learn that all objects can be measured for area.

Some leaves, like the fine pine needle, barely have any surface area. Others, like the very large banana plant leaf, have a very large surface area. The surface area of leaves is directly connected to the amount of sugar and oxygen they produce. One could assume that a single pine needle does not produce as much sugar and oxygen as a banana leaf.

CALCULATE THE AREA OF AN IRREGULAR FIGURE:

1. Trace the figure on graph paper
2. Count the number of whole square units
3. Count the number of partial square units and divide this number by 2
4. Add the two numbers together





● Whole Squares	+	● Partial Squares/2	=	Area
44	+	22/2	=	Area
44	+	11	+	55

SOLVE IT

1. Find a leaf.
2. Calculate the area of your leaf.
3. Compare the area of your leaf to the area of the leaf above.
4. Which produces more sugar and oxygen?
5. Why are there bigger leaves in rainier/shady places and smaller leaves in hot and dry places?

SWIMMING DEEPER:

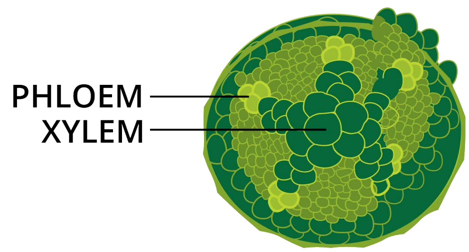
Have students predict what they will discover about surface area of leaves and revisit after they have calculated. How do different leaves work in different ecosystems?

Add more leaves to the study of surface area or have students bring a specified number of leaves from home or their surrounding area. Have students guess the surface area of each leave prior to calculating and see who comes the closest. These graphs can also be kept for the academic year in a binder.

ACTIVITY #7: HOW DOES WATER MOVE IN A PLANT?

NGSS: HS-LS1-3

TEACHER BACKGROUND:
When you cut a thin slice of a plant stem or root and look at it under a microscope, you can see the tissues that form the transport system.



One of these tissues is xylem, which moves water and minerals up from the roots. Like a straw would move water from a glass and into a mouth. As water moves up the plant, some of it is stored in the vacuoles of the xylem tissue cells. Most of the layers of a tree trunk are made of xylem.

MATERIALS:

- Magnifying glass
- Celery stalk
- Food coloring
- Water
- Mason jar
- Spoon
- Colored pencils or crayons
- Knife

MAKE A PREDICTION:
What will happen if you leave a celery stalk in colored water? What would happen if you left the roots on the stalk? Create a hypothesis.

ACTION:

- ***Observe*** – Use a magnifying glass to look at the celery stalk.
- Cut the end of the celery stalk and place the celery stalk in a container with water.
- Put five drops of red or blue food coloring into the container. Stir water until food coloring is thoroughly mixed.
- ***Record Data*** – Use colored pencils to draw a picture of the celery stalk. Record the date and time.
- ***Observe*** – On the following day; use the magnifying glass to look at the celery stalk. Note any changes.
- ***Record Data*** – Use colored pencils to draw a picture of the celery stalk. Record the date and time.

FURTHER DISCUSSION:

What can you conclude about how water moves in a plant? Communicate – Write a report of your investigation. Describe any differences between your results and those of your classmates. Have students each bring in a straw from home and a healthy beverage and have them drink the beverage correlating the drinking of the beverage to the action of the plant. Try the food dye experiment with carnations - which doubles as a nice take-home gift!

SWIMMING DEEPER:

Give pairs of students a white carnation or a white rose. Students should slice the stem of the flower length wise into four sections with a scalpel (be sure to remind students about safety when using scalpels). Direct students to put drops of four different food coloring colors into four different test tubes or small cups with water. Students should set a quarter of the stem in each of the four containers. Let stand and observe daily.

The more food coloring in the water, the darker the color will come about on the flower. Have students do experiments on number of drops in water compared to amount of water and time it takes to see a color change, etc.

ACTIVITY #8: SEED PACK BOOKMARK

NGSS: HS-ESS3-3

OBJECTIVE:

To teach the students how to read a seed packet and have a clear understanding of the difference in how we would plant seeds in a soil garden verses the way we plant seeds in an ECO-Cycle.

QUESTIONS FOR DISCUSSION:

What are the main differences we see when we look at planting seeds in the ECO-Cycle verses planting in a garden bed? As we read a seed packet, what are some of the most important things we see on the back of the packet? Seeds need spacing, proper depth for planting, days to harvest and finally time of year to plant the seeds. In a closed ECO-Cycle system like ours do we need to follow the same parameters as we would if were planting or sowing seeds in a garden bed?

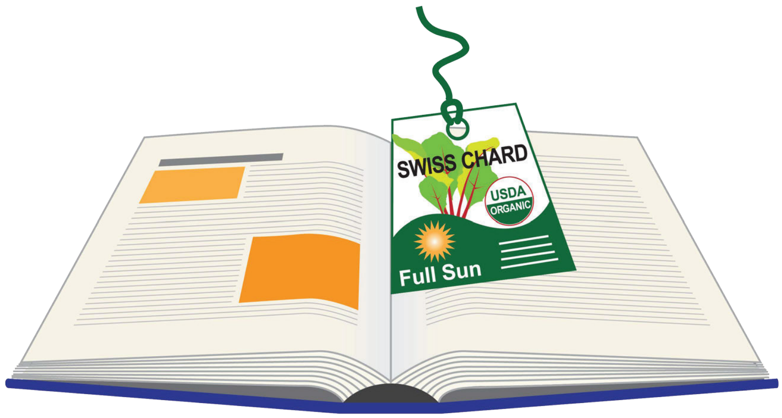
MATERIALS:

- Construction paper
- Crayons or markers
- Scissors
- Photo copies of seeds packs

BUILDING BACKGROUND:
How can we grow anytime in the ECO-Cycle but we can't always grow outside? Look at multiple seed packets and chart what is happening and decide what your understanding is.

Explain to the students how there are different climate zones throughout the planet, and why we can grow in the ECO-Cycle anytime of the year. This is important in places where we have long harsh winters where in typical farming you have to wait until the last frost before sowing seeds or may even have to start seeds indoors before we bring them into our garden beds.

ACTION:
Students can create a memorable bookmark they will use with all there reading materials throughout the school year. Have students draw a picture of the seed pack they have been given with the following information on the bookmark.



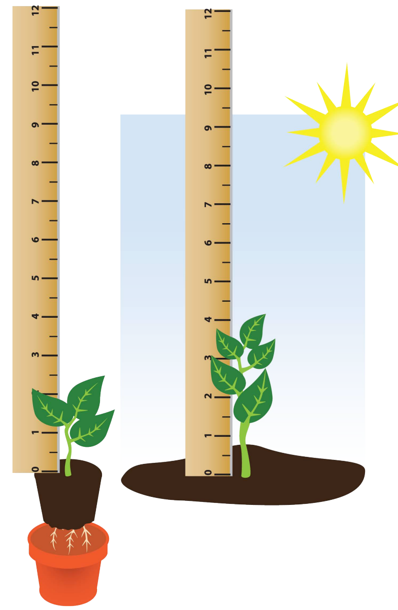
NAME OF SEEDS	DAYS TO GERMINATE	DAYS TO HARVEST	SPACING	COLOR OF VEGETABLE	SUGGESTIONS	HAVE YOU TASTED?

SWIMMING DEEPER:

- Have students design their own two-sided seed packet by drawing or creating a collage on a sheet of paper.
- Students can grow the seeds they designed for their bookmark. A few seeds should be planted in the ECO-Cycle and the others in soil. Once the seeds have begun to sprout, have students measure and observe changes daily and keep a record of their findings. Students should be asked to predict which plants they believe will grow faster, greener, and bigger. Teachers should determine how long observations should go on until the comparisons are complete. At the end of the specified amount of time, ask students to revisit their predications and determine if they were correct or incorrect.

ACTIVITY #9: TIME TO GO AND GROW

NGSS: HS-PS4-3



DESCRIPTION:
Students learn how to transplant seedlings from seed start trays. Students will plant seedlings in both the ECO-Cycle and a traditional outdoor garden bed.

OBJECTIVE:
To learn how to transplant seedlings and plant in both soil and the substrate fire clay rock and properly handle these delicate seedlings.

BUILDING BACKGROUND:
It is very important that students learn and understand the proper way of handling such a delicate plant when transplanting. The roots are very fragile and the plants need to be handled carefully and by the stem. Students will learn about spacing in a garden setting and how to plant in our grow cups found in the ECO-Cycle. It is very important that the dirt has been removed from the roots of the seedlings before placed into the net cups to prevent from dirtying up the water and fish tank.

MATERIALS:
Trowels, seedlings ready for transplant, paper, and pencils

CLASS DISCUSSION:
Have the students observe and look at the seedlings in our seed start tray. Observe how the plants began growing closely together. It is imperative that the plants are handled carefully and given space so when they are fully grown, they have plenty of room.

ACTION:
In groups of two, have the students work together carefully removing the seedling from the start tray using a hand trowel.

Have students dig a hole twice the size of the root ball in the soil for the outside garden bed. For the fire clay rocks tell the students to remove all dirt from the seedling so the dirt does not cloud the water in the fish tank.

Have the students plant the seedlings and press the soil firmly around the plant. In the ECO-Cycle Aquaponics Kit, make sure the fire rock clay covers the roots in the grow basket. Have the students record the transplants size and start date for growth.

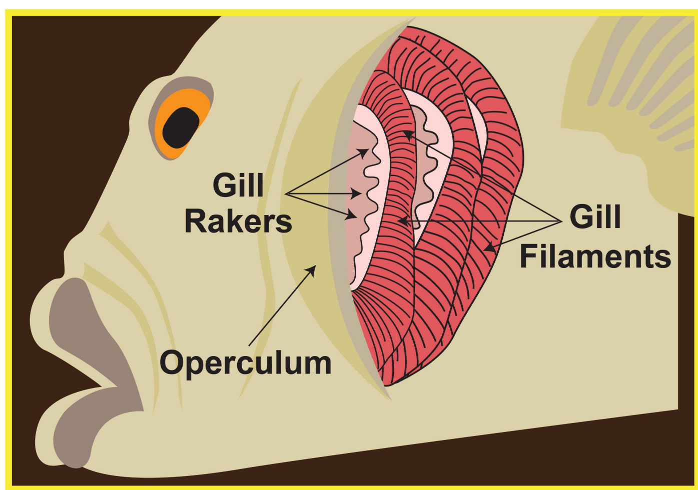
Instruct the students to study the rate of growth between both transplants, to see which way the plants grew better. The students can also measure how much water was used over a period of time to grow the transplants into full mature plants in the garden versus in the ECO-Cycle.

- Why was it necessary to transplant the seedlings?
- Ask students about spacing between both the ECO-Cycle and a traditional garden.
- Ask students to explain the importance of proper spacing for plant growth.

SWIMMING DEEPER:
Conduct an academic year long study. Each student should maintain a lab book, noting the type of new seedlings being planted, the weather conditions outside for planter bed transplants, new fish in the ECO-Cycle, water temperature, etc. Both sets of plants should be maintained regularly by students. Students should record weekly growth of each plant, aquarium and outside. At the conclusion of the school year, a final project could be a presentation about which plants grow better in the aquarium and which plants grow better outside. Students should be encouraged to grow all types of plants, not just those recommended by ECOLIFE, and make assessments as to why some plants grow more efficiently than others aquaponically and outdoors in a traditional soil garden bed.

ACTIVITY #10: HOW DO FISH GET OXYGEN?

NGSS: HS-LS1-7



OBJECTIVE:
Explain the basic method in which fish get oxygen, how they breathe underwater and understand the structures of the fish body that aide breathing and the exchange of oxygen and carbon dioxide.

MATERIALS:
Description of how fish get oxygen, teachers choice of materials for a sample model of how fish get oxygen.

BUILDING BACKGROUND:
During observations in previous lessons, students should have a clear understanding that while fish move around an aquarium, they continually open their mouths.

Explain in this lesson, students will plan and create a small model demonstrating how fish get oxygen. The teacher can direct the simplicity or complexity of student models, types of materials to use, steps of completion, in class or homework assignment, etc. Have students work in groups (determined by class size).

SIMPLE CLASSROOM DEMONSTRATION:
Place a small amount of ground coffee onto a coffee filter. The ground coffee represents anything that could be floating in water, including oxygen molecules. The filter represents a gill filament.

Have a student or two hold the filter flat above a large bowl and pour warm water through the coffee grounds.

Have students look at the water in the bowl. Although there are no solid pieces of coffee, the water is not clear. The brown in the water is what the water took away from the coffee grounds. For the purpose of this demonstration, the brown color in the water is caused by the oxygen that moved through the gill, or coffee filter, and into the fish's lungs.

SWIMMING DEEPER:

Suggestions for older students:

1. Make models more complicated or ask that they only use specific materials (e.g. your model must be made out of all recycled materials).
2. Ask students to conduct peer reviews using the same grading rubric or create a different grading rubric for peer reviews.
3. Ask a guest judge to come to class. This could be a principal, science teacher, local aquaponics or fish expert and conduct a small science fair asking students to demonstrate their models for judging.

HOW FISH GET OXYGEN:
Unlike marine mammals such as whales and dolphins with lungs that store oxygen from the surface air, fishes have gills. Gills are a series of membranes located on each side of the fish that function as respiratory organs. As water passes over this system of extremely fine gill membranes, the fishes absorb the oxygen from the water. The gills contain a network of fine blood vessels (capillaries) that take up the oxygen and diffuse it through the membranes. When fishes are taken out of water, they suffocate, because their gills collapse and they are unable to absorb oxygen. In many ways, the interior of the fish resembles that of many other animals. The digestive, circulatory, and nervous systems are very similar to those of other vertebrates. However, what really makes a fish different from other animals is its respiratory system.

A fish’s respiratory system is determined primarily by the fact that it spends its entire life in water. Unlike the marine mammals such as whales, a fish has evolved in such a way as to not require frequent trips to the surface to breathe air. Fish have developed gills, on which they rely for the oxygen necessary for a fish’s limited metabolism.

Many animals have gills at some stage of their life (even humans have them at an early stage of their development in the womb), but fish retained these gills and they are still a functional part of their anatomy. Fish use their gills to extract oxygen from their watery environment. The process starts with the fish’s mouth, which is how the fish takes in water.

When a fish opens and closes its mouth, it is actually pumping water back through the gills and is thus breathing. Most fish have an effective pumping system that involves the mouth and the outer cover of the gills, called the operculum. When the fish's mouth opens, the operculum closes, drawing water into the fish's mouth. When the fish closes its mouth, the operculum opens, allowing fresh water to cross the gills. Other fish have a less effective pumping system, requiring them to swim constantly to keep fresh, oxygenated water flowing over the gills. These types of fish, such as tuna, generally swim with their mouths partly open. Incidentally, while many fish have nostrils, the nostrils are used only for a sense of smell, and play no part in respiration.

Once through the mouth, the water continues past structures called gill rakers. The gill rakers are essentially a filter system for the gills, straining the water to sift out floating food particles or foreign material. After passing through the gill rakers, the water continues through the gill arches and actually passes over the gills, which are suspended between the mouth cavity and the operculum. Each gill is made of two rows of gill filaments, which are extremely thin membranes sticking out into the water flow. Each of the gill filaments is composed of rows upon rows of lamellae, which are thin, disc-like membranes loaded with a capillary network. The water flows across the lamellae, and oxygen and carbon dioxide are exchanged directly across the capillary membrane. The capillaries are situated to take best advantage of the water flow; fish can actually extract up to 85% of available oxygen out of the water. Since water contains only 2-5% of the available oxygen that air at sea level does, such a high efficiency is extremely important.

From the gills, the deoxygenated water passes out the operculum, and the oxygenated blood joins the circulatory system. Despite the efficiency, some fish require more oxygen than others. This helps to explain why some fish thrive in specific habitats. For example, trout prefer northern streams because the cool water of the streams tends to retain dissolved oxygen, and the active trout need the extra oxygen. Carp, on the other hand, are sluggish and do not need as much oxygen, which is why carp can thrive in warm, relatively stagnant ponds, such as ornamental ponds. Goldfish, unlike most fish found in home aquariums, can survive in a non-aerated fish bowl because goldfish spend the majority of their time at the surface, where the oxygen content is highest due to the contact of the water with the atmosphere.

Despite the obvious advantages of having such an efficient surface for air exchange, the gill method of breathing was replaced in land animals with the lung. There are two reasons for this. First, the gills provide an excellent surface not only for air exchange but for water exchange, and a terrestrial animal with gills would lose too much water too rapidly. Second, the gills are efficient structures, but extremely fine ones, ones which require the buoyancy provided by water to retain their integrity. On land, the gills would quickly collapse into a mound of useless flesh, which is why the most efficient breathers on Earth would die in the rich atmosphere.

Source: www.coralfilm.com and www.papa.essortment.com

Sample Grading Rubric:

Building A Structure: How Fish Get Oxygen Model

Team Name: ______________________________

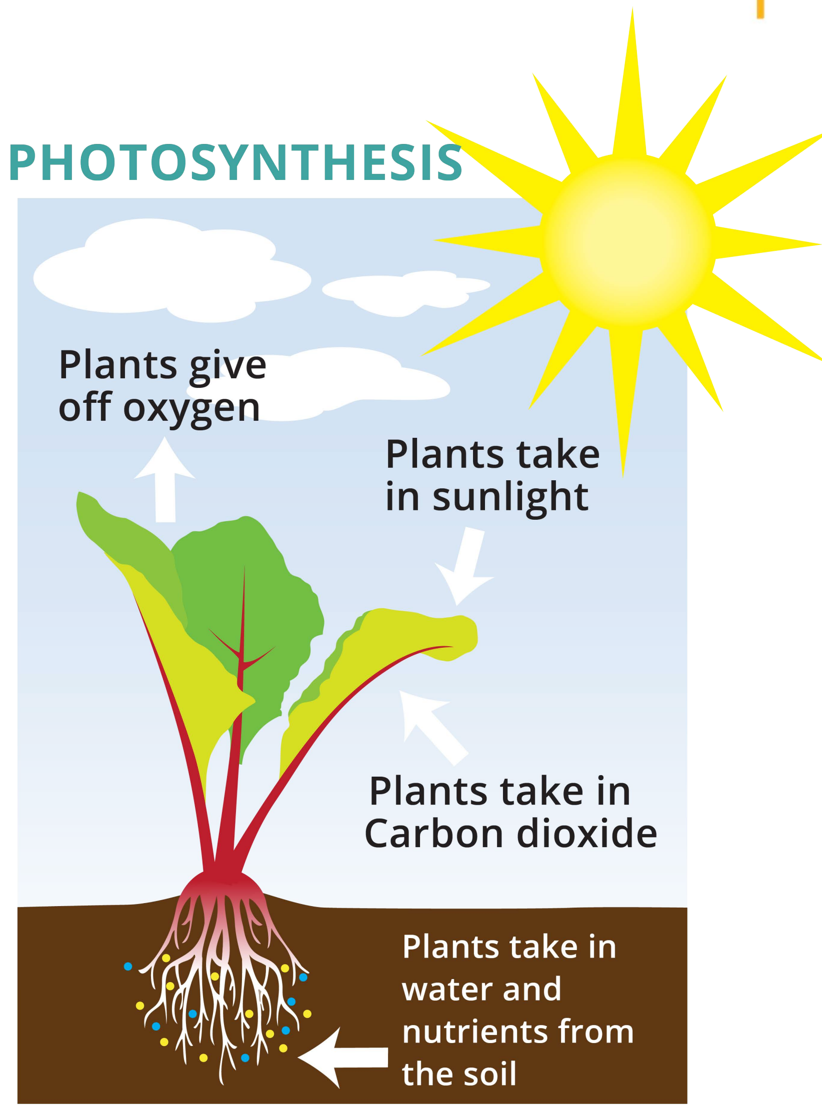
Student Name: ______________________________

CATEGORY	4	3	2	1
PLAN	Plan is neat with clear measurements and labeling for all components.	Plan is neat with clear measurements and labeling for most components.	Plan provides clear measurements and labeling for most components.	Plan does not show measurements clearly or is otherwise inadequately labeled.
CONSTRUCTION MATERIALS	Appropriate materials were selected and creatively modified in ways that made them even better.	Appropriate materials were selected and there was an attempt at creative modification to make them even better.	Appropriate materials were selected.	Inappropriate materials were selected and contributed to a product that performed poorly.
CONSTRUCTION CARE TAKEN	Great care taken in construction process so that the structure is neat, attractive and follows plans accurately.	Construction was careful and accurate for the most part, but 1-2 details could have been refined for a more attractive product.	Construction accurately followed the plans, but 3-4 details could have been refined for a more attractive product.	Construction appears careless or haphazard. Many details need refinement for a strong or attractive product.
FUNCTION	Structure functions extraordinarily well, holding up under atypical stresses.	Structure functions well, holding up under typical stresses.	Structure functions pretty well, but deteriorates under typical stresses.	Fatal flaws in function with complete failure under typical stresses.

Photosynthesis

TEACHER BACKGROUND:

Although plants differ in their shapes and sizes, all plants are alike in one way. They make their own food in a process called photosynthesis. All organisms, or living things, need energy to grow healthy and reproduce. Plants get the energy they need from the food they make.

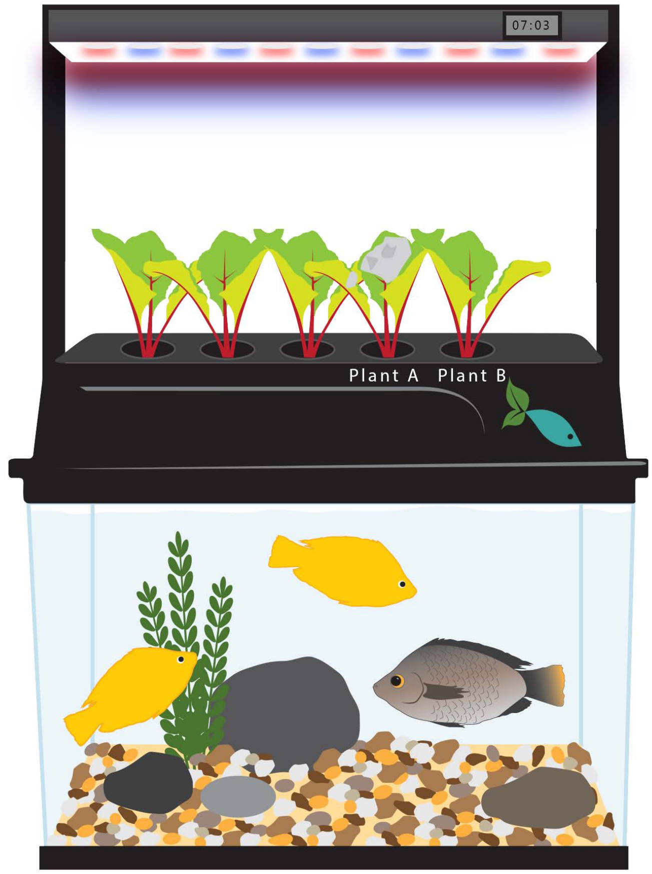


During photosynthesis, plants take in sunlight (the lights in the ECO-Cycle supplement that of natural sunlight), water (H2O), and a gas in the air called carbon dioxide (CO2). Plants use these 3 ingredients to make sugar, which is a plant's source of food and energy.

Plants have a material called chlorophyll that helps them take in sunlight. Chlorophyll is the material that gives plants their green color. With the help of chlorophyll, plants take in energy from the sun and use it to produce sugar. Energy from the sun is called solar energy.

ACTIVITY #11: LET THERE BE LIGHT!

NGSS: HS-LS1-3



MATERIALS:

- Two mature plants
- Tin foil
- Water
- Your ECO-Cycle

ACTION:
Label two identical plants "Plant A" and "Plant B". Wrap each leaf of Plant A with aluminum foil. Keep the leaves of Plant B uncovered. Each plant should receive the same amount of light and water.

PREDICT:
What do you think will happen to each plant?

OBSERVE:
Uncover Plant A after four days. Record your observations about each plant in a chart.

INFER:
Why do Plant A and Plant B differ after four days?

DRAWING CONCLUSIONS:
How can you tell plants need light to grow?

SWIMMING DEEPER:

- Students can use different plants and locations with various materials to cover leaves (copy paper, newspaper, magazine pages, card stock, wax, parchment paper, etc.
- Group students and fill the entire ECO-Cycle with a variety of plants. Ask students to compare and discuss why some plants might need more light than others
- Students discuss the variations in what they observed at the conclusion of the experiment time.

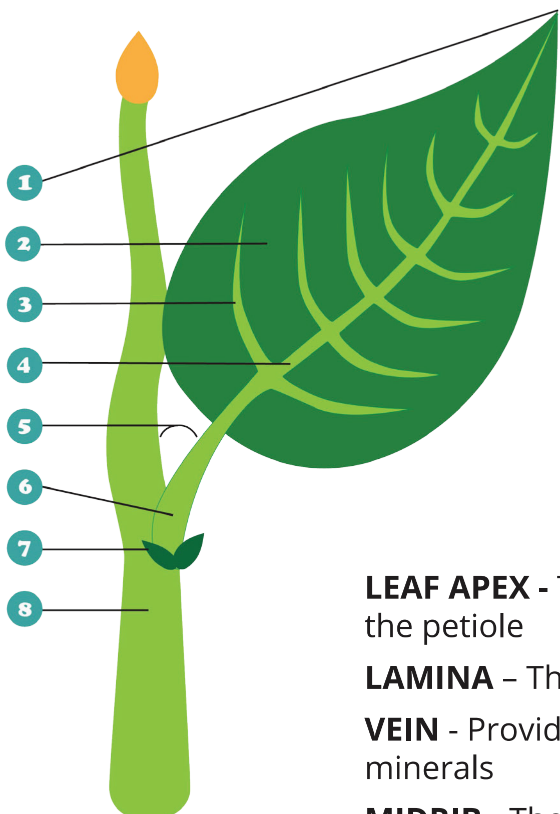
ACTIVITY #: LEAVES, CARBON DIOXIDE & OXYGEN

STANDARD: HS-LS1-5

MATERIALS:

- Small plant with multiple leaves
- Petroleum jelly
- Q-tips or small paint brush
- Magnifying glass
- Drawing paper
- Colored pencils or crayons

ACTION:
Observe the leaves of the plant, both the top of the leaf and the bottom of the leaf. Use the drawing paper to draw, color, and label the top and bottom of the leaf.



1. LEAF APEX
2. LAMINA
3. VEIN
4. MIDRIB
5. AXIL
6. PETIOLE
7. STIPULE
8. STEM

LEAF APEX - The outer end of a leaf; the end that is opposite the petiole

LAMINA – The blade of a leaf

VEIN - Provides support to the leaf; Transports both water and minerals

MIDRIB - The central rib of a leaf – it is usually continuous with the petiole

AXIL - The angle between the upper side of the stem and a leaf or petiole

PETIOLE - A leaf stalk; it attaches the leaf to the plant

STIPULE - The small paired appendages (sometimes leaf-like) that are found at the base of the petiole

STEM – (Also called the axis) main support of the plant

On another leaf, cover the top of the leaf with petroleum jelly. On another leaf, cover the bottom of the leaf with petroleum jelly. Leave at least one leaf with no petroleum jelly.

PREDICT:
What do you think will happen to each leaf?

OBSERVE:
Observe the leaves over several days. Record observations about each leaf in a chart.

INFER:
How do the leaves differ after four days?

DRAW CONCLUSIONS:
Where on a plant does photosynthesis take place? How can you tell?

SWIMMING DEEPER:
Students should decide on a variety of different mediums to place on leaves in small amounts. Suggests would be water based paint, liquid make-up, petroleum jelly, small bits of paper, etc and hypothesize about the effects these items on leaves might have on photosynthesis. Students should be encouraged to think about situations where the plant might be able to get sunlight but no oxygen. Have students write the chemical formula for photosynthesis without the part they believe will be missing with the different compounds placed on a leaf. Think-Pair-Share exercises are a great way to help.

ACTIVITY #16: PHOTOSYNTHESIS

STANDARD: HS-LS1-5

OBJECTIVE:
Help students understand the general process of photosynthesis

MATERIALS:
ECO-Cycle, blank paper, colored pencils

BUILDING BACKGROUND:
Photosynthesis is the process of plants making food for themselves an oxygen for people using light and other factors. Chlorophyll in plant leaves trap light energy and produce sugar. Sugar, along with nutrients from soil, helps the plant create the energy needed to produce food and other compounds needed for survival, which can be in the form of starch, fat, protein and vitamins. Oxygen is a byproduct of photosynthesis, a compound needed by humans and other animals for survival.

In this activity, students will learn solidify their knowledge of photosynthesis through creating a graphic organizer or visual of the chemical reaction equation

KEY TERMS:

Photosynthesis - Carbon Dioxide - Oxygen - Glucose

Chemical Reaction Equation For Photosynthesis

$6CO_2$	+	**$6H_2O$**	**Light Energy**	+	**$C_6H_{12}O_6$**	+	**$6O_2$**
CARBON		**WATER**	**CHLOROPHYLL**		**GLUCOSE**		OXYGEN

ACTION:

1. At the conclusion of any general photosynthesis lesson, ask students to describe the photosynthesis equation in words only. They should write this down on a sheet of paper and be a specific as possible. For added creativity, ask students to write a fantasy story about photosynthesis using the starting line "Once upon a time, in a microscopic part of a plant growing in your ECO-Cycle.
2. Once students have written their story, have them translate their story into a visual picture or graphic organizer. A simple start is to have students fold an 11x17" sheet of construction paper into 3 sections to represent the basic three parts of the chemical equation for photosynthesis. Whatever students chose to do, remind students that their explanation is in picture form. They may only use chemical symbols if they are part of the picture (i.e.: O2's floating in the sky to represent the oxygen released by the plant. This activity is even more thought provoking if students are told they cannot use any words accept in the title.

SWIMMING DEEPER:

To create a more complex assignment for higher grades, ask students to create a 3D model of photosynthesis or have students create models or drawings of specific cells involved in photosynthesis, such as mesophyll cells (where chloroplasts are located in a leaf) and chloroplasts.

ACTIVITY #17: TAKE A HIKE: JOURNEY THROUGH SOME ECOSYSTEMS

NGSS: HS-LS2-3; HS-ESS3-3

OBJECTIVE:

To understand the differences in types of organisms found in ecosystems.

MATERIALS:

- Construction paper
- Regular paper
- Markers
- Pen or pencil

BUILDING BACKGROUND:

Ecosystems are both simple and complex, depending on where an observer is and what they may be observing. In order for an ecosystem and all organisms in that ecosystem to survive and thrive there needs to be both *biotic* and *abiotic* parts to the ecosystem.

KEY TERMS:

- ***Biotic*** - describes a living or once living component of a community. (For example - organisms such as plants and animals.
- ***Abiotic*** - The non-living parts of an ecosystem.
- ***Ecology*** - the study of the interaction of organisms and their environment or the study of the interaction of biotic organisms with abiotic organisms.
- ***Ecosystem*** - a system formed by the interaction of a community of organisms with their environment.

ACTION:

1. Discuss with students what they believe biotic and abiotic mean. Also discuss what ecology means and how the terns biotic and abiotic fit into their definition of ecology. Write student ideas on classroom board.

2. Think-Pair-Share preparation: Have the student make two columns on their paper, one labeled 'biotic' and one labeled 'abiotic'. Refer to the ECO-Cycle for observation and have students write down what they believe all biotic and abiotic organisms. Once they are finished, have them pair up and share what they believe are the biotic and abiotic organisms in the ECO-Cycle. Bring students together to discuss their answers.

3. Share with the students the correct definition of abiotic, biotic, ecology, and ecosystem. Have them write this down on the same paper they folded, placing the correct definition in the correct column where the term can be found.

4. Take students on a walk around school. Visit different locations (athletic fields, swimming pool, cafeteria, main quad area) and have students conduct the same observations, identifying the biotic and abiotic organisms in a specific area. Allow students to discuss with each other as they observe and record. Remind students of simple things that can be overlooked, such as their role in this particular ecosystem, trash, planters, bicycles, benches, etc.

5. Upon returning to class or for homework, have students describe the role of each abiotic organism they listed (i.e. a bench is where an organism can rest and regain its strength so that it may continue surviving in this ecosystem).

SWIMMING DEEPER:
Ask students to create an ecosystem map of the entire campus. Students should color code each abiotic and biotic item on the map and identify places on the may where certain biotic species thrive and why (i.e. humans would thrive on our campus ecosystem in or near the cafeteria and around vending machines where the food can be found). Encourage students to be creative, thorough and open minded with very detailed and specific ideas for this type of assignment.

ACTIVITY #18: WHAT'S YOUR ROLE - THE ECOSYSTEM PLAY

NGSS: HS-LS2-3

OBJECTIVE:
To understand the role of all organisms, abiotic and biotic, in various ecosystems.

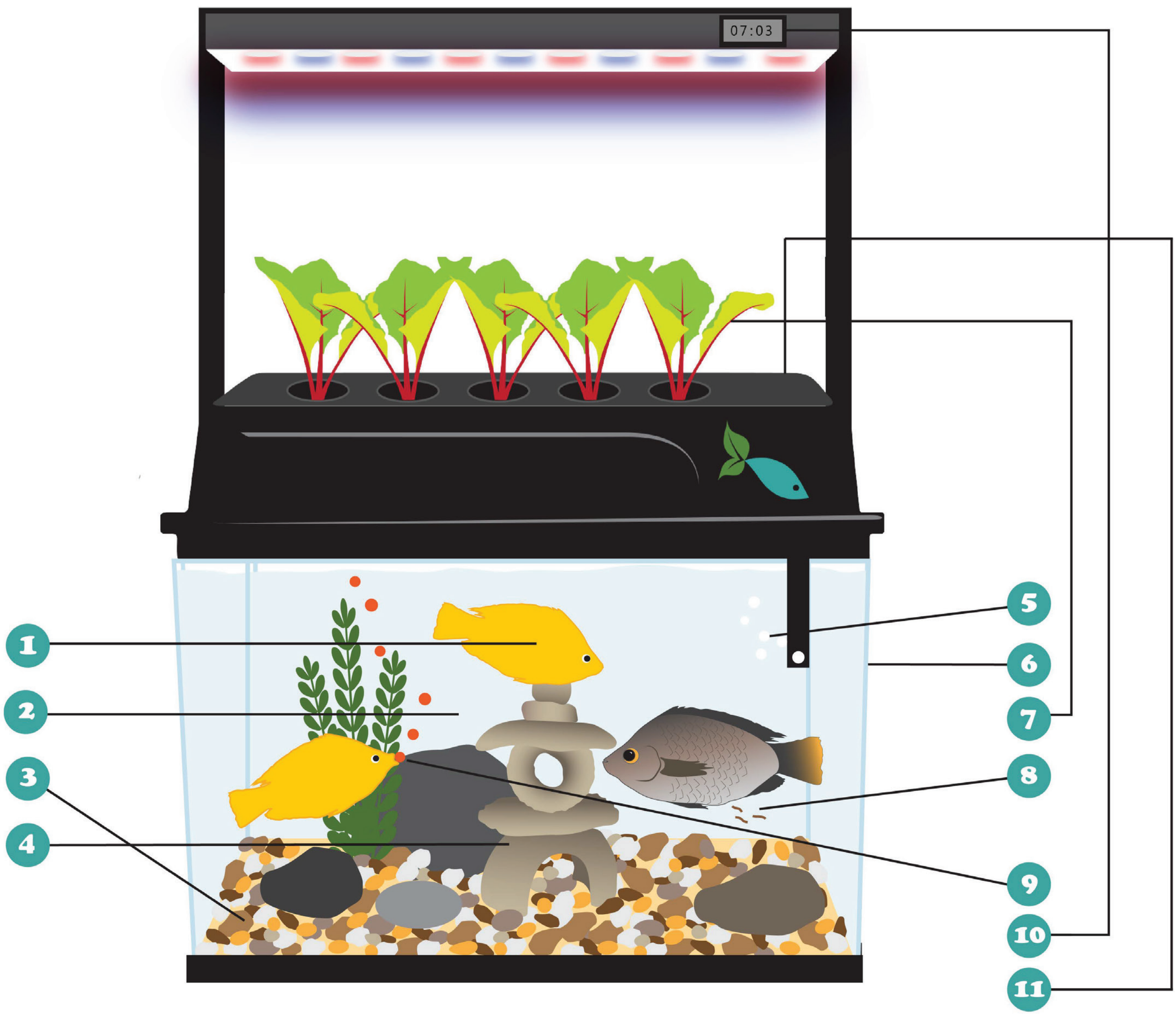
MATERIALS:
Any appropriate materials determined by teacher and students to complete the activity.

BUILDING BACKGROUND:
Our world is made up of a variety of different ecosystems. An ecosystem is a biological community of interacting organisms and their physical environment and the specific types include: Desert, Jungle/Tropical, Grassland, Forests

Ocean/Freshwater. The ECO-Cycle is a small version of a freshwater ecosystem. In this activity, students will be assigned an ecosystem to research and will write a 5-10 minute "play" where all students in a group will have at least one speaking part. The "roles" will be all of the organisms that make up and ecosystem.

For example: The roles in the play called the ECO-Cycle would include the following:

- Fish
- Water
- Gravel
- Decor
- Oxygen
- Fish tank
- Plants
- Fish waste
- Fish food
- Light
- Filters



key terms

1. FISH
2. WATER
3. GRAVEL
4. DECOR
5. OXYGEN
6. FISH TANK
7. PLANTS
8. FISH WASTE
9. FISH FOOD
10. LIGHTS
11. FILTERS

ACTION

1.: Write the name of each of the ecosystem types on a small piece of paper. Each slip of paper should be folded once and placed in a hat or basket. Divide the class into groups and ask a representative from each group to come forward and pick an ecosystem out of the basket.
2. Explain to students that they are to make a list of all the roles in their ecosystem, abiotic and biotic. After they complete their list, students should determine who will play each of the rolls in their ecosystem play. If there are more roles that students, students should take on a second and perhaps even a third role in the play.
3. Once students know what role they will be playing, they should research their own role and determine between 3 and 6 statements that they should make about their role in the ecosystem. At east one statement should include identifying their part of the ecosystem as abiotic or biotic (see activity #5) in their lines for the play.
4. Teachers should check that all ecosystems are represented, by organisms found to how each works together. See editable worksheet at the end of this activity.
5. Allow time in class for each ecosystem play.
6. Ask student audience to discuss each play or run the presentations as if they were acts in a play and conduct a class discussion on how matter transfers at the conclusion of all the ecosystem acts.

SWIMMING DEEPER:

To enhance this activity for older students:ask students to create props and costumes for their ecosystem play. Ask students to create a storyline or theme for their play with characters from other stories or books, using characters moving through an ecosystem.

At the conclusion of each play or act, depending on how the teacher determines the activity should run, have students write a critique of the play or act as if they were a critic in arts and entertainment, identifying the strong points of the play and the areas that need improvement. Students could rank on a number scale or with a “thumbs up/ thumbs down” or in a way that entertainment critics regularly do, being sure to justify a low number or a thumbs down.

ECOSYSTEM PLAY: Student Organizational Worksheet

My groups play is about the ______________________________ ecosytem.

ABIOTIC roles in this play ______________________________.

BIOTIC roles in this play______________________________ .

I will play ______________ in our ______________ ecosystem play.

Facts about my role:______________________________

My lines for our ecosystem play: ______________________________

ACTIVITY #19: WATER CONSERVATION VS. SOIL CONSERVATION - WHAT IS THE CONNECTION?

NGSS: HS-ESS3-3, HS-ESS3-4

OBJECTIVE:
To gain a better understanding of both water conservation and soil conservation without bias to either; to understand how both conservation efforts effect people, either negatively or positively; to better understand the role of that aquaponics plays in both water and soil conservation.

MATERIALS:
Presentation materials as determined by student groups, internet or library access for topical research.

BUILDING BACKGROUND:
Conservation in general is a topic of many discussions around the globe. Water conservation and soil conservation are specific areas discussed regularly. The ECO-Cycle represents both conservation efforts. For instance, aquaponics only uses a 10th of the amount of water that it takes to water an acre of land. Soil erosion can be caused by over watering land and regular windy conditions. Conservationists can work together to reduce the waste of both soil and water.

ACTION:

1. Divide students into groups, depending on the size of the class. Four groups is ideal, with two soil conservation and two representing water conservation.
2. Explain to students that while two groups will research soil conservation and two group will research water conservation, the two groups with each topic will come together and work as one large group eventually.
3. Give students a certain amount of time, teacher directed, to research soil conservation and water conservation. Each group should list 10 - 15 facts or statements about their topic. Remind students to incorporate industries like aquaponics in their research. Resources at the school library should be considered. Remind students when using the internet to use reputable websites, not Wikipedia. There are several internet sites available with reliable information. Here are a few:
   - http://www.nrcs.usda.gov/wps/portal/nrcs/site/national/home/
   - http://www.swcs.org/
   - http://soils.usda.gov/

4. After each of the groups has completed their list, bring the various groups together to form two large groups, either soil conservation or water conservation. Both large groups should compare their lists and create one large list that represents their conservation subject.
5. After having time to make their list of facts, have one student from each group alternate making a statement to the class about their conservation effort topic. (One student from soil, then one student from water, one student from soil, one from water, and so on). In between, have students write down their own thoughts on how, if they are in the water group, the soil fact overlaps with their list. Some items will be obvious, while some will need prompting to understand the overlap.
6. Continue until all statements have been made and all assessments have been completed by students.

SWIMMING DEEPER:

Activity #1

Coordinate a presentation of both soil and water conservation for school administration, parents or other classes. Encourage creativity with presentation materials and be sure each student has a responsibility in the event. Including aquaponics as an example in each presentation is important.

Ask each group of students to create a game to play based on their conservation effort. Trivia games or simple board games work best.

Walk with students around the school campus, including athletic fields. Students should make a list of sites on campus where either soil conservation or water conservation could be practiced more efficiently. Ask students to create a map of problem locations and a list of recommendations for better conservation practices for the school.

Activity #2

Assign small groups of students a growing region of the United States or a specific state. Student groups should work together to create a presentation about the types of crops grown in their region, amount of acreage dedicated to growing food, number of people working to grow or raise crops in their region or state, any common agricultural pests, amount of food their region or state grows as compared to the rest of the US, export crops grown, any hydroponic or aquaculture efforts in that region or state and the dollar amount that their state or region contributes to the over-all US agriculture industry.

Using the same state or regions in the US, have students pretend they are news reporter teams, reporting on soil and water erosion problems in their assigned region or state. They should share statistics as well as efforts in their area being made in both soil conservation and water conservation. Their report should end with suggestions for aquaponic use in their region or state as related to the ECO-Cycle.

Glossary

Ammonia – The Nitrogen/Hydrogen compound (NH 3) excreted from the gills of fish and the decay of organic matter such as plants, fish waste, and excess fish food.

Aquaponics – The system or the development of a system that is beneficial to both plants and aquatic animals and bacteria in a recirculating environment where all can thrive and grow; a sustainable food production system that combines a traditional aquaculture (raising aquatic animals such as fish in tanks) with hydroponics (growing plants in water) in a symbiotic environment

Bacteria – Any of the smallest kinds of microorganisms; one-celled living things that do not have a nucleus

Biome – A place with certain kinds of living and nonliving things

Cell – The smallest part of a living thing that can carry out processes of life

Chloroplast – A part of a plant cell that uses energy from sunlight to make food

Consumer – A living thing that eats other living things

Decomposer – A living thing that breaks down dead plants and animals

Ecosystem – All the living and nonliving things working together in an area

Environment – All the living things and nonliving things in a place

Food chain – The path of energy in the form of food going from one living thing to another

Food web – A way of showing how food chains in any place are inked together

Fresh water – An environment that has water with little or no salt in it

Germination – The development of a plant from a seed or spore after a period of dormancy habitat – the place where a living thing makes its home

Microorganism – Any kind of living thing that is too small to be seen with just our eyes

Nitrate – Nitrate is an ion produced as the last step in the Nitrogen Cycle and is only toxic to fish at high levels, above 160 ppm. Nitrate is removed from the water and used by plants for growth.

Nitrite – Nitrite is an ion produced as the second step in the Nitrogen Cycle. Nitrite is toxic to fish and will kill them quickly if levels are high. An ideal level of nitrite in a cycled system is 0 ppm.

Nitrifying Bacteria – Bacteria that plays a role in the Nitrogen Cycle. The first set of bacteria in your system converts ammonia into nitrite. The second set of bacteria in your system converts nitrite into nitrate. Nitrifying bacteria thrive in environments that are rich in oxygen, with no UV light and warm temperatures.

Nitrogen Cycle – The Nitrogen Cycle is the process in which nitrogen moves through an environment, taking different forms and interacting with different organisms.

Nonvascular – Any plant that soaks up water from the ground directly into its cells

Nutrients – A substance that provides nourishment essential for growth and the maintenance of life

Phloem – tissue that moves food (sugar) from the leaves to other parts of a plant

Photosynthesis – the way plants use sunlight to make food; how a plant changes raw materials into food in the presence of sunlight

Pistil – the part of a plant where seeds are made

Pollen – a powdery material that flowers need to make seeds

Pollination – the movement of pollen to the seed-making part of a flower

Producer – any living thing that makes, or produces, its own food

Recycle – to turn an old thing into something new

Reduce – to use less of something

Respiration (in cells) – the release of energy from food

Reuse – to use something again

Salt Water - an environment that has water with salt in it

Seed – an undeveloped plant with stored food inside a protective coat

Spore – a single cell that can develop into a new plant exactly like the plant that produced it

Stamen – the part of a plant where pollen comes from

Stomata – tiny holes in the bottom of a leaf that allow gases in and out

Symbiotic – a mutually beneficial relationship of animals and plants

Transpiration – the evaporation of water from the leaves of a plant

Vascular – any plant that has tubes for moving water and other materials to where they are needed

Xylem – tissue that moves water and minerals up from the roots

Next Generation Science Standards: 9 - 12:

HS - PS3 - 2: Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motion of particles (objects) and energy associated with the relative positions of particles (objects)

HS - PS4 - 1: Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.

HS - PS4 - 3: Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other.

HS - LS1 - 3: Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.

HS - LS1 - 5: Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.

HS - LS1 - 7: Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed, resulting in a net transfer of energy.

HS - LS2 - 1: Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.

HS - LS2 - 3: Construct and revise an explanation based on evidence for cycling of matter and flow of energy in aerobic and anaerobic conditions.

HS - LS2 - 4: Use mathematical representations to support claims for cycling of matter and flow of energy among organisms in an ecosystem.

HS - 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.

HS - ESS2 - 6: Develop a quantitative model to describe the cycling of carbon among hydrosphere, atmosphere, geosphere, and biosphere.

HS- ESS3 - 3: Create a computational simulation to illustrate the relationships among the management of natural resources, the sustainability of human populations, and biodiversity.

HS - ESS3 - 4: Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.