Citizen Science in the Southwest

Adapted from the Hands on the Land Ozone-Bio Monitoring Program

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Project Description:
Students will learn plant identification skills and how to identify foliar damage on two ozone sensitive plants growing in their community for the purpose of collecting data to determine quantities of ground level ozone pollution. Students will receive background knowledge on plant identification, the definition and causes of ground level ozone pollution, the importance of air quality for the environment and human health, as well as the connection of ground level ozone to current climate change.

Standards Addressed (Language from the HotL Ozone Bio-Monitoring Guide document):
Science, Geography, Mathematics Concepts
Inquiry

- Ask a question about plant injury and events in the environment
- Plan and conduct an investigation
- Use data to construct reasonable explanations
- Maintain a journal

Person and Social Perspectives

- Changes in the environment can be natural or influenced by humans
- Material from human societies affect both physical and chemical cycles of earth

Earth and Space

- The atmosphere is made up of different gases
- Materials from human societies affect the chemical cycles of the Earth

Life Science

- Cells carry on many functions needed to sustain life.
- Demise is a breakdown in the structure and functions of an organism

Geography

- Human activity can modify the physical environment.

Mathematics

- Understand and apply ratios, proportions, and percentages in a wide variety of situations
- Formulate and solve problems that involve collecting and analyzing data
- Construct, read, and interpret displays of data
- Communicate results

Learning Objectives:

- Students will gain basic knowledge of what ozone is and how it plays a role in the ecosystem.

- Students will gain basic knowledge of the "transport patterns of local, regional and global levels of ozone air pollution and its impact on vegetation as it is transported from urban industrial centers to more rural and forested downwind regions." HotL
- Students will be able to positively identify two native plants of AZ and NM (evening primrose, *Oenothera elata or Oenothera Pallida*, and skunkbush, *Rhus trilobata*).
- Students will be able to recognize ozone-induced foliar symptoms on plants by examining leaf appearance and structure.
- Students will be able to make observations and collect data on foliar injury levels at their school or community space with some assistance from educators.
- Students will gain basic knowledge of how levels of ground ozone pollution play a role in human caused global climate change.

Materials needed: (1 per student except for plant tags and marking flags)

- Tags with string, and black permanent markers
- Site location flag for each plant with the plant number on the flag
- Metric measuring tape
- % ozone leaf injury identification chart
- Clipboard and Pencil
- Small hand mirror to place under the leaf to look for damage
- Small 10X hand lens
- 'Oh No Ozone' game cards
- Backpacks or bags for students to carry their observation and measuring equipment.
- Optional - Zikua Ozone reader and test strips found on http://www.carolina.com/air-quality-kits-supplies/ozone-test-paper-pack-of-12/653105.pr?question=ozone+test+strips

Lesson #1
Ground Level Ozone Background Information

Time needed: 2-3 hours

Learning Objectives:

- Students will be able to describe what ozone is and how it affects earth's natural systems.
- Students will be able to identify some human activities that can positively or negatively affect air quality and ozone pollution.

Procedure:

1. Students watch the following video for a brief introduction to Ground level Ozone and its causes. http://youtu.be/THYoUULn_2U (3.5 min)
    - Other ozone intro videos if needed:
        - http://youtu.be/3s5G-mP4_qg
        - http://youtu.be/q8-UDE5SEJs

2. Students read the 'Introduction to Ozone Formation Handout'
    - Additional Resources to explore
        - Air Quality and National Parks http://www.nature.nps.gov/air/
        - http://www.airnow.gov/ (see real time air quality in the U.S.)
        - http://airnow.gov/index.cfm?action=aqibasics.ozone
        - http://cfpub.epa.gov/airnow/index.cfm?action=gooduphigh.index
        - http://www.airnow.gov/index.cfm?action=ozone_facts.index
        - http://www.stateoftheair.org/2015/health-risks/
        - This is an additional online learning game for determining the effects of ozone. http://www.smogcity2.org/smogcity.cfm?preset=ozone
        - General Climate Change information and activities from NASA http://climatekids.nasa.gov/

3. Students work through the 'Ozone, Good or Bad?' worksheet in groups with educators.

4. Students play the 'Oh No, Ozone!" Game. (This game is designed to be played outside but can be played inside in a gym if there is bad weather.)

Related Vocabulary:

Atmosphere - the gaseous envelope of a celestial body (as a planet); the whole mass of air surrounding the Earth
Argon - Argon is a chemical element with symbol Ar and atomic number 18. It is in group 18 of the periodic table and is a noble gas
Carbon Dioxide - Carbon dioxide is a colorless and odorless gas vital to life on Earth. This naturally occurring chemical compound is composed of a carbon atom covalently double bonded to two oxygen atoms
Climate - the average conditions of the weather at a place usually over a period of years as exhibited by temperature, wind velocity, and precipitation.
Foliage - the leaves of a plant or of many plants
Fossil Fuels - a fuel (such as coal, oil, or natural gas) that is formed in the earth from dead plants or animals
Hydrocarbon - a compound of hydrogen and carbon, such as any of those that are the chief components of petroleum and natural gas.
Nitrogen - the chemical element of atomic number 7, a colorless, odorless unreactive gas that forms about 78 percent of the earth's atmosphere
Oxide - a compound in which oxygen is bonded to one or more electropositiveatoms.
Ozone - a form of oxygen, O 3, with a peculiar odor suggesting that of weak chlorine.
In the upper atmosphere, itabsorbs ultraviolet rays, thereby preventing them from reaching the surface of the earth.
PPB – parts per billion; is the number of units of mass of a contaminant per 1000 million units of total mass. Written as µg/L or micrograms per liter
Pollution - the introduction of harmful substances or products into the environment
Radiation - the process in which energy is emitted as particles or waves.
The complete process in which energy is emitted by one body, transmitted through an intervening medium or space, and absorbed by another body
Smog - smoke or other atmospheric pollutants combined with fog in an unhealthy or irritating mixture.
Stratosphere - the region of the upper atmosphere extending upward from the tropopause to about 30 miles (50 km) above the earth, characterized by little vertical change in temperature
Trace gases - A trace gas is a gas which makes up less than 1% by volume of the Earth's atmosphere, and it includes all gases except nitrogen (78.1%) and oxygen (20.9%). The most abundant trace gas at 0.934% is argon. Water vapor also occurs in the atmosphere with highly variable abundance.
Troposphere - the lowest layer of the atmosphere, 6 miles (10 km) high in some areas and as much as 12 miles (20 km) high in others, within which there is a steady drop in temperature with increasing altitude and within which nearly all cloud formations occur and weather conditions manifest themselves
Ultraviolet Rays - UV radiation. Invisible rays that are part of the energy that comes from the sun. UV radiation can damage the skin and cause melanoma and other types of skin cancer
V.O.C. – (abbreviation) volatile organic compound: one of a number of chemicals, including benzene and acetone, which evaporate or vaporize readily and are harmful to human health and the environment
Water Vapor

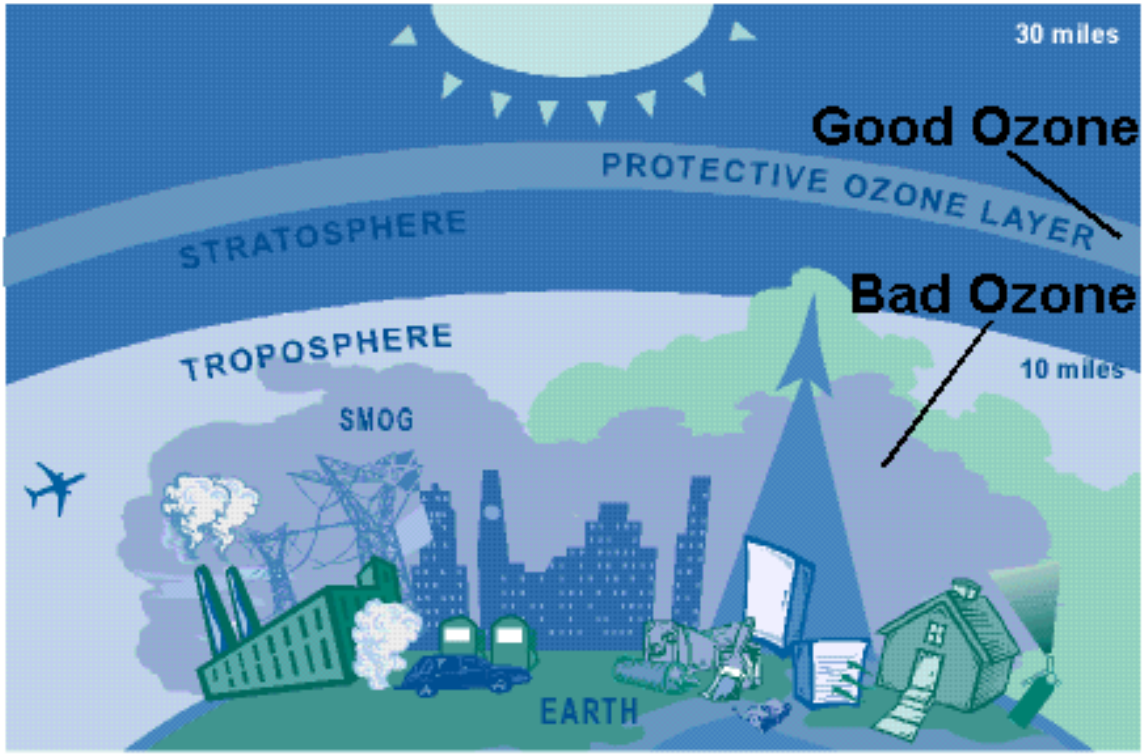
Introduction to Ozone Formation

(Text and graphics from HotL Ozone Bio-monitoring Guide)

Quality of Air

The atmosphere is made up of a mixture of gases. These gases include nitrogen, oxygen, carbon dioxide, water vapor, argon, and trace gases. The atmosphere is made of about 78% Nitrogen and 21% oxygen. Only about 1% of the atmosphere is made of the other gases. The quality of air is determined by the amounts and types of gases and materials the atmosphere. The addition of pollution human activities such as driving cars gradually makes air quality worse.

Ozone gas is a form of oxygen. It is a colorless, highly reactive gas that exists from the surface of the Earth to miles up in the atmosphere. Ozone has three atoms of oxygen (O3), instead of 2 atoms of oxygen like the kind we need to breathe. It is this third atom that makes ozone a highly reactive gas. Ozone can be good or bad for the environment depending on where is exists in the atmosphere.



http://capita.wustl.edu/capita/capitareports/GLOBEO3/GoodBad_files/image001.gif

“Good” ozone is located in the level of the atmosphere called the stratosphere. It traps ultraviolet rays and protects the living things on Earth. In contrast, ozone that is in the troposphere at the level we breathe is considered a pollutant and harmful to plants and animals. Ozone at this level is called surface ozone, or “bad” ozone. Smog is made mostly of bad ozone.

Some surface level ozone exists naturally but in very small amounts. This ozone comes from two main sources. One is the chemical reaction between sunlight and the hydrocarbons given off by plants. The other source is nitrogen oxides from the natural cycles of Earth’s atmosphere. Under normal conditions the natural levels of surface ozone are between 10-40 ppb depending upon the season of the year (Lefohn et at. 1990).

Other natural sources of surface ozone are from lightning and violent weather that brings ozone down to Earth’s surface from the stratosphere. This increase in natural surface ozone occurs on the tops of mountains during thunderstorms. The tops of mountains are where pine trees often grow and ozone there has damaged eastern white pine trees in the Appalachian Mountains.

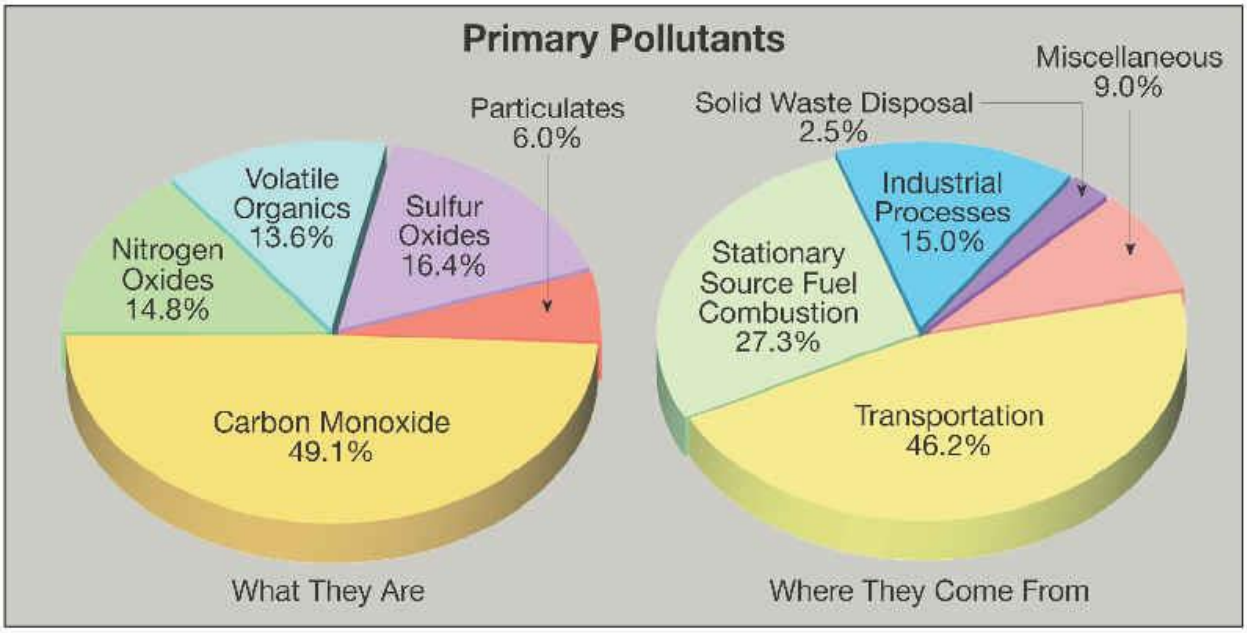
Ozone Pollution Cycle

Human activity has increased the pollution in the air we breathe. The main sources of human caused pollution are burning fossil fuels; in vehicles (automobiles, trucks, buses and airplanes) and for generating electricity. Most of the pollution that causes surface ozone is exhaust gas from internal combustion engines that are fueled by gasoline. The main gases that come from the combustion process are: carbon monoxide (CO), nitrogen oxides (NO), and partially burned hydrocarbons called volatile organic compounds (VOCs) that are very reactive.

The problem with combustion engines is that they don’t have a 100% combustion reaction. This causes left over hydrocarbons from the gasoline to remain in the air as VOCs. The imperfect reactions of engines also create nitrogen oxide and carbon monoxide. Nitrogen oxides are what cause surface level ozone. If engines had complete combustion they would be only give off carbon dioxide (CO2) and water vapor. The intense heat within the combustion chamber of an engine causes nitrogen molecules to split into two nitrogen atoms. These split nitrogen atoms attach to oxygen

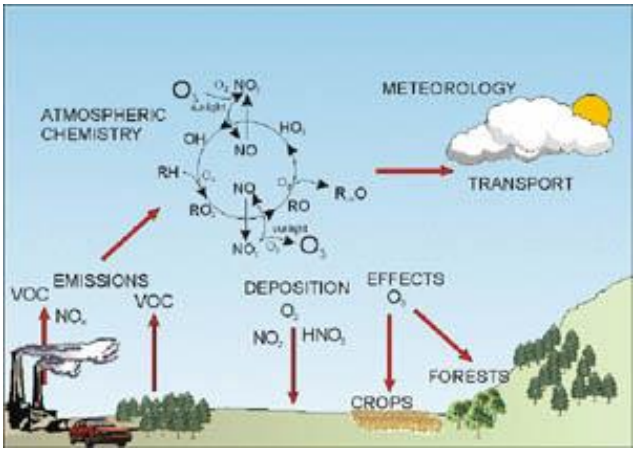
atoms from the air that is taken in by the engine and creates nitrogen oxide (NO).

Hydrocarbons are also created when things are burned. For example, a forest fire produces hydrocarbons, which are molecules of carbon and hydrogen. But these are made in far less amounts than the VOC's emitted by industrial and car exhausts. The pie graphs below identify the major sources of air pollutants that contribute to the production of surface ozone.



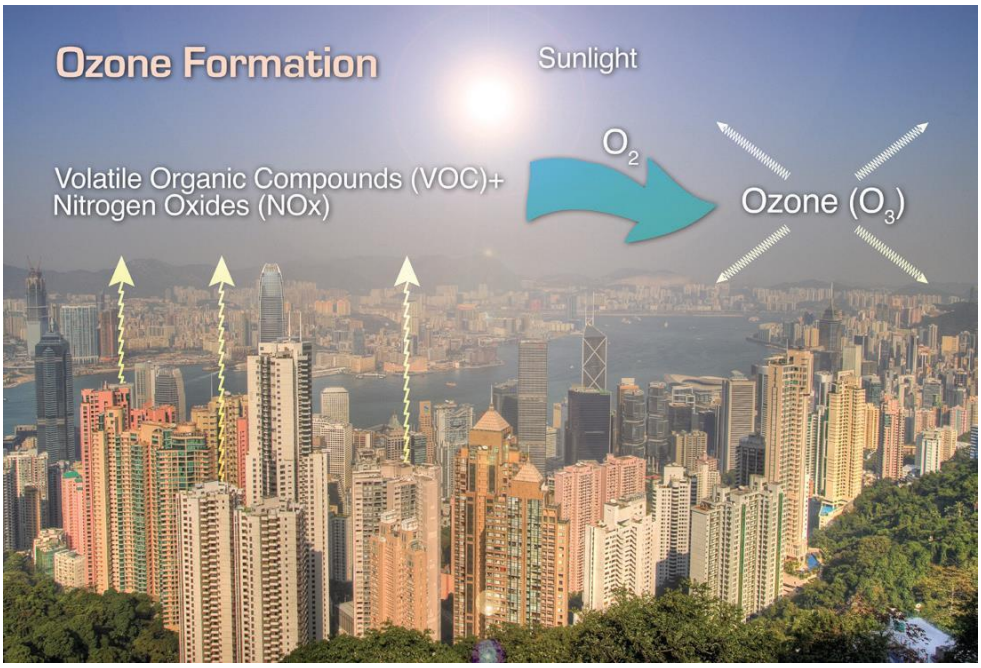
http://www.geography.hunter.cuny.edu/tbw/wc.notes/13.air.pollution/primary.pollution.percentages.jpg

These new gases have contributed to the production of higher concentrations of surface ozone, i.e. the formation of ozone air pollution. In general, ozone is a main component of urban smog, and it is commonly referred to as photochemical smog. The production of surface ozone air pollution usually peaks in the later afternoon at low elevations, but may remain high all day at higher elevations, such as in the mountains.

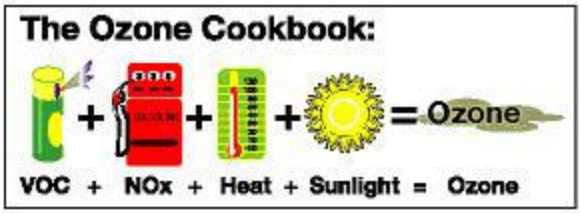


The afternoon peak at low elevations occurs because the formation of ozone is dependent on the sun's energy, and it proceeds faster at higher temperatures, so the concentrations tend to build up from morning to the afternoon. At night though, other chemicals in the atmosphere may break down the ozone, which is why it starts off each day at a lower concentration than the preceding afternoon.

During the course of the day, the pollutants react in the presence of the sun's radiant energy and the oxides of nitrogen (NO) produce concentrations of ozone, air pollution. A photo-chemically formed hazy air mass is formed that has a brown tinge due to combustion in fuel powered engines.



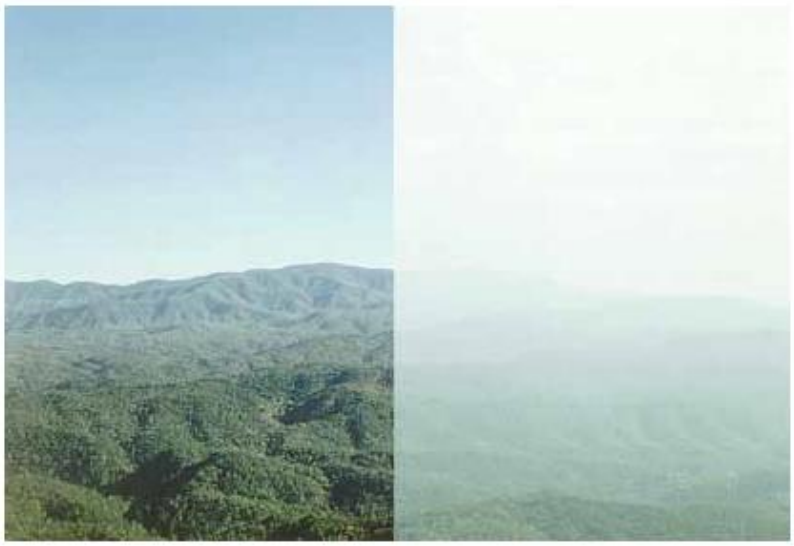
http://science-edu.larc.nasa.gov/ozonegarden/**images/page-graphics/pic4_ozoneformation.jpg**



http://www.washco-md.net/images/Ozone_QA2.jpg

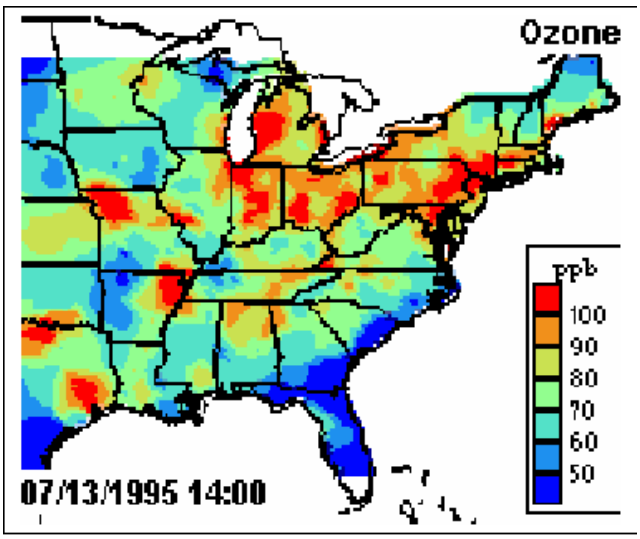
Whether the primary pollutants are produced through a forest fire or the fire of a combustion engine, the byproducts produced are the precursors needed for the production of surface ozone. These primary pollutants react with the energy of the sun to produce a secondary pollutant, surface ozone.

Surface concentrations of ozone air pollution begin to increase seasonally from April through September in the eastern regions of the United States. This is the time period of increased amounts of sunlight, higher temperatures, and commonly occurring stagnating high-pressure systems (Burmuda Highs) over vast regions of the Midwest and Mid-Atlantic States. Under these atmospheric conditions ozone air pollution reaches its highest levels during the hottest and most sunlit months of the year. Depending upon weather patterns, the concentrations of ozone air pollution though usually higher in the summer, can vary year to year. For example, during the hot, dry years of the mid- to late 1990s, ozone reached record levels in the Great Smoky Mountains National Park, but in 2004, a wet and cool year, ozone levels were greatly reduced. The amount of ozone formed each year is highly dependent on weather conditions, and less so on variations in pollutant emission, which are relatively constant from year to year.



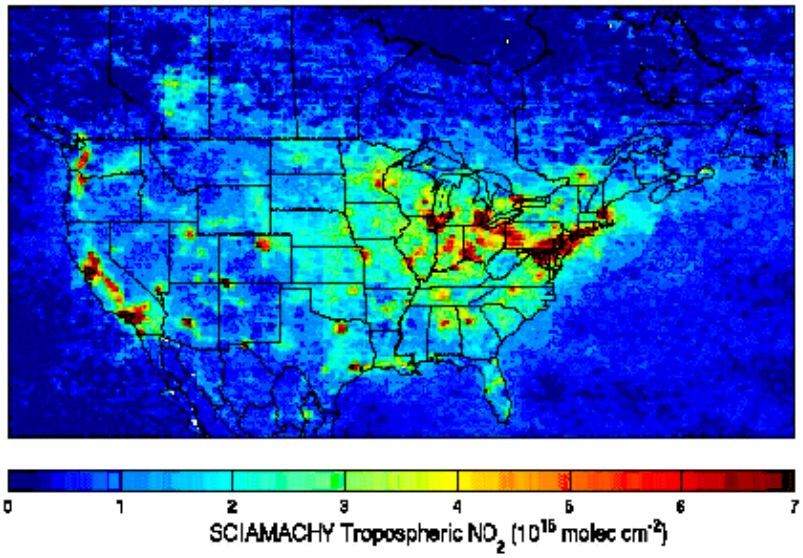
The two side by side photos above show the haze problem in Great Smoky Mountains National Park. The weather conditions of hot, humid, stagnant air that cause sulfur particles to combine with water vapor to create haze, are the same conditions that increase the ground level ozone levels. Initially surface ozone was thought to be a local problem, but the pollution-laden air masses may travel beyond the local areas where they were originally produced. The slow moving air masses pick up pollutants all day long as they travel over industrial centers; large fossil fuel fired power plants, incinerators, and most importantly over large and even small urban areas with many forms of fossil fuel fired transportation.

The collection of pollutant gases in slow-moving air masses quickly reacts in the warm sunlit air. The most important air pollutant formed within these air masses is ozone air pollution. In the 1950s and 1960s, the Los Angeles area was the region most affected by the production of photochemical smog. After the passage of the Clean Air Act in 1970, many more monitoring stations were set up across the United States and now we commonly see increased pollution well beyond the local areas where they were initially produced. Slow moving air masses allow pollutants to “cook” all day long. As they meander, even more ozone can be formed as they pass over even relatively small urban areas. Complicated chemistry and meteorology can result in the transport of surface ozone pollution to areas that are generally considered rural or even pristine, such as National Parks.



The above figure for July 13, 1995, shows the sketchy high ozone patterns where detrimental concentrations are found throughout rural areas in Indiana, Ohio and Pennsylvania as well as in densely forested regions in Tennessee, Georgia, and North Carolina. Depending on the meteorological situation, high levels of ozone can remain over an area for a period of time and plants will be exposed to ozone air pollution.

Slow moving high-pressure air masses are common occurrences in the eastern United States. These air masses transport significant concentrations of ozone air pollution to the plant communities of mountainous, forested, and rural areas downwind of the industrial urban areas.



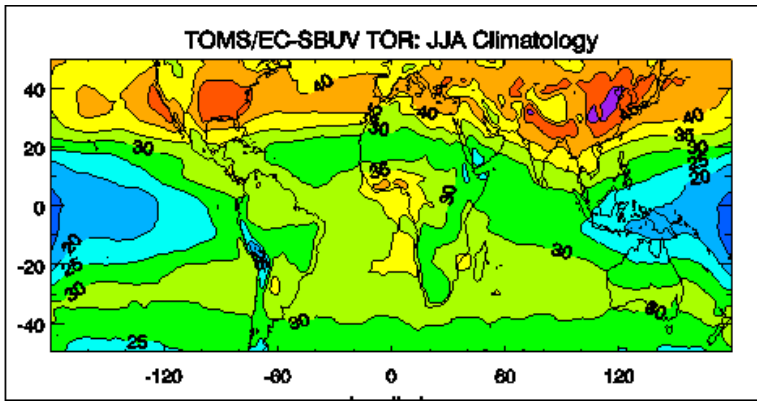
Location of Industrial Emissions in U.S. derived from a satellite.

It is the climatology for the year 2003.

Location of Industrial Emissions in U.S. derived from a satellite.
It is the climatology for the year 2003.

The map above is a satellite image that identifies the location of industrial emissions in the U.S.. Due to the continuing photo-chemically driven processes as the air mass slowly moves downwind, these more remote areas often have greater ozone exposures for longer periods of time. If the high air pressure mass stagnates and remains over an area for a period of time, the pollution can build up and expose plants to more severe levels of ozone.

Although some controls have been implemented that have helped to decrease the level of primary pollutant gases entering the atmosphere that contribute to the production of ozone air pollution, the large increase in the numbers of vehicles and the increase in the miles driven have offset many of the gains that have been made through the implementation of pollution controls. New satellite instruments can now map ozone pollution and the global depiction above shows that high ozone concentrations are not unique to the eastern U.S. or California. In the summertime, even higher concentrations are now found over China and India, where pollution controls are not as rigid as in the U.S. Furthermore, scientists also believe that emissions from these regions will continue to grow as these countries continue to develop.



Additional Ozone Information Resources for reference

http://www.airnow.gov/ (see real time air quality in the U.S.)

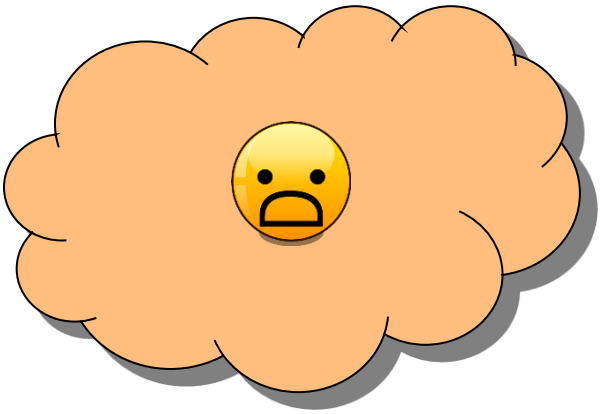
http://www.airnow.gov/index.cfm?action=aqibasics.ozone

http://www.airnow.gov/index.cfm?action=gooduphigh.index

http://www.airnow.gov/index.cfm?action=ozone_facts.index

http://www.stateoftheair.org/2013/health-risks/health-risks-ozone.html

Student Copy



Ozone, Good or Bad?

Watch the Ozone introduction video and read through the Introduction to Ozone Formation handout to find answers to the following questions.

What part of Earth's atmosphere contains good ozone?

Bad Ozone has a chemical composition of O_3. True or False?

How does good Ozone high in the Earth's atmosphere help keep us safe?

What types of human activities contribute to ground level ozone pollution?

What is another name for ground level ozone? (Hint: It rhymes with frog.)

How can bad ozone hurt humans and plants?

Is ground level ozone pollution worse in cold weather or hot weather? Why?

Ozone Vocabulary Word Search

S	E	N	K	C	O	T	L	H	Z	E	T	N	F
F	T	T	O	Z	L	A	P	B	F	F	R	O	O
A	J	R	O	I	C	I	Y	I	O	C	O	I	L
J	Y	N	A	I	T	O	M	S	E	O	P	T	I
E	E	C	M	T	Y	U	S	A	H	V	O	A	A
Y	N	E	N	P	O	I	L	T	T	L	S	I	G
L	H	U	B	K	L	S	J	L	C	E	P	D	E
C	S	P	N	F	S	F	P	Q	O	Z	H	A	T
Z	D	U	U	J	J	G	R	H	H	P	E	R	V
X	W	E	N	I	T	R	O	G	E	N	R	O	X
X	L	E	D	I	X	O	W	M	Z	R	E	Y	Z
S	M	G	B	D	U	P	N	P	S	W	E	Z	T
N	O	B	R	A	C	O	R	D	Y	H	D	Y	U

Look for and circle the following words among the letters to the left.

CHEMICAL
CLIMATE
FOLIAGE
FOSSILFUELS
HYDROCARBON
NITROGEN
OXIDE
OZONE
POLLUTION
RADIATION
SMOG
STRATOSPHERE
SUN
TROPOSPHERE
VOC

Puzzle generated by http://puzzlemaker.discoveryeducation.com/

Fill in the blanks in the following poem.

_____ in my lungs helps me run outside

It's fun

Enjoying nature down here in the _____sphere

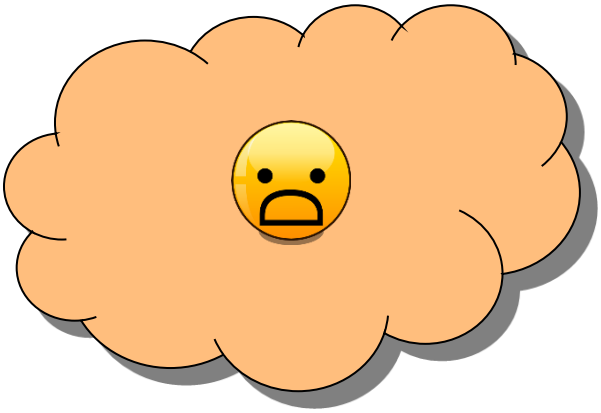
The sun is bright but the _____ layer up there protects me

Pollutants from _____ fuels make ozone down here

It's bad

When the air is clouded with _____ (rhymes with frog)

Teacher's Copy:
Worksheet Answers



Ozone, Good or Bad?

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What part of Earth's atmosphere contains good ozone? The stratosphere

Bad Ozone has a chemical composition of O_3. True or False?

How does good Ozone high in the Earth's atmosphere help keep us safe? The ozone layer in the stratosphere helps block harmful ultraviolet radiation from the sun.

What types of human activities contribute to ground level ozone pollution? Activities that burn fossil fuels like gasoline, coal, and oil. Examples are driving cars, burning coal to generate electricity, and using airplanes.

What is another name for ground level ozone? (Hint: It rhymes with frog.)

Smog

How can bad ozone hurt humans? Ozone causes a 'sunburn' on human's lungs when they breathe it.

Is ground level ozone pollution worse in cold weather or hot weather? Why? It is worse in hot weather because the formation of ozone depends on the sun and it forms faster when temperatures are higher.

Ozone Vocabulary Word Search

S	E	N	K	C	O	T	L	H	Z	E	T	N	F
F	T	T	O	Z	L	A	P	B	F	F	R	O	O
A	J	R	O	I	C	I	Y	I	O	C	O	I	L
J	Y	N	A	I	T	O	M	S	E	O	P	T	I
E	E	C	M	T	Y	U	S	A	H	V	O	A	A
Y	N	E	N	P	O	I	L	T	T	L	S	I	G
L	H	U	B	K	L	S	J	L	C	E	P	D	E
C	S	P	N	F	S	F	P	Q	O	Z	H	A	T
Z	D	U	U	J	J	G	R	H	H	P	E	R	V
X	W	E	N	I	T	R	O	G	E	N	R	O	X
X	L	E	D	I	X	O	W	M	Z	R	E	Y	Z
S	M	G	B	D	U	P	N	P	S	W	E	Z	T
N	O	B	R	A	C	O	R	D	Y	H	D	Y	U

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The sun is bright but the ozone layer up there protects me

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It's bad

When the air is clouded with smog (rhymes with frog)

OH NO OZONE! Activity Game

How to play:

1. In this activity, the students will need a large space, such as a courtyard or field. (Can be played inside a gym during bad weather) Divide the class into 2 teams. This activity is similar to the game “Red Rover”. Inform the students that one team represents the Health of the Earth and the other team represents Human Activities.

2. Game cards are distributed to students. Members of each team stand side by side in a line facing away from the other team. Earth’s Health cards are given to one team and Human Activity Cards to the other team. Students can be paired up if there is an odd number of students or a large range of ages (older student paired with a younger student in that case).

3. The students with the Earth’s Health Cards decide which side of the card will be showing first. They will hang their card facing out in front of them.

4. When the teacher says GO, all students turn around to face each other.

5. The Human Activity team then runs across and tags a student with a card that their activity will have an effect on. For example if a student has an airplane card they can run and tag a student with a clean cloud card, a student with a recycle card could tag a student with a smog cloud or black leaf card.

6. The students who got tagged then flip their Earth’s Health card over to show the other side representing the effect the human activity had on the health of the Earth.

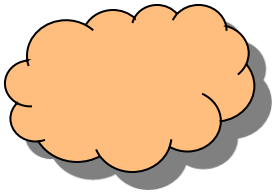
7. Any students on the Human Activity team that could not find someone to tag join the Earth’s Health Team, become a Rock, and place their hands on the top of their head. These students are now neutral and cannot be affected by being tagged.

8. The Human Activity team members go back to their original places for the next round. The Earth’s Health team members run around to mix themselves up and line back up with their backs to the other team making sure their cards still show the correct side from the last round.

9. Repeat steps 4-8 until all students are on the Earth’s Health side.

Earth's Health Cards:

Front is Clean Cloud - Back is Smog Cloud



Front is Green Leaf - Back is Black Leaf

Human Activity Cards:

Air Cleaning

Plant a Tree

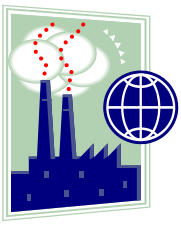
Recycle

Reusable Energy

Bad Ozone Contributors:

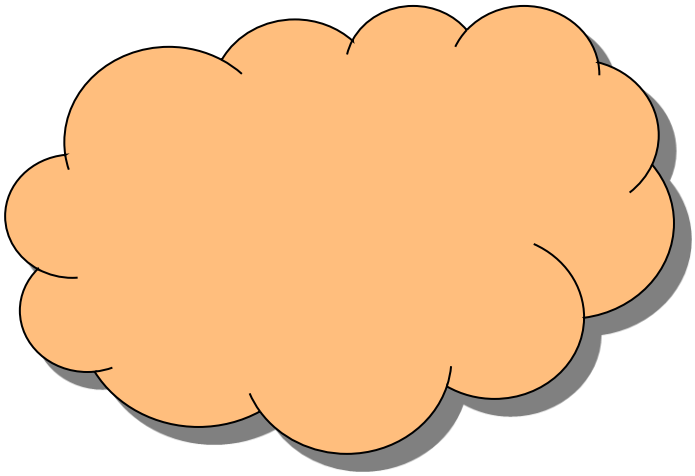
Car

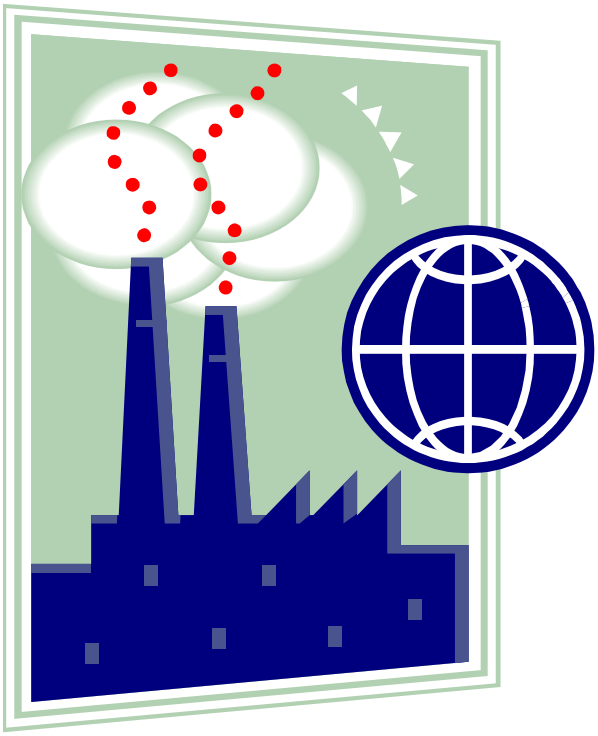
Factory

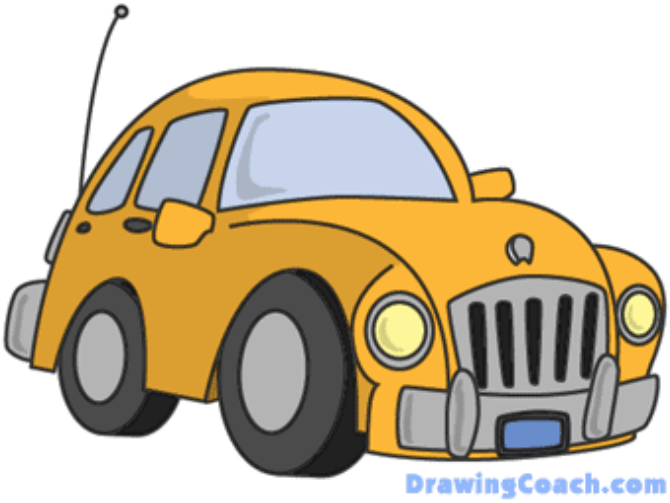


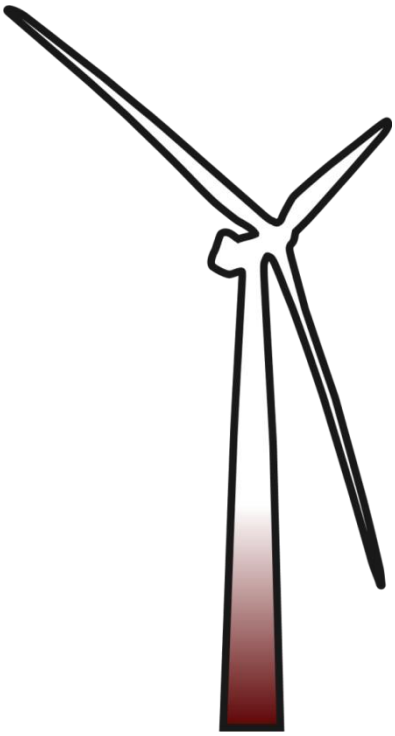
Airplane

Pictures for making extra game cards






DrawingCoach.com



Lesson #2
Plant Structure and Ozone Damage

Time needed: 1-2 hours

Learning Objectives:

- Students will be able to identify major parts of plant's leaf structure and articulate the process of photosynthesis.
- Students will be able to recognize ozone-induced foliar symptoms on plants by examining leaf appearance and structure.

Procedure: (Educators should help facilitate this for younger students.)

1. Students watch the following videos for a brief introduction on plant leaf structure and how ground level ozone can damage plants.
    - http://youtu.be/co0JdqUlycg - Explains leaf structure and photosynthesis.
    - http://youtu.be/q8-UDE5SEJs - Student made video of an ozone pollution experiment. (The sound is low in this video so turn up the volume to hear it.)

2. Students read through the Investigation of Ozone Injury Handout

3. Students Complete the Plants and Ozone worksheet

Investigation of Ozone Injury Induced Foliar Damage to Plants (Introduction)

Surface Ozone is Harmful

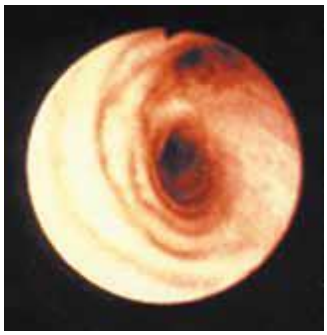
(Text and graphics from HotL Ozone Bio-monitoring Guide)

The study of surface ozone (ozone produced near the ground where people breathe the air) and using ozone sensitive plants as bio-indicators of ozone induced plant injury will help develop an understanding of how human behavior affects the quality of air and an awareness of its environmental impact.

Ozone Air Pollution is Harmful to Humans

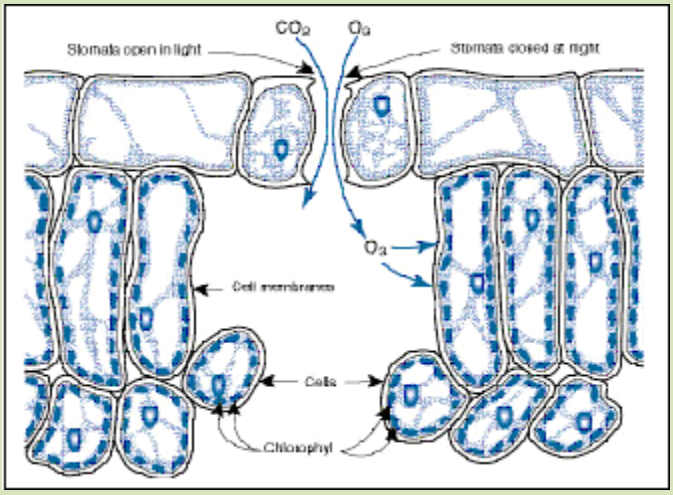
High concentrations of ozone air pollution are harmful to both animals and plants. Concern for air quality is reflected most during hot summer days as “ozone alert days” or some other phrase is used to warn children and the elderly to restrict outside activity due to the likelihood of higher exposures to ozone. Why? Because exposure to elevated concentrations of surface ozone over extended periods of time causes health problems. It damages the immune system’s defenses making one susceptible to lung infections.

Ozone causes acute respiratory irritation, breathing problems, and aggravates asthma. The pollutant decreases lung capacity by 15% to over 20%. This is because ozone “sunburns” your lungs. Ozone damages the cells that line the air spaces in the lung. Within a few days, the damaged cells are replaced and the old cells are shed-much in the way that skin peels after a sunburn. If this kind of damage occurs repeatedly, the lung may change permanently in a way that could cause long-term health effects and a lower quality of life. Children are at greatest risk from surface ozone exposure, because they spend more time outside involved in vigorous activities and have a greater demand for intake of air. Their respiratory systems are developing and are most susceptible to permanent damage. The elderly are also more sensitive to zone because their immune system is not as good as it used to be. For more information, visit the EPA website and view their publication called “What You Need to Know About Ozone and Your Health” at http://www.airnow.gov/index.cfm?action=health2.smog1#3



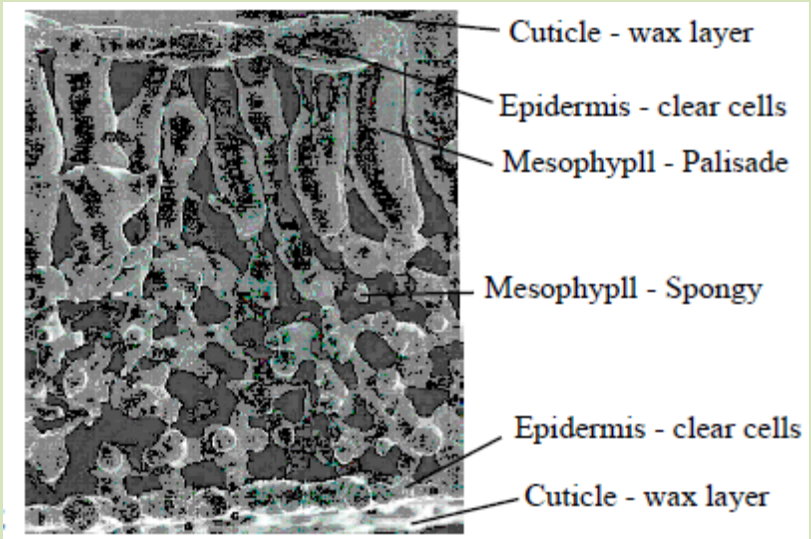
The photos above show a healthy lung air way (left) and an inflamed lung air way (right). Ozone can inflame the lung’s lining, and repeated episodes of inflammation may cause permanent changes in the lung. (EPA photos from “What You Need to Know About Ozone and Your Health”)

Ozone Air Pollution is Harmful to Plants.
Plants are not unlike humans. They need to take in carbon dioxide for photosynthesis, the process they use to produce their own food, and give off oxygen as a byproduct. The healthy plants, like young children, are actively …"taking"… in the air. Ozone enters leaves through their stomata. Stomata are small pores in the leaf that allow gases to enter or leave. When they are open, carbon dioxide can enter, which the plant uses to make its food, such as sugars and starches. At the same time, water exits the leaf, through the process known as transpiration. If ozone is present in the air, it too will enter the leaf through the open stomata, following much the same path as the carbon dioxide.



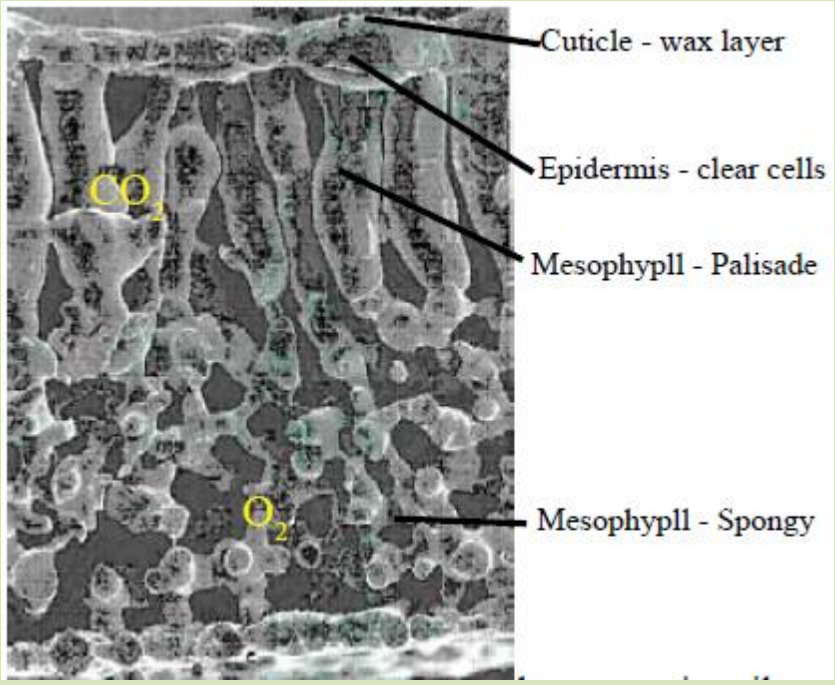
http://res2.agr.gc.ca/publications/ha/3d_e.htm

Ozone, however, is a highly reactive molecule, and once it enters the leaf, it will find its way through the leaf interior to the cells responsible for photosynthesis, particularly the palisade and spongy mesophyll tissues.

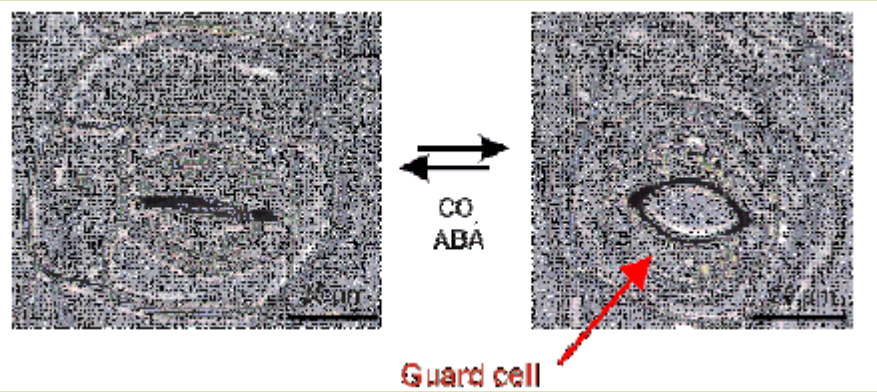


Cross section view of a leaf, source US Forest Service

The surface layer of cells in a leaf is called the epidermis. The long cells below are the palisade mesophyll cells, where much of the photosynthesis occurs in leaves. The irregular cells further down are spongy mesophyll cells, and they also participate in photosynthesis. At the bottom is the lower epidermal layer, and the curved cells represent guard cells for stomata where the ozone enters on the underside of the leaf. As soon as the ozone enters, it most likely reacts with molecules in the cell wall that end up triggering production of the ROS molecules, which damage the cell. Ozone itself rarely gets far into a cell to cause damage. Note the enhanced airspaces between the spongy mesophyll cells compared to that in the palisade layer. This is where photosynthesis occurs in the leaf.



It is of interest that even though ozone primarily comes through the lower epidermal stomata, it is the upper epidermal layer, and eventually the palisade cells that suffer injury first, due to their interaction with light, in reactions not yet fully understood. It has been noticed that a leaf partially shaded by the leaf above may only show injury in the area of the leaf fully exposed, the shaded part of the leaf shows no injury. Very little ozone can get into a leaf through the cuticle, a waxy layer that covers most of the surfaces of leaves and stems. This waxy layer is nearly impermeable to water, and also to most gases, including both carbon dioxide and ozone. Therefore, the uptake of ozone depends nearly entirely on whether the stomata are open or closed. Stomata open in response to certain environmental stimuli. These include light, high humidity, and high temperatures. At night, stomata tend to close because of the lack of light. Thus ozone uptake is greatly reduced at this time of the day. If the humidity should go down, this causes excessive water loss from the cells surrounding the stomatal pore, and the stomata close. With respect to temperature, stomata generally open more the warmer it gets. Finally, high carbon dioxide levels will also close stomata.



A stomata is comprised of two guard cells, and some accessory cells that assist in opening and closing. When the guard cells fill with water, they pull away from each other, and the stomatal pore is opened. When they lose water, the two guard cells collapse against each other, closing the pore. The figure above shows a closed pore on the left, and an open one on the right.

All plant cells are surrounded by a cell wall, composed mainly of cellulose and lignins. These fairly rigid molecules provide support for the plant. In order for ozone to damage a cell, it must go through the cell wall first, before reaching the cell's membrane. The cell wall may contain anti-oxidants, which are molecules that can react with, and detoxify, the ozone. This is one way for the plant to protect itself from pathogens and to avoid problems from ozone.

One such anti-oxidant is Vitamin C (also known as ascorbic acid) which is produced by plants. If there is a lot of Vitamin C in the cell wall, it can destroy the ozone before it reaches the cell membrane. If not, then the ozone can reach the cell membrane, where it can cause damage, eventually killing the cell. If a plant is suffering from drought stress, it will close its stomata to save on water. While this may prevent the plant from drying out, it also lowers photosynthesis, since the carbon dioxide cannot get into the leaf. However, one benefit is that ozone also cannot get into the leaf. Thus, plants under drought stress often show fewer symptoms than well-watered plants.

When ozone is taken into a leaf, it can interfere with a plant's ability to produce and store food. It weakens the plant making it less resistant to disease and insect infestations. In some sensitive agricultural crops such as varieties of soybeans and snap bean, exposure to ozone air pollution also affects the plant's ability to reproduce, thus decreasing crop yield. Some plants are more sensitive to surface ozone than others, and show visible symptoms within days or weeks of their exposure under field and forest conditions.

Ozone causes very specific and unique symptoms on broadleaf plants in the field. The most common symptom is stippling (also called purpling) on the upper side of the leaf's surface with the lower leaf surface absent of symptoms. Stippling consists of very small spots much like someone shook fine pepper onto the leaf surface. The color of the stippling depends on the species of plant. The amount of stippling can vary depending upon the environment (nutrients in the soil, amount of water, amount of sunlight that are

local weather conditions), and the physiological conditions or make up of the plant. The stippling may occur only within certain areas of the leaf's surface, but does not involve any of the large or small veins in the leaf. That is, with ozone-induced stippling, the veins are free of any symptoms whereas many insects while feeding and certain fungus pathogens cause direct injuries to the veins. In general, the lower older leaves on the plant exhibit more stippling than the newer leaves on the plant.

Plants grow from the tips of their stems and hence the new leaves that were produced first in the spring are at the base of the new shoot and are therefore exposed to the ozone air pollution as it occurs throughout the entire spring and summer season. New leaves produced later in the summer "see" far less ozone pollution because they have not been present all season long.

Cut-leaf Coneflower showing ozone damage. NPS photo

Plants and Ozone

The small openings on a leaf that allow a plant to breathe are called _____.

Do plants take in more carbon dioxide (and therefore more ozone) during the day or during the night? Why?

Which side of the leaf shows more visible damage from ozone pollution?

What are some results of ozone damage to the health of a plant?

What vitamin, also found in citrus fruits, is contained in leaves and helps a plant protect itself against ozone?

One visible symptom of ozone pollution on a leaf is small dark spots covering the leaf surface. This is called purpling or _____.

Teacher Copy
Answers

Plants and Ozone

The small openings on a leaf that allow a plant to breathe are called Stoma/Stomata.

Do plants take in more carbon dioxide (and therefore more ozone) during the day or during the night? Why? Plants take in more carbon dioxide during the day because that is when their stomata are open.

Which side of the leaf shows more visible damage from ozone pollution? The top side of the leaf shows more damage.

What are some results of ozone damage to the health of a plant? Ozone can make a plant more susceptible to disease and bug infestation, harm its ability to produce and store food, and reduce its ability to reproduce.

What vitamin, also found in citrus fruits, is contained in leaves and helps a plant protect itself against ozone? Vitamin C

One visible symptom of ozone pollution on a leaf is small dark spots covering the leaf surface. This is called purpling or stippling.

Lesson #3

Plant Identification Basics; Evening Primrose and Skunkbush.

Time Needed: 2-3 hours

Learning Objectives:

- Students will be able to articulate the steps involved in identifying plants.
- Students will be able to positively identify two native plants of AZ and NM (evening primrose, *Oenothera elata or Oenothera Pallida,* and skunkbush, *Rhus trilobata*).

Procedure:

1. Students read through the Plant ID basics handout (educators can help younger students with the readings in this lesson.)

2. Students read the Primrose and Skunkbush background handouts.

3. Students complete the "How are my Petals, How are my Leaves?" activity.

Plant ID Basics

Identifying plants takes a little bit of practice but there are some easy steps you can take to narrow down the plant you are looking at. Starting with broad categories, you can use the physical characteristics of a plant to determine what it is. This process involves observing the plant and asking questions about the plant.

Annual – a plant that grows from a seed, flowers, sets seeds, and dies in the same year.
Biennial – a flowering plant that takes two years to complete its life cycle. (Wikipedia)
Perennial – a plant that lives for more than two years.

Plant ID Questions to ask:

1. **Is this a hazardous plant?**
    - Plants can be poisonous, spiky, or cause irritation to the skin. Your safety is the most important thing. Know the hazardous plants in your area and NEVER put a wild plant in your mouth unless you, and at least one other person, have positively identified it AND you KNOW it is safe!
    - Poisonous Plants of AZ - http://azpoison.com/poison/plants/poisonous-plants
    - Poisonous Plants of NM - http://nmpoisoncenter.unm.edu/education/pub-ed/upload_files/docs/poison_plant_broc.pdf#Poisonous Plants

2. **Is it a tree, shrub, grass, herb, or cactus?**
    - **Tree** – A perennial plant that has a central stem (trunk) that supports branches and leaves or needles. Some trees have flowers, some do not. Height is generally above 10m at maturity.

    - **Shrub** – a plant with multiple woody stems but no central trunk. Height is generally 4.5 – 8m. (some small trees may look like shrubs)

    - **Grass** –
        - "GRASS FAMILY (POACEAE) Grasses have round stems and flat leaf blades. The stems, called culms, are usually hollow and jointed with solid nodes. The most conspicuous grasses are perennial bunch grasses. Bunch grasses form tufts, clumps, or tussocks by sending up new shoots called tillers. The tillers remain attached to

the base of the grass and the plant gradually thickens. (Darris and Gonzalves 2008).

- SEDGE FAMILY (CYPERACEAE) Sedges often have triangular stems. The female flowers of sedges are enclosed in a single sheath-like scale called a perigynia. Many sedge species spread through long rhizomes making them useful in erosion control of moister soils." (http://www.sonoma.edu/preserves/prairie/prairie_desc/grasses_rushes_sedges.shtml)

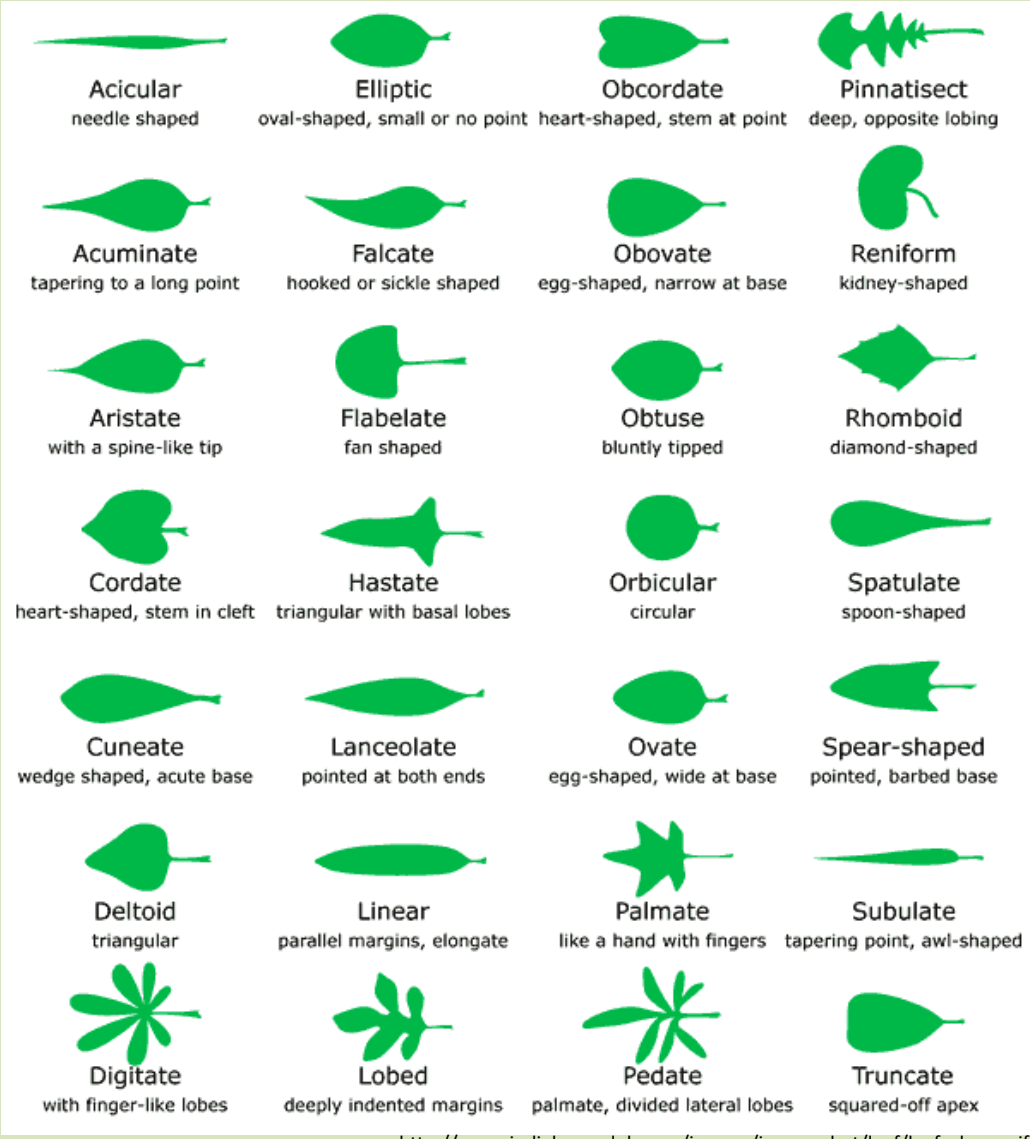
- **Herb** – "A herbaceous plant (in American botanical use simply herb) is a plant that has leaves and stems that die down at the end of the growing season to the soil level. They have no persistent woody stem above ground." (Wikipedia)

- **Cactus** – "Cacti show many adaptations to conserve water. Almost all cacti are succulents. Unlike many other succulents, the stem is the only part of most cacti where this vital process takes place. Cactus stems store water. Most species of cacti have lost true leaves, retaining only spines, which are highly modified leaves. As well as defending against herbivores, spines help prevent water loss by reducing air flow close to the cactus and providing some shade. In the absence of leaves, enlarged stems [pads] carry out photosynthesis. Cacti are native to the Americas." (Wikipedia)

3. **If the plant is flowering, what color is the flower, what shape is the flower, how many petals does the flower have and what is the shape of the petals?**
    - Flower shapes:
        - Campanulate – bell shape
        - Funnelform – funnel, gradual widening of mouth from base
        - Trumpet-shaped – a narrow tube with a wide mouth
        - Salverform – long thin tube with a flat face on the end
        - Tubular – long tube of petals with a flared end
        - Urceolate – urn shaped, a globe with a small flared mouth
        - Bowl-shaped – like a cup or a deep round dish

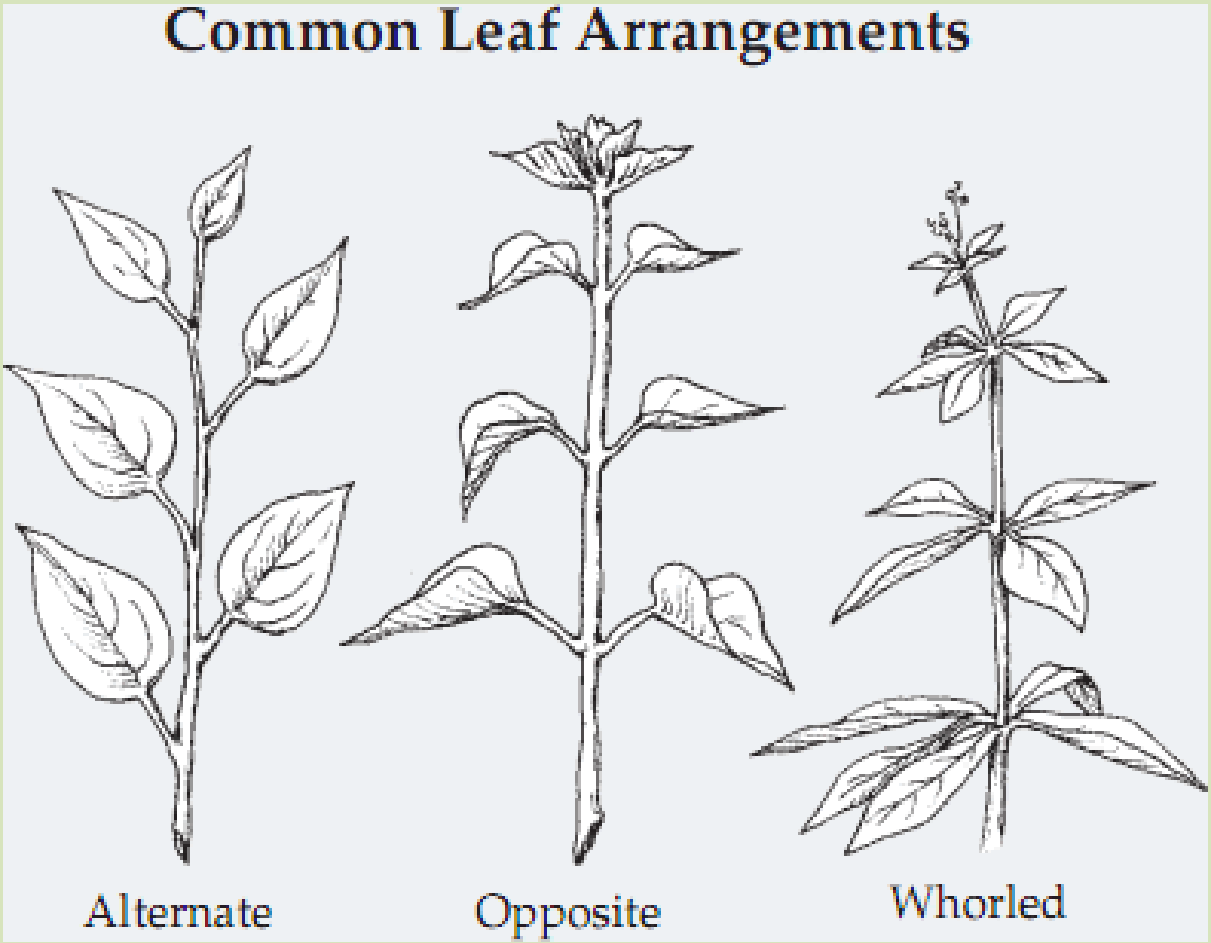
- Saucer-shaped – flower is nearly flat with up-turned petals
- Stellate (Star-shaped) - many narrow petals coming out from the center.
- Cruciform (Cross-shaped) - four petals coming out from the center at right angles to each other.
- Labiate (Lipped) - an upper 'hood' petal and a lower flat or pouched petal
- Papilionaceous (Pea-shaped) – flowers that have a 'standard' or large upper petal, two 'wings' or large side petals, and a keel made of two lower petals which are often fused together.
- Ligulate (Strap-shaped) - one large, long petal making up the entire flower.
    - For graphics and photos of flower shapes visit: http://theseedsite.co.uk/flowershapes.html

4. **Does the plant have broad or narrow leaves (needles)? What is the shape if the leaf?**



http://www.indiahomeclub.com/images/images_bot/leaf/leaf_shape.gif

5. **How many leaves are together on a stem? What is the arrangement of the leaves around the stem?**



https://3herbmamas.files.wordpress.com/2014/07/leaf-arrangements-1.gif

Using the answers to all of the above questions and comparing them to plant field guides of your area, or descriptions of plants that grow where you live, you can more easily identify what kind of plant you are looking at.

Additional resources for identifying plants:

http://plants.usda.gov/java/

http://www.desertmuseumdigitallibrary.org/kids/Plants.html

http://www.desertusa.com/flora.html#trees

http://www.swcoloradowildflowers.com/

http://captainplanetfoundation.org/wp-content/uploads/2012/09/which_plant_is_which_final.pdf

http://www.animalrangeextension.montana.edu/amazgraze/pdf/lesson3.pdf

Primrose Background Information

"The evening primrose is a biennial plant that is perhaps best known for its seeds. Oil is extracted from the seeds and used for a variety of health problems.

Distinguishing Features: This plant is an herbaceous forb that earned its common name because of flowering only late in the day and into the evening. Each flowers only last one to two days but one plant produces several flowers over a period of time. The stem does not grow until the second year, are hairy, and they may have tinges of purple or red. These plants reproduce by seed and each plant has numerous seed capsules that are upright. Evening primrose loves well-drained soils in full sun.

Flowers: This flower has 4 petals, a stigma X-shaped, sepal turned down against stem; axillary and the terminal is above. It has a long flowering period from late spring to late summer; and the flowers tend to open late afternoon and into the evening. They have a mild lemony scent and its pollinators are bees, butterflies and moths. Hummingbirds are attracted to these flowers because of its nectar.

Leaves: The first year you'll see elliptic to lanceolate shaped leaves that measure about 5 to 20cm long and 1-2.5cm in width. They have wavy margins, a prominent white mid-vein, perhaps some red tinges on the leaf tips and they grow in a tight rosette. The second year a stem grows and the leaves grow alternate and they become smaller with height.

Height: This biennial grows anywhere between 30 and 150 cm (12-60 inches) in height.

Habitat: Evening primrose grows in meadows, on beaches, in dunes, roadsides, and in waste places. This plant is native to Canada and the US and grows in all provinces (not the territories) and most states. It has been naturalized in Great Britain, parts of Europe, Russia, eastern Asia, South American, Australia and some Pacific islands including New Zealand."

Source: http://www.ediblewildfood.com/evening-primrose.aspx

Skunkbush Background Information

Common Name(s): Skunkbush Sumac, Skunkbrush, Squawbush

Scientific Name: Rhus trilobata Nutt.

Description:

Life Span: Perennial

Origin: Native (not an invasive plant)

Season: Cool

Growth Characteristics: Skunkbush grows 2 to 8 feet (0.5-2.5 m) in height.
Height as well as growth form varies by geographic location: skunkbush is more branched and compact in the Southwest and taller in the North. The growth form of this thicket-forming shrub may be rounded, mound-like, or upright. Reproduction of skunkbrush is by seed and rhizomes. In many areas, annual growth of skunkbush begins in April or May.

Flowers of skunkbush develop early in the spring prior to leaf emergence. Fruit generally ripens from August to October. Drupes mature from June to October. Fruit persists throughout the winter.

Flowers/Inflorescence: Numerous small, yellowish-green to cream-colored flowers are borne on crowded catkin-like clusters near the tips of branches.

Fruits/Seeds: The fruit is a small, red or reddish-orange drupe containing a single nutlet. The fruit is highly acidic.

Leaves: The compound, three-lobed, (sometimes simple), alternate leaves are green above but pale below and are skunky to somewhat sweet-smelling when crushed. Leaflets grow in groups of three and are waxy, and soft-textured. The leaves turn a bright red or orange in the fall.

Stems: Twigs are alternate, brown, pliable, hairy when young, and fragrant when bruised. Older stems have white sapwood, pinkish-red heartwood, and a band of narrow gray-green between the two. Buds are small, yellow, and covered by the persistent leaf stalk bases.

Ecological Adaptations: Skunkbush occurs in a variety of habitats including dry rocky slopes, along streams and canyon bottoms, waste places, pastures, roadsides, and on sand dunes, at elevations of 4,500 to 8,000 feet. It is drought resistant; it is intolerant of flooding and high water tables. It typically grows where maximum annual precipitation ranges from 10 to 20 inches. Skunkbush grows well in sun or partial shade.

Skunkbush has spreading woody rhizomes and sprouts readily from both the root and crown after disturbance.

Soils: Tolerant of a wide range of soils from nearly bare rock to sand and heavy clay. It grows well on medium to coarsely textured, moist to dry, acidic to slightly alkaline soils. Growth is optimal in fairly deep soil. Skunkbush grows well on depleted soils.

Uses and Management:

Skunkbush's forage value is poor for all classes of livestock. Skunkbush provides some browse for deer, elk, and pronghorn when other more preferred forage is unavailable. In most locations, big game use tends to be heaviest during the winter when food supplies are most limited.

Because the fruit of skunkbrush persists through the fall and winter, this species can provide a ready food source for birds and small mammals when other foods are scarce or unavailable.

Skunkbush is valued for its fruit, twigs, leaves, and shoots. The fruits have been used in foods and medicines, and in the preparation of lemonade-like beverages. Pliable young stems can be woven into durable baskets. Early pioneers ate the salted drupes like popcorn and exudates from the stem as a chewing gum."

Source: http://extension.usu.edu/rangeplants/htm/skunkbush-sumac

How are my Petals? How are my Leaves?

Use the information from the plant ID basics handout to complete the following activity. This is activity is practice for learning general plant identification skills. Students will only be identifying and studying two plants (primrose and skunkbush) in the field for this project.

Procedure:

1. Use the provided laminated copies of the following pictures of plants and display them on a board so all students can see them. You can also use digital versions and project them onto a screen, or print out additional copies to pass around. Most of the pictures are landscape oriented.
2. Students then take turns reading the descriptions of the mystery plants out loud to the class.
3. Using the descriptions, students will match each description to the pictures of the plant displayed**.**
4. The teacher tells the students what the plants in the photos are once the students correctly identify the plant. If an attempt to identify a plant is incorrect the first time, move on to another description and come back to try the previous one again.

Mystery Plant Descriptions

#1. I am a perennial evergreen plant with long, stiff, narrow leaves coming out from the center in a rosette. My leaves have needlelike spikes on the ends. My flowers are white with red buds, belled shaped, and drooping down in clusters.

#2. I am a perennial herb that grows in clumps and can grow up to 40in tall. My leaves are grayish green, 3-lobed, with scalloped edges. My flowers are small, have five petals in a bowl shape growing in clusters on upper stems, and can range from light pink to bright orange and almost red in color.

#3. I am a perennial shrub that can grow up to 10ft tall. My leaves are green when new, turn yellow and brown in the fall, grow in a compound shape on the stems with three lobed shaped leaflets. I have small yellow flowers that grow in a dense cluster on a spike then turn into small, sticky, yellow to orange-red berries.

#4. I am a perennial herb with narrow, grass-like, grayish green leaves. My flowers are bowl shaped with three large yellow petals that are turned out at the top.

#5. I am a perennial, warm season bunchgrass that can grow 6-12in tall. During the spring and summer I have needle like flowers with long reddish, bristles extending out.

#6. I am a flowering herb that can be either annual or perennial and can grow to 16" tall. My leaves can be up to 2in long, linear to linear-lobed shaped, and reddish green in color. My flowers are reddish to orange and grow in terminal clusters with petals that are slightly wider and shorter than the leaves.

#7. I am a perennial herb that can grow up to 3ft. in height. My leaves are 4in long, silvery-green in color, oblong or lance shaped and wavy on the sides, with spines on the underside. My flowers are bluish-purple, star-like with five wide petals, and bright yellow anthers in the center. After my flowers bloom I have bright yellow berries that are poisonous.

#8. I am a flowering herb that can be an annual or a perennial plant. My leaves are up to 6in long with elliptical shaped leaflets in an opposing (opposite) pattern. My flowers are pinkish purple, pea shaped, and grow in an alternating pattern along a raceme (stem-like), followed by inflated whitish seed pod.

#9. I am a large deciduous tree that can grow up to 50ft in height with a center trunk up to 1 1/2ft in diameter. My leaves are deltoid shaped, finely saw-toothed, turn a golden yellow and fall off in the fall-winter. My flowers are tiny and greenish yellow turning into fuzzy white cotton seeds after blooming.

#10. I am a perennial herb that can grow up to 4ft in height. My leaves are gray-ish green colored, heart or oval shaped and 6in long. I have large white trumped shaped flowers that open in the early evening and close the next day when the sun hits them. All parts of me are poisonous.

#11. I am an evergreen shrub or small tree that can grow up to 25ft tall. My branches look shrub-like because of the density of the limbs. I have yellow-green scale-like leaves, gray fibrous bark, and small blue, waxy cones and berries.

#12. I am a biennial flowering plant that can grow an average 12" tall. My leaves are gray-ish green, linear and lobed or toothed, covered in fine hairs, and spreading out from the center in a basal rosette. My flowers can be pink, white, or pale yellow with four large heart shaped petals with long yellow stamens in the center, and held above the ground with a long thin tube.

#13. I am a cactus that can grow up to 16in tall. I do not have leaves but instead have succulent oval shaped stems called pads. These green pads grow low in mats and can be 7in long with spines of various sizes sticking out. My flowers can be yellow or magenta in color and can grow up to 1 ½ in long with many petals in a rosette shape. After flowering I have fruit that is cylindrical, brownish-red or purple with small spines. (Wikipedia)

Answers:

#1. Narrow leaf yucca. Scientific name: *Yucca* b*accata*

#2 . Globemallow. Scientific name: *Sphaeralcea incana*

#3. Skunkbush. Scientific name: *Rhus trilobata*

#4. Golden mariposa lily. Scientific name: *Calochortus aureus*

#5. Purple threeawn grass. Scientific name: *longiseta Fendler threeawn*

#6. Indian paintbrush.Scientific name: *Castilleja sp paintbrush*

#7. Silverleaf nightshade.Scientific name: *Solanum elaeagnifolium*

#8. Milkvetch, or locoweed. Scientific name: Astragalus sp milkvetch

#9. Cottonwood tree. Scientific name: *Populus sp Cottonwood*

#10. Datura or thornapple.Scientific name *Datura wrightii*

#11. One seed juniper tree. Scientific name: *Juniperus monosperma*

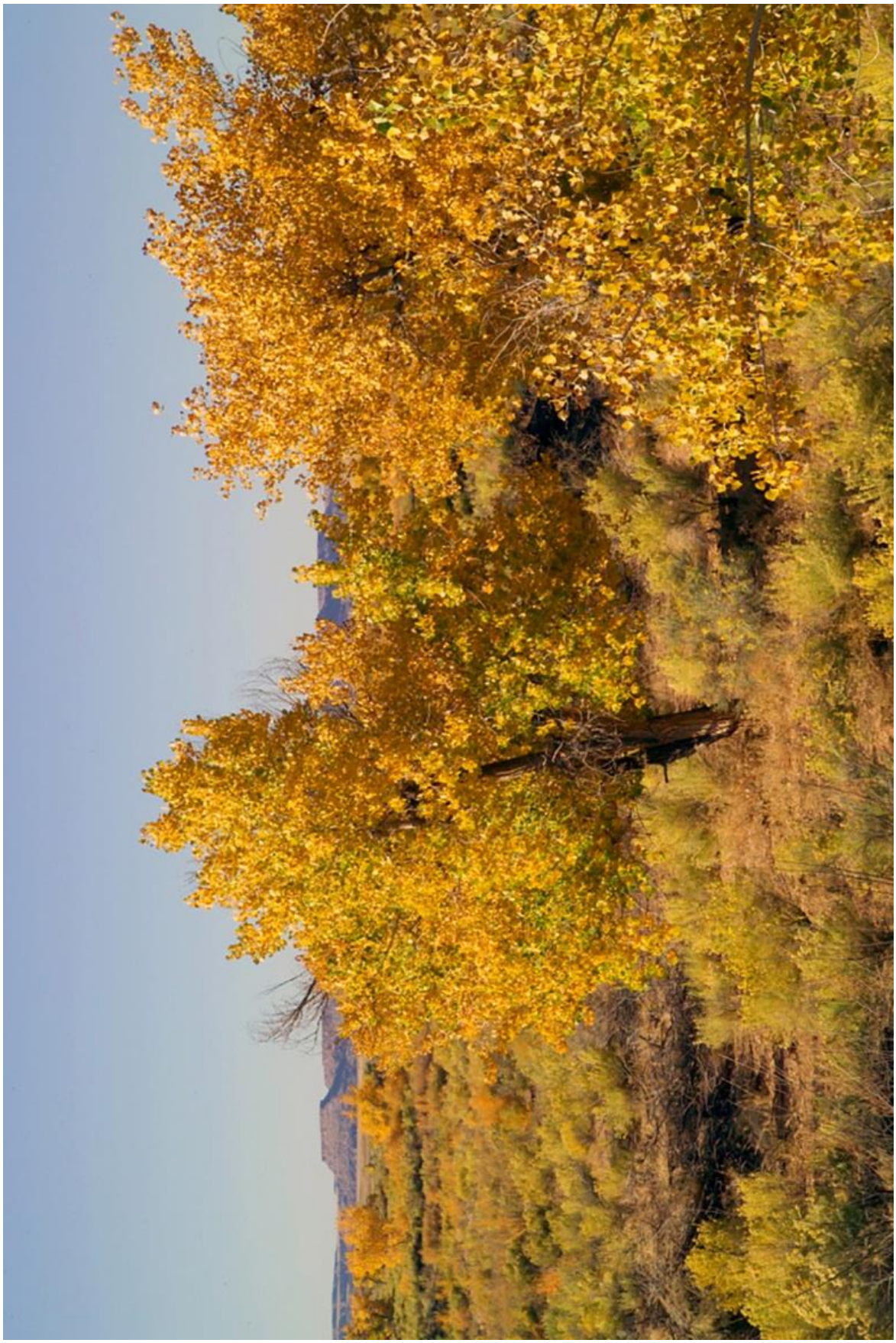
#12. Primrose. Scientific name: *Oenothera elata or Oenothera Pallida*

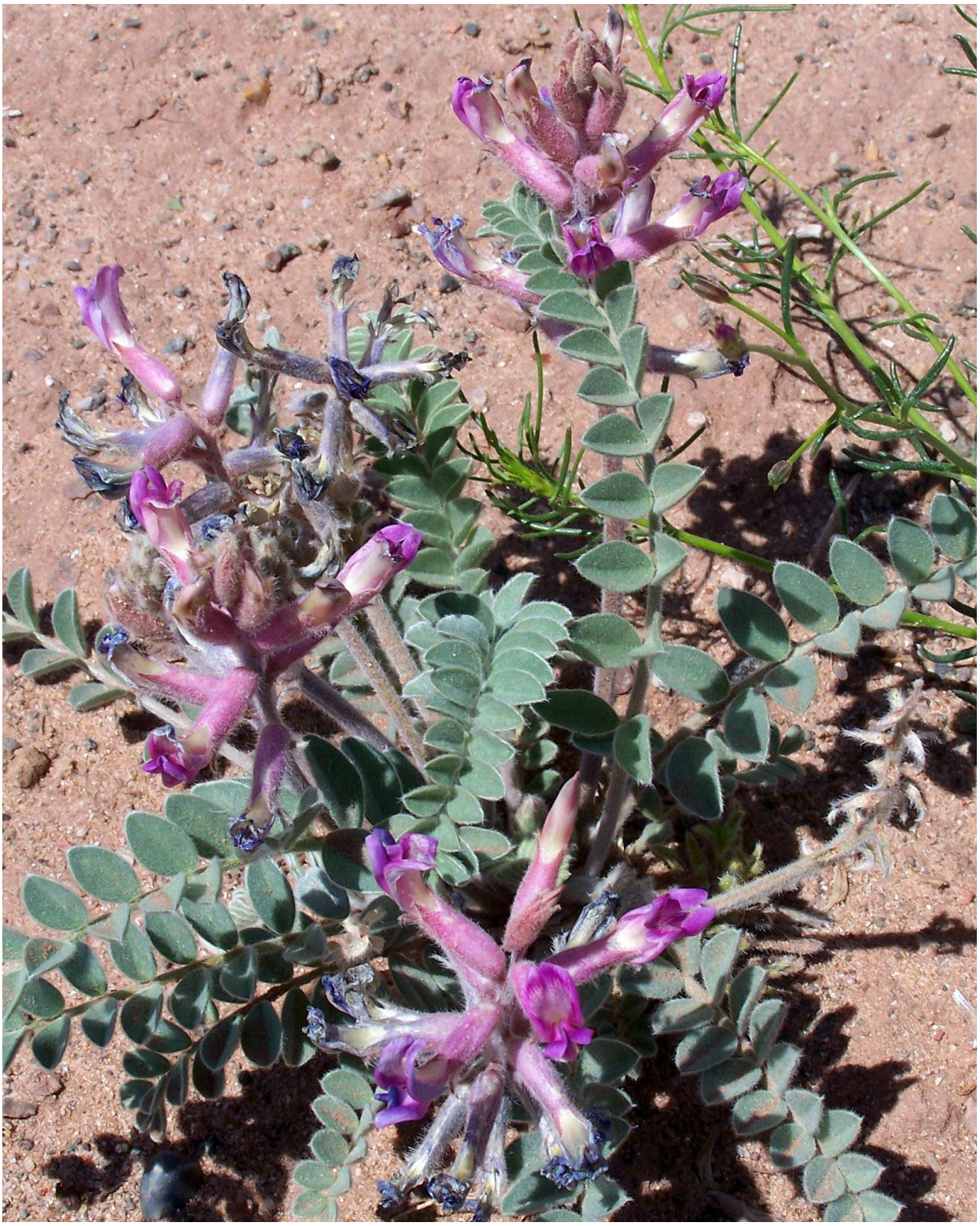
#13. Hairspine prickly pear cactus. Scientific name: *Opuntia polyacantha*

References:

Epple, Anne Orth (1995) *A field Guide to the Plants of Arizona*. Guilford, CT: Falcon Publishing Inc.

Harris, James G. Melinda Woolf Harris. (1994 & 2001) *Plant Identification Terminology; an Illustrated Glossary, Second Edition*. Spring Lake, UT: Spring Lake Publishing





Lesson #4
Observations and Data Collection

Time Needed: 3-4 hours

Learning Objectives:

- Students will be able to recognize ozone-induced foliar symptoms on plants by examining leaf appearance and structure.
- Students will be able to make observations and collect data on foliar injury levels at their school with some assistance from educators.

Procedure:

1. Students read Identifying Ozone injury in Plants handout.

2. Students practice identifying foliar damage with the Leaf Game and complete the Leaf Game worksheet
   http://www.nature.nps.gov/air/edu/O3Training/index.cfm

3. Students complete the O_3 Student Center Skills Worksheet. This can be completed as a group if computer availability is limited.

Identifying Ozone injury in Plants
(Text from HotL Ozone Bio-monitoring Guide)

Observation Support
Ozone induced foliar injury is commonly measured using the National Park Service's rating scale. The graphic chart identifies the varying percentage of ozone injury to a plant using the ratings of: 0%, 1-6%, 7-25%, 26-50%, 51-75% and 76-100%. The greater the amount of ozone air pollution present, the more foliar injury that will likely be observed on ozone- sensitive plants. The plant is observed using a 10X magnifying glass and plant data are then recorded. The first data collecting event should occur no later than June 15 each year, subsequent observations should be taken one day each week or every two weeks, trying to maintain a regular schedule. Remember, *no injury* is relevant data.

Supporting Measurements
The percentage of injury to a plant depends upon the level or amount of ozone present and the amount of sunlight. Strong sunlight supports photosynthesis, producing food the plant needs. This requires more intake of air by the plant, and increased intake of air containing higher levels of ozone damage to the plant. Hot sunny days, high temperatures, wind direction, humidity, and cloud cover all affect the amount of ozone produced.

Participant Preparation
Anyone assessing foliar (plant) injury or submitting data Hands on the Land website must be trained. It is important to the accuracy of the measurements that participants are able to:
1. Work in cooperative groups to setup the site and gather, analyze, and discuss results.
2. Organize all materials needed to assess plant injury.
3. Follow a schedule for taking measurements.
4. Identify and record, date, time, plant location, plant ID number, number of leaves on the entire plant and other observations required on the data sheet.
5. Estimate the percentage of foliar injury using the graphically designed chart summarizing the National Park Service's rating scale.

Questions for Further Investigation
How is the amount of foliar injury related to other atmospheric phenomena?
Which ones?
How is it related?
What variability of foliar injury did you observe over a period of time?.....Daily? Weekly? Seasonally?
How could you use your data on plant injury to characterize any changes in the ozone exposures…weekly?, seasonally?, between years?

The Leaf Game

Navigate to the Foliar Injury Assessment Module website:
http://www.nature.nps.gov/air/edu/O3Training/index.cfm

- Change the number of leaf images for training to 10
- Click "select"
- Start training on Common Milkweed

Record your results here

Trial 1 = 10 leaves
1. Which species did you use?

2. Errors are to be expected, but it is important to record and track the categories in which you have wrong answers. Please write the total wrong answers in each category in the spaces below.

__ 0% __ 1%-4% __5%- 12% __ 13%-25% __ 26% - 50% __ 51% - 75% ___ 76% - 100%

Trial 2 = 10 leaves
1. Which species did you use?

2. Errors are to be expected, but it is important to record and track the categories in which you have wrong answers. Please write the total wrong answers in each category in the spaces below.

__ 0% __ 1%-4% __5%- 12% __ 13%-25% __ 26% - 50% ___ 51% - 75% ___ 76% - 100%

Trial 3 = 10 leaves
1. Which species did you use?

2. Errors are to be expected, but it is important to record and track the categories in which you have wrong answers. Please write the total wrong answers in each category in the spaces below.

__ 0% __ 1%-4% __5%- 12% __ 13%-25% __ 26% - 50% __ 51% - 75% ___ 76% - 100%

Trial 4 = 10 leaves
1. Which species did you use?

2. Errors are to be expected, but it is important to record and track the categories in which you have wrong answers. Please write the total wrong answers in each category in the spaces below.

__ 0% __ 1%-4% __5%- 12% __ 13%-25% __ 26% - 50% __ 51% - 75% ___ 76% - 100%

Did you get any better with each trial? In order to collect data in the ozone garden, you must get at least 80% correct on one of the 4 trials and be no more than one category off on incorrect answers.

Name _____

O_3 Skills Center Student Worksheet

Go to the O3 Inquiry website: http://www.handsontheland.org/ozone-inquiry

Answer the following questions in a few phrases or in a sentence.

1. What does chlorosis look like?

2. What does chlorosis mean for the plant?

3. What does necrosis look like?

4. What does necrosis mean for the plant?

5. What does purpling/stippling look like?

6. What does purpling/stippling mean for the plant?

7. What is happening inside of the leaf?

8. How do we know that the symptoms are from ozone?

9. Choose one Plant in the drop down menu. Circle the one chosen: Plant 1, Plant 2, Plant 3, Plant 4

10. Choose one of the following Dates in the drop down menu.
Circle which one you chose: June 29, July 6, July 13, July 20, July 27, August 4

11. Complete the following table using the following foliar area injury codes: 0 = leaf missing 1 = 0% 2 = 1%-6% 3 = 7%-25% 4 = 26%-50% 5 = 51%-75% 6 = 76%-100%

	Chlorosis		Purpling		Necrosis	
	Leaf A	Leaf B	Leaf A	Leaf B	Leaf A	Leaf B
Set 8						
Set 7						
Set 6						
Set 5						
Set 4						
Set 3						
Set 2						
Set 1						

12. Insert the above data into the O_3 Skills Center website and click the "Check" button. What is your score? _____

13. When was the first observed date the selected plant flowered (click at the top of the plant for each week to determine if the plant has flowered)?
Circle which date the selected plant flowered: July 27, August 4, August 11, August 31, September 7, September 14

14. Choose another Date (use a date listed below) in the drop down menu using the same selected Plant as before. Circle which one you chose: August 11, August 31, September 7, September 14, September 20, September 28

15. Complete the following table using the following foliar area injury codes: 0 = leaf missing 1 = 0% 2 = 1%-6% 3 = 7%-25% 4 = 26%-50% 5 = 51%-75% 6 = 76%-100%

	Chlorosis		Purpling		Necrosis	
	Leaf A	Leaf B	Leaf A	Leaf B	Leaf A	Leaf B
Set 8						
Set 7						
Set 6						
Set 5						
Set 4						
Set 3						
Set 2						
Set 1						

16. Insert the above data into the O_3 Skills Center website and click the "Check" button. What is your score? _____

17. Describe three differences you observed between the two dates selected.
1.

2.

3.