ST[EMpower]

Springtime!

VOLUME 8, ISSUE 5, MAY 2019

THIS MONTH

POWER WORDS

- **catkin:** a flowering spike of trees such as quaking aspen; typically downy, hanging down flowers
- **dormancy**: the state of having normal physical functions suspended or slowed for a period of time

CAREERS

WAKE UP!

The earliest signs of spring are the blush of yellow on tree tips, bird song in the air, and sighting an insect. What triggers plants and animals to emerge from winter **dormancy**?

How organisms emerge in spring is not yet entirely understood. Plants have a series of chemical pathways that sense warmer soil, increasing daylight, and a 20 day cold snap. Hibernating animals are usually underground and insulated from temperature and light. They have an internal clock that ticks down from onset of hibernating to waking. Some species wake several times through the winter and return to hibernation until spring.

This issue of the ST[EMpower] newsletter will focus on Aspen (or any other deciduous tree). The September issue 44:Aspen focused activities on a specific tree as it prepared for dormancy. This issue picks up as the trees reawaken.

Trees are flowering plants. Tree flowers are usually quite small and often overlooked. Flowers range in size from the 15 pound bloom of *Rafflesia arnoldii* to *Wolffia* sp.

Quaking aspen female **catkins.** Photo by B. Campbell.

flowers that would fit on the point of a pin. They attract pollinators.

Pollinated flowers produce seeds. The size of the seed does not indicate how large the plant will grow. Coco de mer palms have the largest seeds that weigh 40 pounds! (Palms are a type of grass and not a true tree). The smallest seeds are from some orchids from tropical rain forests.

Who are the pollinators? Different flowers attract insects, bats, and bird pollinators. The largest flower, *Rafflesia arnoldii,* smells like rotting flesh to attract flies. Seed dispersal methods include wind and animals to carry the seeds far from the parent plant.

COLORADO STATE UNIVERSITY EXTENSION

PLANT CLASSIFICATION

Carolus Linnaeus (born Carl von Linne in 1707) developed the **taxonomic** system by naming each species with two unique names, genus and species. This was during the time of European exploration, and many new and exotic species were discovered by the Western World. In fact, Linnaeus named over 4,400 animal and 7,700 species of plants!

Scientists expanded on **taxonomic** classifying species to better represent the relationships between organisms. Below lists the **hierarchy** and the example (humans):

Domain (Eukaryota)
Kingdom (Animalia)
Phylum (Chordata)
Class (Mammalia)
Order (Primates)
Family (Hominidae)
Genus (*Homo*)
species (*H. sapiens*)

Plants use Division instead of Phylum, but everything else follows the animal system of **hierarchy**. The example is for quaking aspen:
Domain (Eukarya)
Kingdom (Plantae)
Division (Magnoliophyta)
Class (Magnoliopsida) (Dicots)
Order (Salicales)
Family (Salicaceae)
Genus (*Populus*)
species (*P. tremuloides*)

There are four major groups of plants (formerly divisions, but now grouped a bit differently with DNA data):

- Flowering plants (angiosperms)
- Naked seeded plants (gymnosperms) includes cone-bearing plants like pine and fir trees, cycads, ginkgo, and odd-ball plants like ephedra and welwitschia.
- Seedless vascular plants (Pterophyta) ferns, horsetails, club mosses, and psilopsida.
- Seedless, (spore producing) non-vascular plants (Bryophyta) including mosses, liverworts and hornworts.

Directions:

- Call your local extension office and make an appointment with the Native Plant Masters or the Master Gardeners. They have been informed that youth will be calling with this request. To find your county extension office, go the the website below, and click on the link at the top of the page: Contact your local county Extension office through our County Office List: https://extension.colostate.edu/
- Ask the Native Plant Masters or the Master Gardeners to help you examine these four groups of plants. They may have specimens in the office, or they may opt to take you out to look at the local plants.
- With each of the 4 groups of plants, sketch the reproductive systems of each as depicted on the data sheet.
- Compare and contrast the similarities and differences among these four groups.

Most drugs are derived from plants!

POWER WORDS

- **hierarchy**: a system of organization in which groups are ranked according to shared biological structures Example: the Order Carnivora (carnivores) include the Families Canidae, Felidae, Ur.sidae, etc. Canidae include dogs, wolves, coyotes, etc. Felidae includes cats, puma, etc., Urisidae (bears), and others.
- **taxonomic**: concerning the classification of things, especially organisms, and their relationship to each other

MATERIALS:

- magnifying lens
- optional dissecting microscope
- computer with internet access https://extension.colostate.edu/
- print data sheet page 7
- color pencils

What are bryophytes?

Bryophyta include about 16,200 land plants. Bryophytes are thought to be the first true plants to evolve. This division includes:

- Mosses – class Bryopsida
- Liverworts – class Marchantiopsida
- Hornworts – class Anthocerotopsida

The only prime feature of a bryophyte is that it does not have true vascular tissue (xylem and phloem). Some do have specialized tissues which are used to transport water but are not considered to be a true vascular tissue.

Characteristics of Bryophytes:

- primitive vascular plants (no **xylem** and **phloem**)
- they do not have roots but have **rhizoids** instead of roots which helps the plant to anchor to surface
- they have crude stems and leaves
- These roots or **rhizoids** do not absorb nutrients like other plant roots (but can absorb water)
- release spores from their leaves which travels by water and make
- new bryophytes in new locations.
- water is essential for bryophytes to grow and spread; they can dry out, but revive and continue growing when water returns

Reproduction in Bryophytes

- All cells that contain a nucleus are called eukaryote cells. In animals the number of chromosomes or pairs of chromosomes varies. Humans have have 23 pairs of DNA organized into separate strands, one from the mother and the other from the father. This is true for almost every cell except reproductive cells (egg and sperm). When a cell is fertilized by a sperm, the cell has two sets of chromosomes, one from each parent.
- Plants are different than animals in the cycle of one set of chromosomes (called haploid) and two sets of chromosomes (called diploid) referred to as alternation of generations. As plants become more complex, they spend more time in the diploid generation, and less time in the haploid state. The green you see in the images of bryophytes are haploid. The brown/orange and the image in the white box are the diploid tissues.
- The life cycle of bryophytes is like all the other land plants with alternation of generations. The only time the plant produces diploid (two sets of chromosomes) is when it is preparing to reproduce.
- Liverworts are extraordinarily cool. The white box show the diploid stage as the plant prepares for sexual reproduction. Like most plants, they can vegetatively reproduce (multicellular structures become detached from the parent plant and develop into new individuals, and there for genetically the same as the parent plant). Liverworts have gemma cups (red arrow). When rain falls on the liverwort, cells bounce out of the gemma cups and start to grow a new plant where they land.

Note: **chromosome**, **haploid**, and **diploid** are defined on page 4.

POWER WORDS

phloem: vascular tissue in plants that conducts sugars and other metabolic products from leaves

rhizoid: filamentous outgrowth on the underside of the plant serving both to anchor the plant and to conduct water

xylem: the vascular tissue in plants that conducts water and dissolved nutrients upward from the root

Moss


Liverworts


Club Moss

What are pteridophytes?

These primitive spore bearing plants include about 11,000 species of ferns, etc. This Division includes:

- Class Psilopsida - look like woody, green sticks in the tropics
- Class Lycopsida - club moss
- Class Sphenopsida - horsetails
- Class Pteropsida - ferns

Characteristics of pteridophytes:

- true root, stem, and leaves
- vascular system (**xylem** and **phloem**)
- do not produce seeds or flowers
- unlike bryophytes (mosses, etc.), most of their visible tissue is **diploid**
- the **haploid** alternation of generations is a completely separate plant!

Reproduction in Pteridophytes:

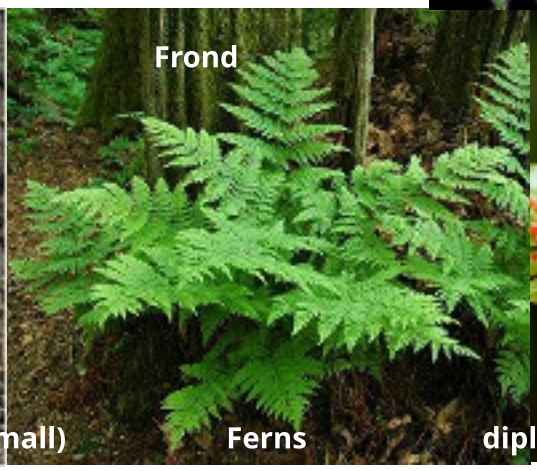
- On the underside of a **diploid** frond, sporangia (singular sporangium) develop (the orange-brown dots on the image below).
- Inside the sporangia, meiotic cell division occurs. Meiotic division is the way cells divide to produce not two sets, but only one set of chromosomes. These are, called spores in ptheridophytes. These spores are dispersed by water, landing on the ground.
- The spore develops into a tiny, heart-shaped plantlet called a prothallus. Inside the prothallus, there are two structures, an antheridium and an archegonium.
- Mitotic cell division (division which preserves the same number of chromosomes the prior cell had. In the prothallus, it only has one set of chromosomes, **haploid**). If this cell division is in the anteridium, it produces sperm. If the division is in the archgonium, it produces eggs.
- Water is necessary for the sperm to swim to an egg for fertilization. It can be on the same prothallus, or it can be on a different prothallus.
- This diploid tissue grows out of the prothallus as a fiddlehead fern (image just to the right), which will grow into a new fern plant.

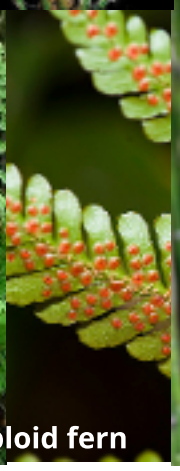
POWER WORDS

chromosome: a threadlike structure of nucleic acids and protein found in the nucleus of most living cells, carrying genetic information in the form of genes

diploid: containing two complete sets of chromosomes, one from each parent

haploid: having a single set of unpaired chromosomes

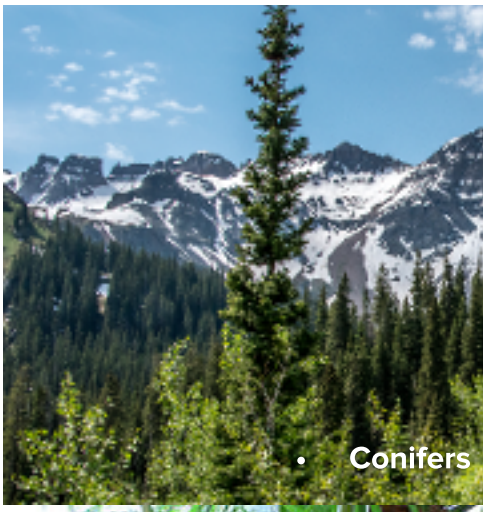




What are gymnosperms?

Gymnosperms have about 1,000 species, and are divided into:

- Class Pinophyta - firs, pines, cedar, and other conifers
- Class Cycadophyta - cycads (also called sago palms)
- Class Ginkgophyta - ginkgo (also called maidenhair tree)
- Class Gnetophyta - some really weird plants, like welwitschia, ephrida, and gnetum (a group of tropical evergreen trees, shrubs, and woody vined lianas)



Characteristics of gymnosperms:

- true root, stem, and leaves
- vascular system (**xylem** and **phloem**)
- produce seeds on the surface of reproductive structures, visible as cones at maturity
- do not produce flowers or fruit
- pollen distributed by wind

Reproduction in gymnosperms:

- The defining differences among bryophytes (mosses), pteridophytes (ferns), gymnosperms (conifers), and angiosperms (flowering plants) is the alternation of generations. Bryophyte plants are primarily **haploid** plants The only time they have **diploid** tissue is during the time they are ready for sexual reproduction. With each group, the **haploid** generation is reduced. Pteridophyte plants have a separate **haploid** plant (prothallus). The **diploid** fern emerges from this small prothallus.
- Following this trend, gymnosperms have a reduction of the haploid alternation of generations stage. There are two types of cones: the large, higher, woody cones are female, and the smaller, lower, easily crushed cones are male. The cones are diploid tissue. Inside each cone, the cells begin to divide, leaving only one set of chromosomes per cell (haploid) called the archegonium to produce eggs, and the pollen which houses sperm.

- Pollen from the male cone is distributed by the wind. Male cones are typically lower on conifers to prevent fertilizing the female cones on the same tree. When pollen lands on a female cone, the pollen begins to bore a tube into the bract of the female, reaching the archegonium. Sperm within the pollen migrate to the egg cells to fertilize and produce seeds
- Seeds may remain in the cone for years, depending on the necessary conditions to start germination.

Ginkgo tree with insert of leaves

What are angiosperms?

This is an informal division of plants that include over 350,000 different species! Generally, these plants can be divided into:

- **monocots** (including plants like cacti)
- **dicots**

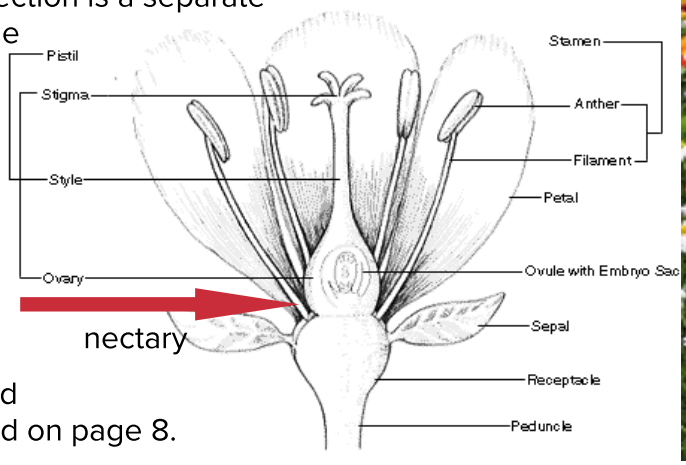
Characteristics of angiosperms:

- true root, stem, and leaves
- vascular system (**xylem** and **phloem**)
- produce flowers (modified leaves) with pollen (sperm located inside) and eggs
- fertilization is primarily though pollinators
- seed located in the flower's ovary that becomes the fruit

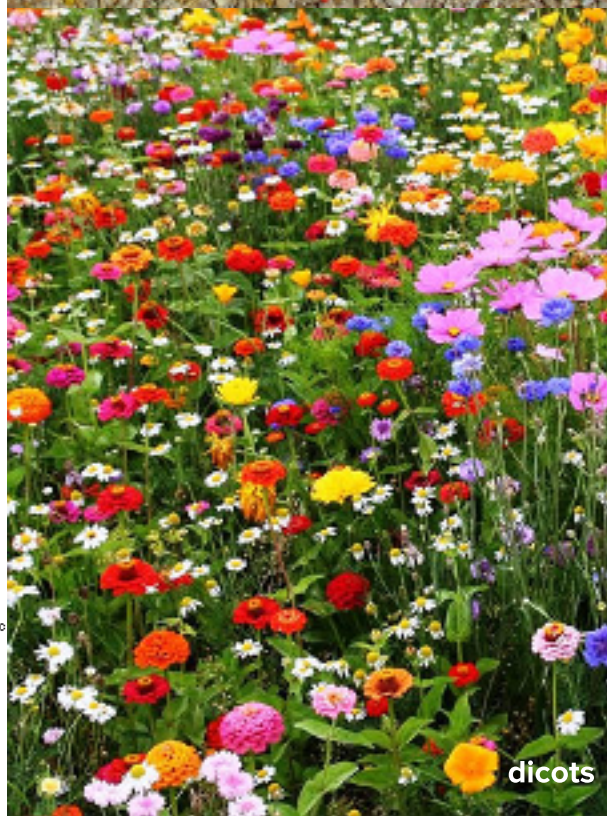
Reproduction in angiosperms:

The activity on page 8 goes into depth on flower anatomy of both **monocots** and **dicots**. The flower diagram is on both this page and page 8 for ease of following this information. As you go through the dissection, review this page for more detailed information about the fertilization process.

- Flowering plants' alternation of generation haploid stage is reduced to several cells within the microsporangium (male structure) and megasporangium (female structure).
- The anthers contain pollen. As the pollinator enters a flower to collect the nectar contained in the nectary, it will brush by the anthers, and the pollen will stick to the body and face of the pollinator.
- It will then move to the next flower, and the pollen will brush by the anthers, as well as deposit pollen on the stigma of the flower.
- The pollen grows a tube (the pollen tube) into the stigma, through the style, and down to the ovary. The sperm migrate into the ovary for fertilization.
- There can be multiple ovaries in a single flower.
- Each ovary grows into a fruit. It can be large, like an orange, or small like a currant.
- Each orange section is a separate ovary in a single flower, producing seeds.



Note: **monocot** and **dicot** are described on page 8.



FOUR GROUPS OF PLANTS - Data Sheet

Bryophyta (moss, liverwort, and hornwort)	**Pterophyta** (ferns, horsetails, and clubmoss)
Gymnosperm (conifers, cycads, ginkgos, and ephidra)	**Angiosperm** (flowering plants)

FLOWER DISSECTION

Flowering plants are divided into two groups: **monocots** (grass, lilies, corn) with floral parts in multiples of three, and **dicots** (carnations, strawberries, columbines) with floral parts in multiples of four or five.

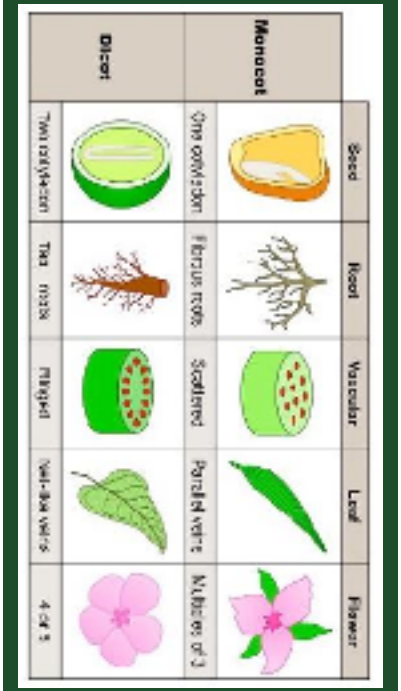
Flowers grow in layers. See the diagram on the lower right.

- The outermost layer - sepals, the outer covering of the flower. The green part of a rosebud are sepals. Lily sepals turn the color of the petals when they open.
- The second layer - petals, usually the color part of the flower. This helps to attract pollinators that use sight to find the nectar, like bees, butterflies, hummingbirds, and bats.
- The third layer - male stamen that includes the filament and anther where pollen is located.
- The innermost layer - female pistil that includes the stigma, style, and ovary where a fertilized flower's seeds will grow. The pistil sits on top of the receptacle and peduncle.

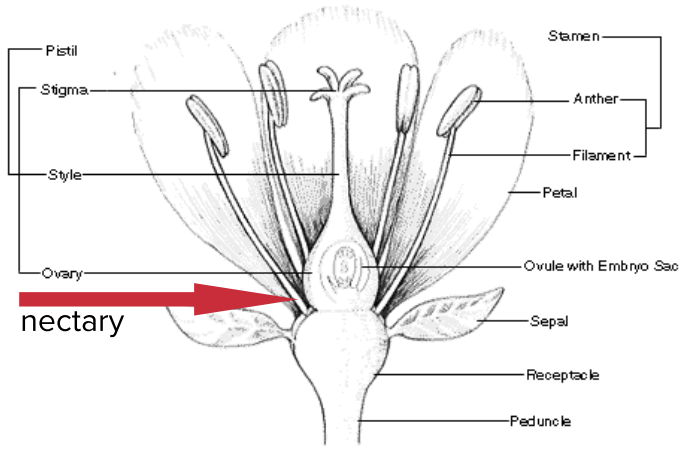
Directions:

- Start with the lily. For each layer, tape on the data sheet and count the number of each. Record that number.
- Remove the outer layer - sepals. Tape the individual sepals on the data sheet. How many are there? If the lily is completely open, then the sepals will be the same color as the petals. There are equal number of sepals as petals.
- Remove the next layer - petals. Tape the individual petals on the right and label. How many are there?
- Remove the next layer - stamen. Each stamen is comprised of an anther on a filament. Tape the individual stamen on the data sheet and label.
- The pistil is the remaining structure. Use a safe surface (cutting board or piece of cardboard), cut the pistil in half with the craft knife or box cutter. Tape both halves on the right.
- Repeat these steps with the carnation.
- Examine each closely with your hand lens. Note similarities and differences between these two flowers. Which flower is from a **monocot** plant, and which is from a **dicot** plant?
- Dissect your snapdragon. Follow the same steps. Is your snapdragon a monocot or dicot?
- Flowers, like daisies, are very different, and are called composite flowers. Each "bump" on the daisy head is a flower.

POWER WORDS



	Seed	Root	Vascular	Leaf	Flower
Monocot	One cotyledon	Fibrous roots	Scattered	Parallel veins	Number of 3
Dicot	Two cotyledons	Tap root	Ringed	Veins like veins	4 or 5



MATERIALS:

- magnifying lens
- optional dissecting microscope
- lily, carnation and snapdragon cut flowers
- computer with internet access https://extension.colostate.edu/
- print flower dissection page 9-11 (single sided)
- color pencils
- tape
- box cutter or craft knife
- cutting board with parent supervision

FLOWER DISSECTION - Lily

Tape each structure on this page.

Number of sepals:

Number of petals:

Number of stamen (anther and filament):

Number of pistils (stigma, style, and ovary):

FLOWER DISSECTION - Carnation

Tape each structure on this page.

Number of sepals:

Number of petals:

Number of stamen (anther and filament):

Number of pistils (stigma, style, and ovary):

FLOWER DISSECTION - Snapdragon

Tape each structure on this page.

Number of sepals:

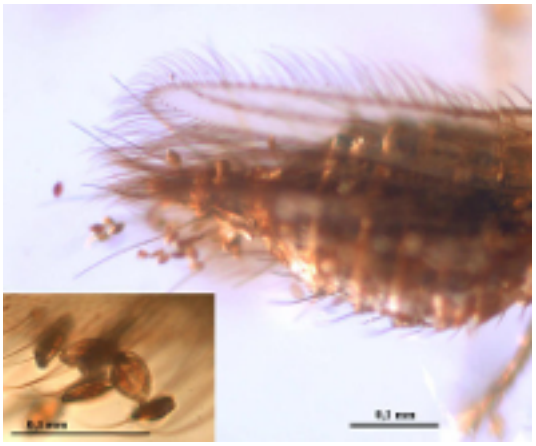
Number of petals:

Number of stamen (anther and filament):

Number of pistils (stigma, style, and ovary):

POLLINATORS

Angiosperms and pollinator animals **co-evolved** at least 100 million years ago with the oldest known pollinating insect fossil found in amber (image below) covered with pollen. DNA **molecular clocks** date flowers appearing as far back as 256 million years ago, and pollinators have probably been part of the flower's story for much of that time.



Directions:

- Before you look at Pollinator Data Sheet 2, focus on Pollinator Data Sheet 1 to make some predictions.
- How many pollinators can you list? There are some pollinators that do not live here, but you may know about them. You can list those too.
- Go through your list again, and note which are local animals.
- The USDA (US Department of Agriculture) has information about native pollinators you may find interesting. You can find it at the website listed in the green box.
- Sketch each of the local pollinators, especially their mouth parts. Estimate the size of each animal. Both of these characteristics are important in pollinating a flower.
- Look carefully at the three flowers you dissected, especially the structure to the nectaries, the location of the anthers and the stigma.
- Make your best guess which pollinator from your list would likely pollinate each of your dissected flowers (lily, carnation, and snapdragon).
- Look at the picture of the titan arum. It is also called a corpse flower. What kind of pollinator would pollinate this flower?
- Hint: it smells like rotting meat. What kinds of animals are attracted to rotting flesh?
- Hint: it has dark magenta petals. If you look at the Pollinator Syndromes on page 15, a list of flower characters attracting specific flower. What kind of animals are attracted by dark magenta petals?
- Time to go outdoors and check this out for yourself! Find an area that has a lot of flowers. They can be garden flowers or wildflowers. Bring your pencil, data sheet 2 (on page 14), clipboard, and folding chair. Carefully watch the flowers. Start jotting down what animals you see.
- The data sheet includes common Colorado pollinators. Record what you see.

POWER WORDS

- **coevolve**: two things that influence each other in the process of development or evolution
- **molecular clock**: average rate at which a species' DNA accumulates mutations, used to measure species separation
- **pollinator**: an animal that moves pollen from the male anther of a flower to the female stigma of a (different) flower

- When you return home, compare it to the Pollinator Syndromes. Do you agree with the that sheet?
- When you see flowers, predict which pollinators will visit.

MATERIALS:

- USDA Pollinator information: https://plants.usda.gov/pollinators/Native_Pollinators.pdf
- pencil
- color pencils
- flower dissection sheets
- magnifying lens
- copy of data sheets pages 13-14
- clipboard
- optional - folding chair

List as many pollinators you can and sketch them:

Look at your flower dissection sheet. Can you guess which flower will attract which pollinator? Look closely at where nectaries are located. Consider the mouth parts of the different pollinators. consider the size of the pollinators. Why do you think each flower will be visited by the pollinator you picked?

Lily

Carnation

Snapdragon

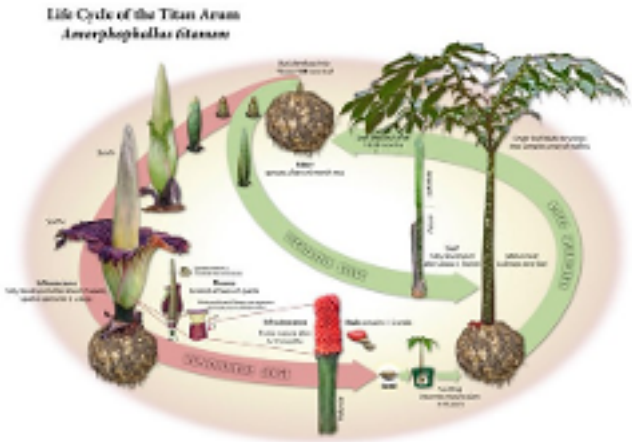
The image on the right is called titan arum (*Amorphophallus titanum)*. It is the tallest flower in the world, and the flower can grow as tall as 8 feet! The plant is native to Sumatra in Indonesia. Can you identify the stamen? Can you identify the pistil? Trick question, since the spike is the pistil, and you can't see the stamen!

What pollinator do you think would pollinate the titan arum?

Hint: It smells like rotting meat.

Hint: the dark magenta petals attract a certain type of pollinator.

The plant has a vegetative stage with only leaves and stems, and a reproductive stage, when the flower grows. The life cycle diagram shows these two stages.



Nature's Partners: Pollinators and Plants Observation Sheet

Animal	Behavior (flying, crawling, drinking nectar, gathering pollen, # of visits, etc.)	Flower Name	Flower Shape (draw flower)	Flower Color	Flower Scent
Bee					
Butterfly					
Hummingbird					
Fly					
(Other)					

Pollinator Syndromes

"Pollinator Syndromes" describe flower characteristics, or traits, that may appeal to a particular type of pollinator. Such characteristics can be used to predict the type of pollinator that will aid the flower in successful reproduction. A combination of color, odor, quantity of nectar, location and type of pollen, and flower structure can each affect a potential pollinator's ability to locate a flower and its food resources.

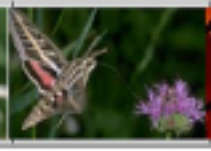
	Type of Pollinator							
Trait	**Bat**	**Bee**	**Beetle**	**Bird**	**Butterfly**	**Fly**	**Moth**	***Wind***
Color	White, green or purple	Bright white, yellow, blue, or UV	White or green	Scarlet, orange, red or white	Bright red and purple	Pale,or dark brown, purple	Pale red, purple, pink or white	Pale green, brown, or colorless
Nectar guides	None	Present	None	None	Present	None	None	None
Odor	Strong and musty; emitted at night	Fresh, mild, pleasant	None to strongly fruity or foul	None	Faint but fresh	Putrid	Strong sweet; emitted at night	None
Nectar	Abundant; somewhat hidden	Usually present	Sometimes present	Ample; deeply hidden	Ample; deeply hidden	Usually absent	Ample; deeply hidden	None
Pollen	Ample	Limited; often sticky, scented	Ample	Limited	Limited	Limited	Limited	Abundant; small, smooth
Flower Shape	Bowl shaped; closed during day	Shallow; with landing platform; tubular	Large and bowl-shaped	Large, funnel -like; strong perch support	Narrow tube with spur; wide landing pad	Shallow; funnel-like or complex with trap	Regular; tubular without a lip	Regular and small
								

Photo credits © Merlin Tuttle, Tom Eisner, Edward Ross, Arla Altman, Chris Carvalho, Paul Growald

WWW.POLLINATOR.ORG

ADOPT A TREE

It is not necessary to do the September issue 44.Aspen newsletter before proceeding. If you did, go get your data! You are going to add to it. Skip to the next activity on page 18.

If you did not start with 44.Aspen, you first need to find a tree. While this issue focuses on the natural history of quaking aspen as the example, you can use any tree near you.

You have two options. You can:

1. Complete the Adopt a Tree from the September issue, collecting additional measurements (website located under the image of the map on the right)
2. Simplified version of Adopt a Tree in this activity.

Directions:

- Gather your supplies in your backpack. Since you are headed outdoors, be sure to dress appropriately for the weather. Layered clothes are the best way to remain comfortable while out and about. As the temperature or your activity level changes, you can remove or add layers.
- Scout around your home, neighborhood, school or park to find a **deciduous** tree (loses its leaves in the fall) that you will "adopt" for all these activities. Find a tree that is on fairly flat ground and separated from other trees. You can also adopt a **conifer** tree (tree with cones) in addition to your deciduous tree.
- On the data sheet, draw a map from your home to the tree. Sketch your tree, and take some pictures. Be sure to include images of the entire tree, the bark, and a couple of leaves). When you return home, download and print your pictures to add to your data sheet.
- With the sharp scissors or pruning shears, cut a sample of the tree (small branch with leaves). Place in the plastic bag and close the bag to keep leaves fresh.
- Determine the species of tree. You can find tree guide books at your county library or use Internet resources. See the Materials list in the green box below for two great sites. If still in doubt, go to your county extension office and ask the master gardeners to help identify your tree.

POWER WORDS

- **conifer**: a tree that bears cones and needle-like leaves or scale-like leaves that are typically evergreen
- **deciduous**: a plant that sheds its leaves annually

ST[EMpower issue 44.Aspent found at this website:
https://tra.extension.colostate.edu/stem-k12/stem-resources/?preview_id=19

MATERIALS:

- cell phone with camera and calculator
- clipboard (9x12" heavy cardboard and binder clip
- color pencils
- datasheet page 17
- resources to identify the tree:
  - iPhone or iPad, free download app LeafSnap: http://leafsnap.com/
  - https://www.arborday.org/trees/whatTree/
- large plastic bag
- pruning or sharp scissors
- backpack
- water bottle
- hat

ADOPT A TREE - Data Sheet

What species is your tree? _____

Draw a map from your house to where your tree is located:

Sketch your tree:

PHOTOSYNTHETIC PIGMENTS

Photosynthesis is a two part **metabolic** process:

- Light Dependent Reaction uses the energy of the sun to make little packets of energy called ATP. ATP is the perfect amount of energy. In the **chloroplast**, ATP is created in the **chlorophyll**, a **pigment** that absorbs most light wave lengths except green.
- Calvin Cycle uses ATP energy to break carbon dioxide gas and water into atoms, rearrange the atoms into a simple sugar and oxygen. This happens in the **chloroplast**.

Chlorophyll has two forms, **chlorophyll** a and **chlorophyll** b. It is not the only **pigment** found in leaves. Two other major pigment are carotenoid and xanthophyll (a type of carotenoid). They are hidden by the chlorophyll during the summer. Sunlight is extremely powerful energy. We get sunburns if we stay out in the sun too long. Carotenoids help to absorb some of this energy, so that the **chlorophylls** can do their job.

One more thing before this activity (and totally cool information). Visible light is what we see in a rainbow once the wavelengths of light have been separated. Red, Orange, Yellow, Green, Blue, Indigo, Violet (ROY G. BIV) combined makes white light. The absorption spectra graph on the right shows **chlorophyll** absorbing blue through purple and red. The green-yellow is not absorbed. That is why leaves are green!

In this activity, you extract leaf **pigments** on a filter paper and use paper chromatography to separate the photosynthetic **pigments**.

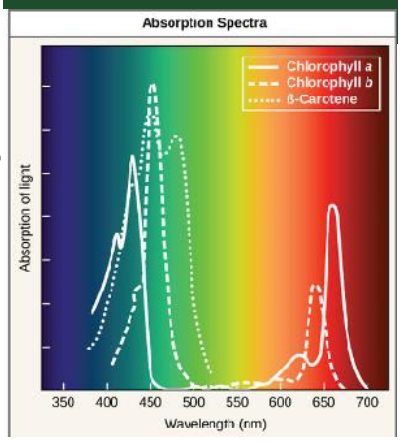
This repeats the activity you did in 44.Aspen, but using a different technique. In the fall, the leaves were changing. Depending on the color of the leaf, you may not have found any green **pigment** in the leaf at all. Now that it is spring, will you find all the **pigments** (**chlorophyll**, carotenoid, and xanthophyll), or only **chlorophyll**?

Directions:

- Cut a strip of coffee filter 3½" x 1".
- Draw a horizontal line with a pencil (not pen) about half an inch from the bottom of the filter strip.
- Crumple your Adopt a Tree leaf to make it more supple.
- Place the leaf on the scratch paper, and put the filter on top of the leaf. With the quarter, press hard and roll the quarter on the pencil line several times until you get a green line. Repeat with another part of the leaf over the same line. Repeat this process until the line is dark green.
- Add about an inch of acetone (clear nail polish) in the canning jar.
- Tape the top of the coffee filter strip to a pencil and balance the pencil across the top of the canning jar. See the image on the next page.
- It is very important that the bottom of the filter strip is in the acetone, but the green line is not in the liquid. If the acetone touches the line directly, the

POWER WORDS

- **chlorophyll**: green pigments in photosynthetic organisms
- **chloroplast**: the organelle that houses chlorophyll and in which photosynthesis takes place
- **metabolic**: relating to the chemical processes that occur in living organisms to sustain life
- **pigment**: substances produced by living organisms which give color (i.e. skin, leaves, eyes, fur, etc.)



MATERIALS:

- cup sized (8 oz) canning jar
- pencil
- tape
- coffee filter
- scissors
- ruler
- acetone (clear nail polish)
- coin (quarter works well)
- scratch paper
- print table page 17 (or copy table on scratch paper)

pigment will just dissolve away.

- Observe what happens to the liquid in the canning jar and the line on the filter paper. Results will take about 20 minutes.
- Remove the filter strip from the acetone and allow to dry.
- Identify the different color bands with the table below.
- Measure the distance from your pencil line to the top of each band in millimeters, and record in PT column in your table.
- Measure the pencil line to the highest point the **solvent** traveled in millimeters. This is your PS distance, and is the same measurement for all 4 pigments. Record this in your table below.
- The distance traveled by any particular **compound** can be used to identify the **compound**. The ratio of the distance traveled by a **compound** to that of the solvent front is known as the Rf value; unknown **compounds** may be identified by comparing their Rf's to the Rf's of **known standards**.
- Paper chromatography works because molecules are different sizes. The larger the molecule, the slower it travels up the filter. the smaller the molecule, the faster it travels up the filter. Order the pigments from smallest to largest. by how far they travel up the filter.

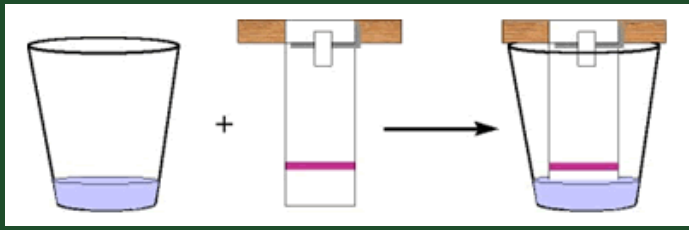
Rf equation:

$$Rf = \frac{\text{distance pigment traveled}}{\text{distance } \textbf{solvent} \text{ traveled}}$$

POWER WORDS

- **compound**: a thing that is composed of two or more separate elements
- **known standard**: set up by an authority as a rule for the measure of quantity, weight, extent, value, or quality to compare to unknowns
- **solute**: the minor component in a solution, dissolved in the solvent
- **solution**: a liquid mixture in which the minor component (solute) is uniformly distributed within the major component
- **solvent**: able to dissolve other substances

Paper chromatography: Filters have the capacity to wick liquid up against gravity. As the **solvent** (acetone) travels up the filter, it passes through the **solutes** (pigments). The pigments are dissolved and carried up the filter with the acetone. The pigments are different sizes and shapes. It is harder for a large pigment to wick through the network of the paper fibers than a small pigment. Therefore, large pigments do not travel as far up the filter. For example, if you run a maze holding one person's hand, you can run it much faster than a group of 8 people holding hands trying to run the maze.



Fill cup canning jar between 1/2 and 1 inch of acetone. Tape the filter to the pencil. Insert into the jar. If the acetone is too low, add a bit more into the jar. If the acetone is too high, readjust the tape on the pencil to raise the filter a bit. **The pigments MUST be above the acetone.**

Band Color	Plant Pigment	PT - Distance pigment traveled	PS - Distance solvent traveled	Rf = PT / PS
yellow to yellow orange	carotene			
yellow	xanthophyll			
bright green to blue green	chlorophyll a			
yellow green to olive green	chlorophyll b			

In the fall, 44.Aspen ST[EMpower] newsletter had a photosynthesis activity. The leaves were beginning to change, and the primary photosynthetic pigments (chlorophyll a and b) are breaking down in preparation for winter. With spring, plants begin to leaf out and photosynthesis is renewing.

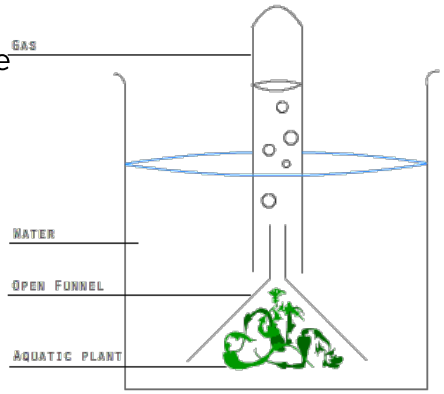
This experiment collects data on the rate of photosynthesis with varying intensity of light. You may have to order supplies on-line. *Elodea nuttallii* (western water weed) is native to Colorado. You may find some submerged in lakes and ponds.

Directions:

- You will collect data in three **trials** on three **treatments**: in full sun, in the shade of the box, and under the box, with no light.
- Start in the morning. Each trial is 2 hours long.
- Fill the three canning jars 3/4 full with water. Line them up the jars to make sure that have the same amount of water.
- Add a teaspoon of baking soda and stir to dissolve in the water.
- Insert the funnel into the three canning jars. You will probably need to squeeze the funnel to fit it into the jar. Place the funnel at the bottom of the canning jar, with the stem pointed up.
- Divide the elodea into three equal pieces. Place one piece of elodea in the water, under the funnel, in each of the three jars.
- Move the experiment outside in full sun to complete the set-up. Place the box upside down.
- Place one of the test tubes in the canning jar and fill with water. Keeping the water in the test tube, turn upside down and insert it over the stem of the funnel.
- Place this experiment under the box. See the diagram below for proper set-up of the experiment.
- Repeat with the other two test tubes in the other two jars. With the second jar, place in the shade of the box. With the third jar, place in full sun (in front or on top of the box).
  1. Measure the distance between the top of the test tube and the waterline and record. Record the start time.
  2. Time the experiment for 2 hours.
  3. Measure the distance between the top of the test tube and the waterline in full sun, the shade, and the dark test tube. Record.
  4. Add 1 teaspoon baking soda and mix to each jar.
  5. Reset the test tubes (fill with water, and insert over the stem of the funnel).
  6. Rotate the jars. Full sun will be the shade, shade will be the dark, and the dark will be the full sun.
- Repeat the data collection steps 1 through 3, above.
- Reset the test tubes, steps 4-6.
- Repeat the data collection steps 1 through 3.

POWER WORDS

- **rate**: a ratio of two related quantities, e.g. miles per hour or gas production per minute
- **ratio**: the relation between two amounts showing the number of times one value contains or is contained within the other
- **treatment**: factor (also called an independent variable) is an explanatory variable manipulated by the experimenter - intensity of sunlight (full, shade, dark)
- **trial**: one of a number of experiment repetitions



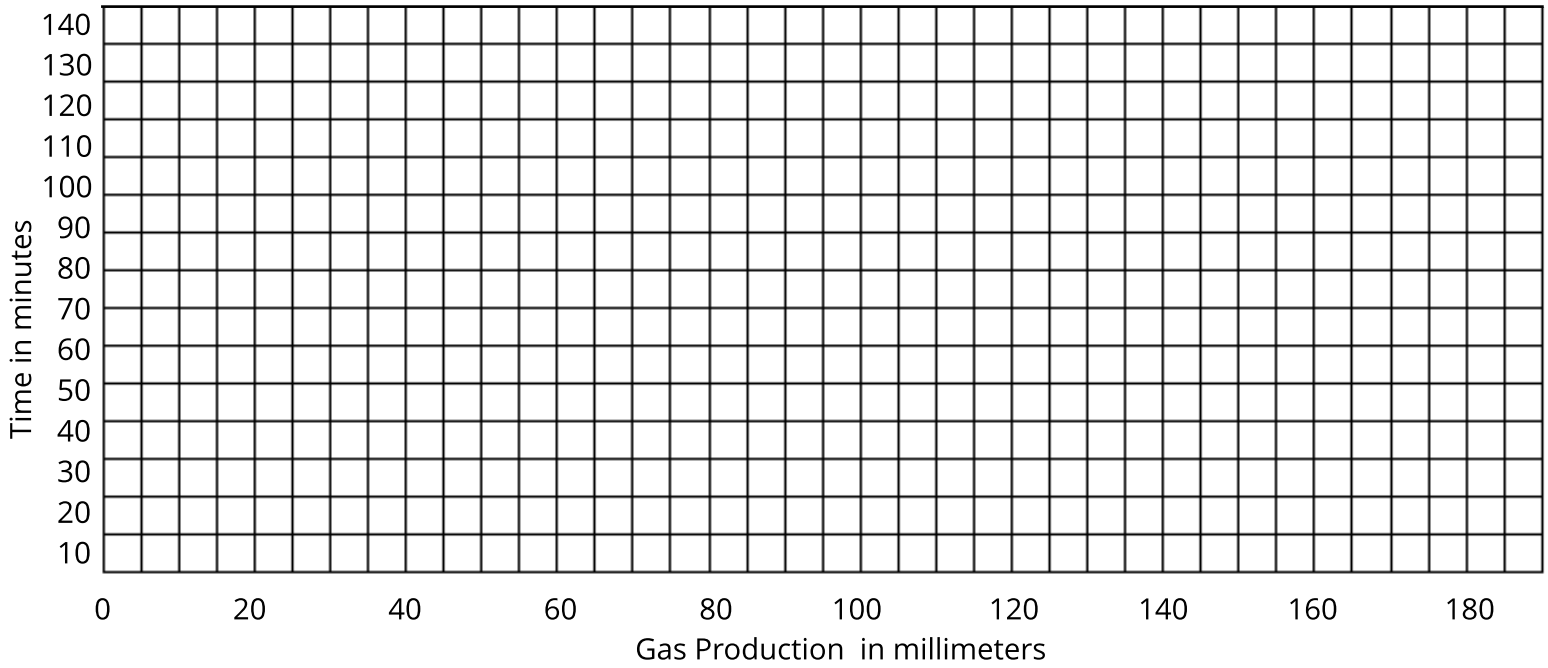
MATERIALS:

- 3 canning jars wide mouth quart or gallon
- baking soda
- measuring teaspoon
- 3 clear plastic 150 mm funnels (must be clear)
- elodea (water weed) or hydrilla (water thyme)
- 3 pack replacement aquarium test tubes
- large cardboard box
- ruler
- watch or timer on cell phone
- data sheet page 21

Time (stop-start = length)	Light (gas in mm)	Shade (gas in mm)	Dark (gas in mm)
_____ - _____ = _____			
_____ - _____ = _____			
_____ - _____ = _____			
Average			

- Find the average of the light, shade, and dark experiment. Find the average time.
- Graph the data. The X axis is gas production in mm. The Y axis is the length of time in minutes (total of 2 hours 10 minutes).
- Confounding factors to consider:
  - Each **trial** of the experiment took two hours, therefore the sun's angle was different for each **trial**. What could you do to control this variable?
  - Baking soda in water will release carbon dioxide. You added 1 teaspoon to each **trial** to ensure there was available CO_2. If the CO_2 was not completely consumed, there may be a higher concentration of that gas with each subsequent **trial**. What could you do to control this variable?
- Analyze your graph. What does it mean?

- What are your conclusions?



ST[EMpower] issues incorporate STEM careers related to the topic of the activities. If you have worked through these connected activities, you will have a ton of information about your interests, careers that incorporate those interests. You have interviewed neighbors and talked to people in those careers. You have discovered the education required as well as starting salaries.

How do you organize massive amounts of information? One way are mind maps (activity located in 49.Earth In Space issue; website listed in green box below).

Digital information becomes **obsolete**. I wrote science activities in the 1980s on 5" floppy disks. I can't access them anymore because I don't have any computer to read those data. You may want to have access to this information until you have completed your education. If you use an electronic program, how will you store that information to access 10 years in the future? As much as we try to eliminate paper, this may be something that you would like to keep as you work towards your future.

Electronic organization programs are phenomenal. They are easy to access, search, and download. You could use an electronic program, and keep a hard copy as back-up support.

There are some really nice electronic index card programs. They are large enough to store the basics and indicating how to find additional information you have collected.

If you choose to keep all the notebooks you have generated over the years of these articles leading you to explore yourself and ideas for careers you would love, number your notebooks **chronologically** (oldest notebook is 1). This will help you retrieve ideas in your notebook as they relate to different careers.

The mind map concentrated a lot of information into basic words and pictures. This is the information you will want to capture.

Label each index card with the career. Include basic information:

- education required
- beginning salary
- basic skills required (they should match your interests)
- what the job encompasses

Each index card is a separate career. After you have completed your most desirable future jobs, go through your notebooks. If you find information directly relevant to one of your careers, identify the notebook number and the page number on the index card. It will make it easier for you to find those additional related ideas.

After completing your index cards, review them. Can you group them? Are your ideas wildly different?

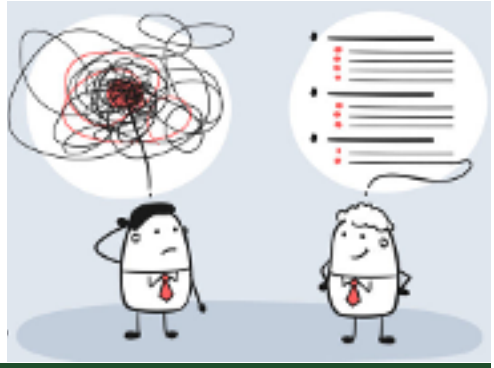
Keep on dreaming!

POWER WORDS

- **chronological**: a record of events) starting with the earliest and following the order in which they occurred
- **obsolete**: no longer produced or used; out of date

Success comes from curiosity, concentration, perseverance and self criticism.

Albert Einstein



MATERIALS:

- Past ST[EMpower] issues: https://tra.extension.colostate.edu/stem-k12/stem-resources/
- computer with internet
- index cards (computer program or paper)
- color pencils or markers
- imagination

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CITATIONS
Information:

- About Aspen: https://www.fs.fed.us/wildflowers/beauty/aspen/grow.shtml
- Chromotography: https://www.biologycorner.com/worksheets/plant_pigments.html
- Classifying plants: https://www.bioexplorer.net/types-of-plants.html/
- Rate of photosynthesis: https://www.biologycorner.com/worksheets/photosynthesis_rate.html
- Plant facts: https://lifeofphyta.weebly.com
- Pollinators: https://pollinator.org/learning-center/education#bb

Images:

- Aspen catkins: https://www.fs.fed.us/wildflowers/beauty/aspen/grow.shtml
- Diagram of a flower:
  https://www.amnh.org/learn/biodiversity_counts/ident_help/Parts_Plants/parts_of_flower.htm
- Examples of plant types:
  Liverwort: http://www.downgardenservices.org.uk/liverwort.htm
  moss: https://ohiomosslichen.org/bryology-101/
- Club Moss: https://glovernursery.com/wp-content/uploads/2016/02/1024px-Hornwort_3144399921.jpg
- Horsetails: http://www.easttennesseewildflowers.com/gallery/index.php/ferns/Copy_of_Horsetails
- Psilotum: https://fr.wikipedia.org/wiki/Psilotum
- Ferns: http://angiospermproject.tripod.com/id7.html; https://lifeofphyta.weebly.com/pterophyta.html;
  https://www.thoughtco.com/fern-life-cycle-4158558
- conifers https://www.denverpost.com/wp-content/uploads/2016/06/dpl2059.jpg;
  https://i.pinimg.com/originals/99/4a/8a/994a8ad3f6a64e9301db487c428868b4.png
- Ginkgo: https://upload.wikimedia.org/wikipedia/commons/e/e0/GINKGOBAUM-2.jpg
  https://newsnetwork.mayoclinic.org/discussion/home-remedies-can-ginkgo-biloba-prevent-memory-loss-2/
- Cycad: https://en.wikipedia.org/wiki/Cycad
- Welwitschia: https://upload.wikimedia.org/wikipedia/commons/0/0c/Welwitschia_mirabilis%282%29.jpg
- Angiosperms: https://localgardener.net/wildflowers-for-your-garden/;
  https://www.gurneys.com/product/fieldgrade_lilies;
  https://www.azplantlady.com/2016/04/cactus-flowers-color-desert-landscape.html
- Map: http://handmaps.org/maps/hand_drawn_map_farm_map.jpg
- Pollinator chart: https://pollinator.org/learning-center/education#bb
- pollinators: https://www.sciencedaily.com/releases/2012/05/120514153113.htm;
  https://m.usbg.gov/three-corpse-flowers-bloomed-usbg-2017;
  http://faculty.montgomerycollege.edu/gyouth/FP_examples/student_examples/suzy_djampouop/growth.html
- Organize information: https://www.grammarly.com/blog/how-to-write-outline/

See you in the fall!