Leaves

Contents:

I. Supply list with sourcing links/tips

Fortune Teller supplies

Item	Source	Notes
Origami fortune tellers, printed in color	Pdf file	The pdf file is designed to print to the page edges. If your printer margins do not allow for this, we suggest cutting off the white area to enable folding
Habitat photos	Pdf file	
Leader board to show which plant "wins" in which habitats	Pdf file	
Stickers to attach to board	Pdf file	These sticker files are created for ULINE Circle Laser Labels - White, 1½ inch http://www.uline.com/Product/Detail/S-13769/Laser-Labels/Circle-Laser-Labels-White-1-1-2

Demo supplies

Demo	Item	Source	Notes
Microscope station	Lay person-friendly Microscope Such as Scope on a Rope	Scope purchasable via http://sciencetechnology resources.com/Products/ Scope_On_A_Rope_L2/ Scope_On_A_Rope_L2.php	Some places have lending programs, such as LSU
	iPad, computer, or other internet enabled device		
Leaf print station	Plastic petri dish		
	Ring stand and clamp		
	Video of chloroplast movement	https://av.tib.eu/media/11292?0	Shows chloroplasts under polarized light
	Bright LED light	A strong flashlight or headlamp will work	
	Black and white image printed on clear transparency film. Strong contrast (with no greys) is recommended		Strong graphics like heats, triangles, bold smiley faces and such as **bold block words** work well.

Plants

Demo	Plant	Source	Notes
Microscope station	Elodea (or other water plant)	Available at pet stores	
	White Pine (or other tree with needles)	Freely available in wild in many areas	
	Thick leaves with a waxy coating (leaves from most plants will do, but Norway Maples or Magnolias will work well)	Freely available in wild in many areas	
Leaf print station	Coleus leaves (lime green ones work best, avoid red)	Available from garden stores and nurseries.	
Venus fly trap demo	Model is housed at US Bot Garden.	In lieu of the model, real VFT's can be purchased at specialty greenhouses, including the Rutgers Floriculture greenhouse on Cook Campus.	

II. Goal & measurable objectives

This educational deliverable has two parts. The first part consists of interactive demonstrations to illustrate some of the movement-related leaf adaptations that help plants manage various environments (e.g. stomata, chloroplast movement).
The second part consists of a manipulative based game in which players explore the ways in which the previously illustrated leaf adaptations help a plant to survive in some (but not all) habitats.

Primary goal: Visitors will learn about several key plant leaf adaptations with a focus on leaf movement at big (whole plant) and small (movements of stomata and chloroplasts) scales through demonstrations and microscope observation, then play an origami game to link leaf adaptations to specific environments and to interspecific plant competition.

Teaching Objectives
Teachers will encourage visitors to:
T1) link leaf adaptations in specific plant species to the environments where they thrive and where they can't survive.
T2) understand that no leaf is perfect everywhere…certain adaptations work in certain environments. For more advanced visitors: understand that plants compete and that leaf adaptations make them more or less competitive in different environments.
T3) "think like a plant" and experience environments from the perspective of a particular plant and to personally identify with a particular plant's strengths and weaknesses.
T4) to leave more likely to observe and wonder about leaf adaptation and plant competition in their everyday environment (parking lots, playgrounds, sidewalks).

Learning goals
Visitors will demonstrate knowledge by:
L1) naming one leaf adaptation that a plant has and why that adaptation helps the plant in a particular environment. (e.g. aquatic plants have air inside their leaves, which helps them survive underwater.)
L2) naming one environment in which their particular chosen plant thrives and one environment where it can't survive. (e.g. white pine trees thrive in dry, windy conditions and can't survive in aquatic environments where air is low.)

Demo specific teaching and learning goals
Microscope & Video – close up looks at key leaf movements

T5) Visitors will observe different aspects of leaf physiology (such as moving chloroplasts, opening / closing stomata, or differences in numbers and positions of stomata on leaves of different plant species) and comment on one thing that they see.

L3) Visitors will respond correctly to a question about chloroplast movement. "Were the areas under the black part of the design greener or whiter?" (greener) "Why?" (because the chloroplasts are spread out to collect as much light as possible underneath the black part of the

design where the light is lower, while in the clear areas the chloroplasts are all stacked up at the edges of the cells to help protect the cells from being exposed to too much light).

Venus Fly Trap Activity – using the working model

L4) Visitors will respond to a question regarding the operation of a Venus fly trap "Is it easier (does it require less energy) for the plant to open or close the leaf trap?" (answer: less energy to close the trap, prompt with the amount of input needed by the visitor to make the trap work – trigger hairs need just a touch to close while the plant requires a lot of energy to reopen the leaf (simulated by the pump).

Origami Game – fold 'fortune tellers' to play a game and learn about plant adaptations for particular environments; competitive element/leader board to see larger systems of adaptation

Visitors will demonstrate an understanding that some leaves are "good" in some habitats but not in others. Visitors can demonstrate this understanding in one of the following ways:

L5) Putting a sticker of their plant in the habitat where their plant has won and respond to the question "What do you notice about where this plant is doing best?"

L6) Adjusting their playing strategy in subsequent rounds to choose a habitat where their plant does better.

L7) Answering a question correctly, such as: "Thinking about the demonstration you saw on ____, what resource is your plant good at competing for? Which habitat has (or does not have) that resource?"

III. Assembly how-to steps/pro tips

There are numerous demonstration options below which can be chosen based on time, space, personnel, available technology, and available plants. The corresponding foldable game origami should then be chosen to match the demonstrations. We recommend a minimum of three species, including the jack-of-all-trades, the dandelion.

No leaf is perfect everywhere…certain leaf adaptations (with a focus on adaptations involving leaf movement) help the plant thrive in certain environments. We want visitors to leave more likely to observe and wonder about leaf adaptation and plant competition in their everyday environment (parking lots, playgrounds, sidewalks).

Station 1: Microscope Station
Expert help required: No, but 5 min training at task
Requires volunteer supervision: Yes

- **Objectives:** Observe chloroplast streaming in Elodea, observe stomata differences between plants, especially sunken stomata of pine needles, look at the air spaces (aerencyma) in waterweed leaves, wax coatings on leaves, explore plant leaves at a microscopic scale.
- **Teaching points**
    - Discuss connections between observations and thriving in vs. not surviving particular environments, link to observations they can make about plants they see everyday.
    - Explain basics of chloroplasts
    - Explain basics of stomata

If microscopes are not freely available, there are videos that show some of the above phenomena

Chloroplast streaming	https://av.tib.eu/media/11292?0	
Stomata opening	https://www.youtube.com/watch?v=cFX4JrsPaUs (0:19 – 0:40)	
Venus fly trap	http://chlorofilms.org/?module=Pages&func=display&pageid=15#223	

Station 2: Venus Fly Trap Model
Expert help required: No, but 5 min training at task
Requires volunteer supervision: Yes

- **Objectives:** Observe working model of a Venus fly trap and compare/contrast with living VFT. Point is to understand how the plant leaves are adapted and the kind of environment this plant thrives in. Understand why the VFT has a sophisticated triggering system and why it would "want" to avoid closing on something that is not an insect.

- **Teaching points**
    - Venus Fly Traps trap insects and then digest them slowly for nutrients.
    - Venus fly traps know when to close using trigger hairs. Two hairs or same hair must be pressed twice in 30 seconds for trap to close
    - It takes energy to close and even more to re-open, so it isn't good for a Venus tly trap to close when they haven't caught an insect.

Video of Venus fly traps opening and closing

Venus fly trap	http://chlorofilms.org/?module=Pages&func=display&pageid=15#223

Station 3: Coleus Leaf Prints
Expert help required: No, but 5 min training at task
Requires volunteer supervision for safety: No

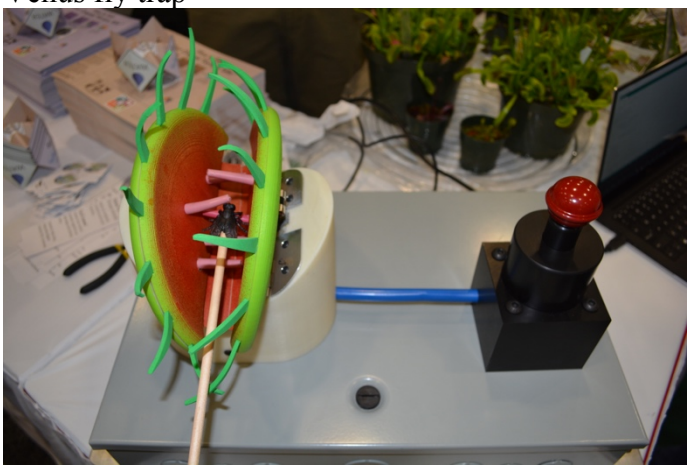
- **Objectives:** Observe changes in a shade leaf when exposed to strong direct light. Understand that chloroplasts move around, stacking to prevent damage in strong light and spreading out to make the most of available light in shade. Understand what causes the "living picture" on the leaf, link the visible to the microscopic movements.
- **Teaching points**
    - Chloroplasts: the green parts of plant cells (the energy factories, called chloroplasts) can move around so that they can make the best use of light. Shade plants are particularly good at this because the light sometimes shines through the trees and hits them and sometimes it stays dark under the canopy.

Station 4: Origami Game
Expert help required: No, but 5-10 min training at task
Requires volunteer supervision for safety: No (but good idea to have someone here to explain the game).

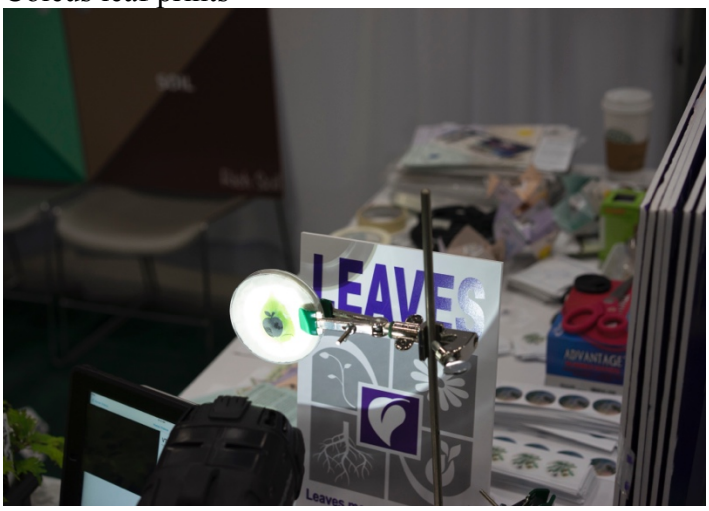
- **Objectives:** Link plant adaptations visitors observe in demonstrations to a plant's ability to thrive in a particular environment. Understand that no leaf is perfect everywhere. Appreciate plant competition and wonder about plant adaptations and survival in plants they see everyday. Personally identify with a particular plant and understand its strengths and weaknesses.
- **Teaching points:**
    - Plants need four resources to survive.
    - Some leaf adaptations work especially well to conserve or access some of these resources (and those same adaptations may be completely useless when it comes to environments where those resources are abundant and other resources are scarce).
    - Different habitats have more or less of different resources, this affects where particular plants can thrive and where they can't survive

IV. Sketches, photos, etc. to clarify directions

Venus fly trap



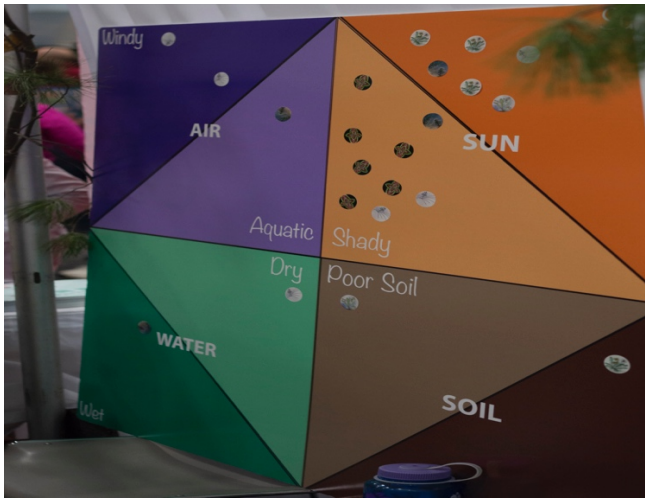
Coleus leaf prints



General set up

Origami


Windy


Windy
AIR
SUN
Aquatic
Shady
Dry
Poor Soil
WATER
Wet
SOIL

V. **Guided questions/interactions to help frame scientist/educator to visitor/user interactions**

Key introduction for all demonstrations!

Plants need three main things to make food – air, water, and sunlight. They also need nutrients in soil to help them stay healthy.

Station 1: Microscope Station / Videos

Example scripts for exploring plant leaves at a microscopic scale.

chloroplast streaming in Elodea

What do you notice in this video? Do you see the green dots moving around? Those are chloroplasts, the miniature food factories of plants. They need the right amount of sunlight to make food: too little sunlight and the plant is hungry, but too much sunlight can burn the chloroplasts.

Because of this the chloroplasts can move around, spreading out to get as much sun as they can when it is shady, stacking up on the sides of the cells when there is too much sun (they can shade each other). *You can demonstrate this with hand movements on a sunny day.*

observe stomata differences between plants, ex. sunken stomata of pine needles

One of the other things plants need to make food is air, but this air has to get *inside* the leaf. Plants allow this to happen by making tiny air holes in their leaves. These holes are called stomata and are bordered by two cells that look kinda like lips. These "lips" open to let in air. The problem with stomata is that when they let air into the leaves they also let water out, which can be bad for the plant.

Some plants have evolved different ways of keeping too much water from escaping. One example is the stomata of pine needles, which are sunken down into the leaf. This keeps the wind from pulling water out of the leaf. Other leaves may have lots of fuzzy hairs on the bottom of the leaf, where the stomata usually are, to help trap the humid air.

look at the air spaces in waterweed leaves

Not all plants live on land. Some live in water, but that doesn't mean these water plants don't need sunlight. Look at the little airspace adaptations in these leaves that help them float and get more sunlight. The air spaces also let the plant keep their own internal atmosphere of gases. Sometimes aquatic insects can tap into the oxygen inside aquatic plants by piercing into the plant with their mouthparts and using the plant leaf like a little scuba tank.

wax coatings on leaves

For plants that live on land, keeping water in their leaves is really important. In addition to their stomata, plants have waxy, water resistant coatings on their leaves that help reduce the amount of water escaping. Look at this coating here. If we tear the leaf just so, it is even easier to see.

Station 2: Venus Fly Trap Model

- **Example Scripts:** Have you ever seen a Venus fly trap before? Why do their leaves move so quickly? (trap insects) Do you know why they trap insects? (nutrients) Is it good for a Venus fly trap close when they haven't caught an insect? (no) How do Venus fly traps know when to close? Let us show you this model of a Venus fly trap and how the trigger hairs work. (show and describe how must press two hairs or same hair twice in 30 seconds). Show how requires continued stimulation to close completely. Show how the plant must use energy to reopen, in this case input by the visitor via the pump.

Station 3: Coleus Leaf Prints

- **Example Scripts:** Did you know that the green parts of plant cells (the energy factories, called chloroplasts) move around so that they can make the best use of light? Shade plants are really good at this because the light sometimes shines through the trees and hits them and sometimes it stays dark under the canopy. They have to deal with changing light levels all the time. If you think of each chloroplast like a little solar panel, to collect more energy from the sun, would it be better for the chloroplasts to stack up on top of each other when it is shady or spread out across the cell? (spread out) What if the sun suddenly beats down on the plant and it starts to cause damage to the cell? How could you protect your solar panels then? (stacking them up). Look at this video of what is happening under a microscope as the light changes. So, we have this leaf under a bright light. It's probably too bright for the shade plant, so the plant is going to try to protect its chloroplasts. Do you think the areas under the black part of the design will be greener or whiter? (greener) Why? (because the chloroplasts are all stacked up on the sides under the black print in the shade and not across the cell where they are getting too much sun.)

Station 4: Origami Game

- **Sample Scripts:** Sample script (this is for one visitor at a time. Otherwise, can choose another visitor with a different plant as "challenger" and walk them through the game together).

  What's your favorite of these 5 plants? or
  Which of these plants do you think has the best leaves?
  Ok, great. Here you go (hand them origami, bookmark and stickers for the plant they choose). Let's see if you are right. I'm a [other species]. Do you think your leaves are better than mine?
  OK, let's see.
  1) Plants need four resources to survive. Can you name one of the four resources? Hint, they are on the outside of the fortune teller.
  SUN. OK, S-U-N.
  2) Next, pick a number, OK, 1-2-3-4-5
  3) OK, now we have 4 choices of environments showing inside the fortune teller. Which of these habitats do you think your plant would thrive (do best) in? Do you think my plant will do better or worse than your plant in that environment?
  4) OK, we're at number 3, where it's sunny. Open your number 3 and I'll open my number 3 and we'll see who has the best leaves where it's sunny.

a) Yay! You won! It's because your plant has {adaptation} and mine doesn't. Put your sticker on the sunny triangle over there [leaderboard] You can try again later with anyone you see holding an origami game to learn where you thrive and where you can't survive!
b) Boo! I won this time. Does that mean my plant is better than yours? Maybe in a sunny environment, but I'll bet yours are better than mine in other places.
    a. Let's try it again, but this time you can move the origami…
    b. …Or…what about in a different environment? (guide them towards winning) Let's see if you would beat me in that environment….yes! Here, go put your sticker on the shady triangle over there.
c) Have you had a chance to see your plant's leaves up close? If not, take a look at the {your plant} demo over there to learn more about what makes your plant's leaves so interesting, and how different adaptations help in different environments.

Interpretation of leaderboard poster:
Hey, do you notice anything about where each plant is winning? Can that help you with your strategy when playing the game? Notice that the dandelion seems to be popping up everywhere, but waterweed shows up mostly in just one place. Why do you think that is the case?

VI. Evaluation A

Staffing

We had between 2 and 6 people at the booth during the event. During the times when we only had two volunteers, the most critical positions were the Origami game station and the Venus fly trap, which had the most visitor interest. We put away the microscope and did not take the light off of the coleus leaf when volunteers were scarce.

Folding the Origami

The origami game was very popular with upper elementary through early high school students. We did not have a very large area for folding the origami, and many people wanted to sit and fold their own origami. Others would have preferred to take a pre-folded origami with them. Many ended up taking unfolded origami with them after playing and learning the game with "demo" prefolded versions. Depending on whether this is done for a very large group or as an activity with a class or smaller group, it would be good to have either a designated folding area or to pre-fold or lead a group through the process of folding the origami. We tried to pre-fold some to use as examples, but these were regularly taken and had to be replenished over the day. It was too optimistic to pre-fold enough of these for an event the size of this one. Even cutting up the stickers into strips took a lot of time for just one person (lots of evenings in the hotel room). We also had rubber bands to staple to the origami so that they could be tied to a bag and not "out of sight, out of mind". However, without adequate folding space and without folding the origamis ahead of time, that plan did not work out.

Playing the Origami Game

The origami game needs a volunteer or two to help explain the rules of the game. For those familiar with the origami "fortune tellers" that this game is based on, the twist to this game is that you are encouraged to "compete" with each other, as every plant has a different fortune in each environment. This caused a bit of confusion at first, because those familiar with the fortune teller format thought each fortune teller was independent from the others or identical, but visitors quickly caught on.

Sets of Origami

Many teachers or home school families who were visiting the booth requested a full set of origami for them to photocopy and use with their classes. It may be a good idea to have these in sets for families or teachers who would prefer to take them home to fold and play.

Leaderboard

We placed the leaderboard initially on the far side of the table, but people did not want to fight their way to the other side of the booth to put a sticker on the leaderboard. They also

wanted to keep the stickers rather than put one on the board. We eventually moved the leaderboard to the center of the booth and placed stickers ourselves based on who had won the game. More space on the same side of the booth that the origamis were would have been a better setup.

Microscope Station

The wireless scope on a rope that we used needed to be right next to the ipad or it lost connection. That may have been due to lots of wifi, phones, etc. in the space. Also, the high magnification that was required to see the stomata meant that the microscope took a little practice to learn how to hold the pine needle just right to show the sunken stomata. Good idea to let the volunteer practice with this a little bit, or a regular microscope would allow for pre-focusing.

Venus Fly Trap Model

It is important that someone be supervising the Venus fly trap at all times to prevent damage to the model. Encourage visitors to use the fly stick as opposed to their fingers. One of the leaf parts sometimes needed to be tapped open once the metal pieces that move to open the leaf were fully retracted by the pump. Also, occasionally the trigger hairs would not react. Some were more sensitive than others. You could shake the table slightly and that was usually enough to make the trap close. There are small balls inside the rubber trigger hairs that move. Giving the hairs a sharp "flick" is the best way to set them off.

Live Venus Fly Trap

If there are live Venus fly traps on display, visitors are sorely tempted to shut the traps with their fingers. This requires quite a bit of vigilance. We had planned to bring a large glass dome to protect the plant, but the plant was a lot bigger than we anticipated. We ended up having a volunteer stationed right in front of the VFT to prevent visitors from closing the traps, instead recommending that the visitors try the model, and using it as a teaching moment to discuss why it is not a good idea to close the traps unless "you are planning to leave your finger behind for the plant to digest for nitrogen ☺"

Coleus Leaf Prints

We needed to replace the batteries in the strong flashlights pretty regularly to keep the light bright enough. Also, it's a good idea to be careful to replace the transparency in as close to the same spot as possible after revealing the "plant print", otherwise the edges get pretty fuzzy. This takes a while to work, so having several lights and ringstands means you can do the "big reveal" more often. It also helps to put the plants that you're planning to use under lights overnight if possible. Lime green coleus worked much better than coleus with any red in it. It also worked best with fresh, healthy plants. After a few hours, it's good to get a new leaf. Many visitors were fascinated by this and intrigued by the potential for biomimicry engineering in solar power. The video

https://av.tib.eu/media/11292?0 was very helpful for explaining what was going on at the microscopic level.

VII. Evaluation B

Summative assessments

1. I liked 'thinking' like a plant leaf to figure out how to survive in different environments.

   Yes / No

2. Thanks to this booth, I'm excited to join the plant movement because plants move and plants matter.

   Yes / No

3. A particular kind of leaf adaptation will help a plant live in any and all habitats.

   True / False

Formative assessments

Visitors will demonstrate knowledge by:
L1) naming one leaf adaptation that a plant has and why that adaptation helps the plant in a particular environment. (e.g. aquatic plants have air inside their leaves, which helps them survive underwater.)

L2) naming one environment in which their particular chosen plant thrives and one environment where it can't survive. (e.g. white pine trees thrive in dry, windy conditions and can't survive in aquatic environments where air is low.)

Demo specific

Microscope & Video – close up looks at key leaf movements

T5) Visitors will observe different aspects of leaf physiology (such as moving chloroplasts, opening / closing stomata, or differences in numbers and positions of stomata on leaves of different plant species) and comment on one thing that they see.

L3) Visitors will respond correctly to a question about chloroplast movement. "Were the areas under the black part of the design greener or whiter?" (greener) "Why?" (because the chloroplasts are spread out to collect as much light as possible underneath the black part of the design where the light is lower, while in the clear areas the chloroplasts are all stacked up at the edges of the cells to help protect the cells from being exposed to too much light).

Venus Fly Trap Activity – using the working model
L4) Visitors will respond to a question regarding the operation of a Venus fly trap "Is it easier (does it require less energy) for the plant to open or close the leaf trap?" (answer: less energy to close the trap, prompt with the amount of input needed by the visitor to make the trap work – trigger hairs need just a touch to close while the plant requires a lot of energy to reopen the leaf (simulated by the pump).

Origami Game – fold 'fortune tellers' to play a game and learn about plant adaptations for particular environments; competitive element/leader board to see larger systems of adaptation

Visitors will demonstrate an understanding that some leaves are good in some habitats but not in others in one of the following ways

L5) Putting a sticker of their plant in the winning habitat and respond to the question "What do you notice about where this plant is doing best?"

L6) Adjusting their playing strategy the second time around to choose a habitat where their plant does better.

L7) Answering a question correctly, such as: "Thinking about the demonstration you saw on ____, what resource is your plant good at competing for? Which habitat has (or does not have) that resource?"