**Chemistry ENVIRONMENTAL LITERACY LESSON**

**(Student Edition)**

**GARRETT COUNTY, MARYLAND**

Composed by:

Brian Price, Northern High School

2011

**Chemistry ELP Lesson Plan**

| **5E Lesson Components** | **Description of Activity** |
| --- | --- |
| **Engagement**  The activities in this section capture the participants’ attention, stimulate their thinking, and help them access prior knowledge. | Location: School-based chemistry classrooms  Activity/ies:   * Paper Chromatography of Inks Used in Markers (Activity 1). |
| **Exploration**  In this section, participants are given time to think, plan, investigate, and organize collected information. | Location: HEEC  Activity/ies:   * Paper Chromatography of Pigments in Leaves (Activity 2) |
| **Explanation**  Participants are now involved in an analysis of their exploration. Their understanding is clarified and modified because of reflective activities. | Location: HEEC  Activity/ies:   * Modeling of Organic Pigments (Activity 4) |
| **Extension**  This section gives participants the opportunity to expand and solidify their understanding of the concept and/or apply it to a real world situation. | Location: HEEC/School-based chemistry classroom  Activity/ies:   * Paper Chromatography of Pigments in Leaves (Activity 3) * Strange Planets (Activity 5) |
| **Evaluation**  Evaluation occurs throughout the lesson. Scoring tools developed by teachers and participants target what participants must know and do. Consistent use of scoring tools improves learning. | Location: HEEC/School-based chemistry classrooms  Activity/ies:   * Lab Report |

**Chemistry STEM**

| **Standard** | **Standard Number (s)** | **Activity** |
| --- | --- | --- |
| **Common Core Standard for Mathematical Practice (SMP)** | 1  2  4  5  7 | Exploration  Extension  Explanation |
| **International Technology Education Association Standards for Technological Literacy (ITEAS)** | 9J  9K  9L  11M  11N | Explanation |
| **Common Core Reading Standards for Literacy in Science and Technical Subjects (RSL)** | 3  9 | Explanation |
| **Common Core Writing Standards for Literacy in History/ Social Studies, Science and Technical Subjects (WSL)** | 1e  4  5  8  9 | Explanation  Evaluation |
| **Maryland Science Standards (CLGs)** | 1.1.1  1.1.2  1.2.1  1.2.2  1.2.5  1.2.7  1.3.1  1.3.2  1.3.3  1.5.8  4.2.1  4.2.2  4.4.1 | Exploration  Extension  Explanation |

**Hickory Environmental Education Center**

**Chemistry**

**TITLE:**How does light (abiotic factor) within an ecosystem affect the pigment molecules of organisms living in that ecosystem?

**Objective:** Students will:

* develop an understanding of how light and pigments in living systems interact.
* analyze chromatograms of four species during different seasons and compare pigments present in those organisms.
* compare absorption spectrums to the visible color of leaves for two species.

**Activity/ies:**

**Materials:**

See teacher Section

**Archival Assessment:**

* Lab Report

**School-based Engagement Activity 1**

**Paper Chromatography of Inks Used in Markers**

**Concepts:** Most materials in our world are mixtures. Very few materials are pure substances. The art of separating mixtures is important because it enables one to isolate pure substances. Paper chromatography is a modern method used to separate mixtures. Paper chromatography uses paper as the stationary phase and a liquid solvent as the mobile phase. Paper chromatography can be used to test markers to see if the color results from a single dye or mixture of dyes.

**Time and Location:** This activity should be done in the classroom the day before the HEEC field trip. It should take 30 to 45 minutes.

**Materials:** per group

* 3 chromatography tape strips
* 1 chromatography tape strip prepared by the teacher
* 50 ml of water
* 4 clear plastic cups
* metric ruler
* tape
* a set of colored markers
* a set of black markers
* blank sheet of paper
* pencil
* paper towels
* calculator

**Procedure**:

1. Use the colored markers to write a word or phrase on a sheet of paper. Be sure to label with a pencil which marker was used for each phrase.
2. Sprinkle water on the written phrases on the paper.
3. Answer the following questions:
   * What happened to the paper when it got wet?
   * What is happening to the marker ink as it gets wet?
   * What colors did you see?
   * What do the different colors tell us about the markers?
   * How do we get so many different colors of markers?
   * Why are some markers green while others are purple?

**Scenario:** You have found a piece of paper with a note written on it “Adam love Eve”. Andy, Bill

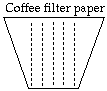
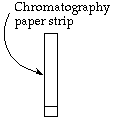
and Charles all possessed black markers. What method can be used to determine who wrote the note?

**NOTE:** Handle all chromatography paper or filer paper by the edges to prevent placing oils from your hands on the paper. These oils may interfere with the solvent movement.

**Procedure**

* 1. Cut chromatography tape into 15 cm length. If using coffee filters or filter paper, cut

a strip 3 cm wide by 15 cm long.



* 1. On each chromatography tape, measure 1 cm from the bottom and the top. The top

line will be your ending point, mark this line with a pencil. The bottom line will be

marked with the marker you will be testing (each filter paper should represent a

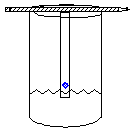
different marker).

* 1. Add 10 mL of water to the cup.
  2. Trace the bottom pencil line with the tested marker.
  3. Place the tested marker in front of you horizontally. Tape the chromatography tape to

the marker it is testing. It will look like the tape is dangling from the marker (see

picture below). Repeat steps 2-5 for each sample being tested including the sample

provided by the teacher. Use the pencil to hang the teacher sample.



* 1. Place the marker across the cup so the chromatography tape is touching the water

(but not so deep that the marker line is touching the water…refer to above picture).

* 1. Allow the water to wick until it reaches the top pencil line. Remove the tape by

lifting the pen off of the cup. The top pencil line now represents the distance the

solvent front moved.

* 1. Place the chromatography tapes on the paper towel to dry.
  2. Circle the color bands, with pencil, after the paper is dry.
  3. Calculate the reference fronts for each band on the developed chromatography tape

for each sample tested.

distance solute center of gravity moved

Rf =

distance solvent front moved

11. Record results in data table below.

**Reference Front Values**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Marker 1** | **Marker 2** | **Marker 3** | **Unknown Marker** |
| **Band 1** |  |  |  |  |
| **Band 2** |  |  |  |  |
| **Band 3** |  |  |  |  |
| **Band 4** |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |

**Evaluation:** Compare the Rf values for the chromatography tapes including the teacher prepared tape in order to determine which marker was used to write the note. Based on your data, which marker wrote the note? Defend your answer below. Use additional paper as needed.

**Hickory Environmental Education Center**

**Exploration Activity 2**

**Paper Chromatography of Pigments in Leaves**

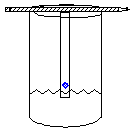
**Concepts:** Most materials in our world are mixtures. Very few materials are pure substances. The art of separating mixtures is important because it enables one to isolate pure substances. Chromatography is a modern method used to separate mixtures. Paper chromatography uses paper as the stationary phase and a liquid solvent as the mobile phase. Paper chromatography can be used to test leaves for different pigments.

**Materials:** per group

* Chromatography tape
* 50 ml of each of the following liquids.
  + Water
  + Isopropyl alcohol
  + Acetone
* 8 clear plastic cups
* Tape
* 8 pencils
* paper towels
* “How Fall Colors Work” article
* 12 leaves (spinach, conifer, red leaf, yellow leaf)
* 4 capillary tubes
* calculator

**Procedure:**

1. Collect 12 leaf samples (or the equivalent with smaller leaves) from one species in each of the three categories (conifer, red leaved trees, and yellow leaved trees). Refer to the category list.
2. Prepare four chromatography strips following the same method as used previously in the marker investigation.
3. Take 4 to 5 large leaves (or the equivalent with smaller leaves) and tear them into small pieces. Place leaf pieces into a mortar. Add 1 to 2 mL of water to the mortar. Grind with pestle. Grind until the leaf pieces are no longer identifiable (approximately 2 minutes).
4. Using a capillary tube to transfer sample, make a small dot in the center of the pencil line on the chromatography paper. Let the dot dry and then reapply another small dot on top of the first one. Repeat this transfer eight (8) times. NOTE: The dot should be small and dark…not wide.
5. Attach a chromatography tape strip to a pencil like in the diagram below.
6. Add 10 mL water to the cup and label cup with the name of the sample. Place the pencil across the cup so the chromatography tape is touching the water (but not so deep that the dot is touching the water…refer to picture below). Repeat steps 3 - 6 for all leaf and spinach samples.



1. Allow the water to wick until it reaches the top pencil line. Remove the tape by lifting the pen off of the cup. The top pencil line now represents the distance the solvent front moved.
2. Place the chromatography tapes on the paper towel to dry.
3. Circle the color bands, with pencil, after the paper is dry.
4. Calculate the reference fronts for each band on the developed chromatography tape for each sample tested

distance solute center of gravity moved

Rf =

distance solvent front moved

11. Record results in data table below.

**Reference Front Values with Water as Solvent**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Spinach** | **Species 1**  **\_\_\_\_\_\_\_\_\_\_\_\_\_** | **Species 2**  **\_\_\_\_\_\_\_\_\_\_\_\_\_** | **Species 3**  **\_\_\_\_\_\_\_\_\_\_\_\_\_** |
| **Band 1** |  |  |  |  |
| **Band 2** |  |  |  |  |
| **Band 3** |  |  |  |  |
| **Band 4** |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
| **Pigment/s Visible** |  |  |  |  |

**Discussion:**

1. Can you identify which pigments are present? If so, which one/s are present?
2. Does the season in which the leaves are picked affect their colors? Explain your answer.
3. Does the season that the leaves are picked affect the pigments? Explain your answer.
4. Does the water solvent separate pigments that would be present in the leaves? Explain your answer.

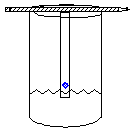
**Hickory Environmental Education Center**

**Exploration Activity 3**

**Paper Chromatography of Pigments in Leaves**

**Procedure:**

1. Prepare four chromatography strips following the same method as used previously in the marker investigation (Activity 1).
2. Take 4 to 5 large leaves (or the equivalent with smaller leaves) and tear them into small pieces. Place leaf pieces into a mortar. Add 1 to 2 mL of solvent assigned by your teacher (acetone or isopropyl) to the mortar. Grind with pestle. Grind until the leaf pieces are no longer identifiable (approximately 2 minutes).
3. Using a capillary tube to transfer sample, make a small dot in the center of the pencil line on the chromatography paper. Let the dot dry and then reapply another small dot on top of the first one. Repeat this transfer eight (8) times. NOTE: The dot should be small and dark…not wide.
4. Attach a chromatography tape strip to a pencil like in the diagram below.
5. Add 10 mL assigned solvent to the cup and label cup with the name of the sample. Place the pencil across the cup so the chromatography tape is touching the water (but not so deep that the dot is touching the solvent…refer to picture below).
6. Repeat steps 2 - 5 for all leaf and spinach samples.



1. Allow the water to wick until it reaches the top pencil line. Remove the tape by lifting the pen off of the cup. The top pencil line now represents the distance the solvent front moved.
2. Place the chromatography tapes on the paper towel to dry.
3. Circle the color bands, with pencil, after the paper is dry.
4. Calculate the reference fronts for each band on the developed chromatography tape for each sample tested

distance solute center of gravity moved

Rf =

distance solvent front moved

11. Record results in data table below.

**Reference Front Values with Alternate Solvent**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Solvent Used  \_\_\_\_\_\_\_\_\_\_\_\_\_ | **Spinach** | **Species 1**  **\_\_\_\_\_\_\_\_\_\_\_\_\_** | **Species 2**  **\_\_\_\_\_\_\_\_\_\_\_\_\_** | **Species 3**  **\_\_\_\_\_\_\_\_\_\_\_\_\_** |
| **Band 1** |  |  |  |  |
| **Band 2** |  |  |  |  |
| **Band 3** |  |  |  |  |
| **Band 4** |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
| **Pigment/s Visible** |  |  |  |  |

**Discussion:**

1. Can you identify which pigments are present? If so, which one/s are present?
2. Does the season in which the leaves are picked affect their colors? Explain your answer.
3. Does the season that the leaves are picked affect the pigments? Explain your answer.
4. Did the alternate liquid work better or worse than the water that was used first and how?
5. Explain how paper chromatography works.

**Explanation Activity 4**

**Modeling of Organic Pigments**

**Concepts:** In science we attempt to model nature in order to understand natural phenomena. Modeling can be used to help students bridge the gap between the abstract two dimensional structural formulas and a more realistic three dimensional representation.

**Time and Location:** This activity should be done during the Exploration Activity and should take approximately 30 minutes.

**Materials:** per group

* “How Fall Colors Work” article
* Organic Chemistry models

**Procedure**: Each group is to choose one of the structural formulas of an organic pigment from the “How Fall Colors Work” article. They should then build a three dimensional representation of the molecule with the organic chemistry models. Take a photograph to compare the two dimensional structure with the 3D model structure. Include the photo, as well as a 2D representation of the model chosen in your lab report.

**Evaluation:**

What are some of the problems associated with trying to visualize what a larger organic molecule looks like from a two dimensional representation?

How did building the molecules help your understanding of what the molecule looks like?

Look up your molecule at <http://www.drugbank.ca/> and find its 3D model and compare it to yours. How are they similar? How are they different?

Do the organic molecules have areas of polarity?

Does the presence or lack of polarity on the pigment molecules have anything to do with how well the pigments were separated in the different liquids? Explain.

**How Fall Colors Work**

**Leaf Colors**

The color of a leaf results from an interaction of different pigments produced by the plant. The main pigment classes responsible for leaf color are porphyrins, carotenoids, and flavonoids. The color that we perceive depends on the amount and types of the pigments that are present. Chemical interactions within the plant, particularly in response to acidity (pH) also affect the leaf color.

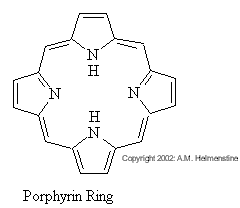
|  |  |  |
| --- | --- | --- |
| Pigment Class | Compound Type | Colors |
| Porphyrin | **chlorophyll** | green |
| Carotenoid | **carotene** and lycopene  xanthophyll | yellow, orange, red  yellow |
| Flavonoid | flavone  flavonol  **anthocyanin** | yellow  yellow  red, blue, purple, magenta |

**Chemistry of Plant Pigments**

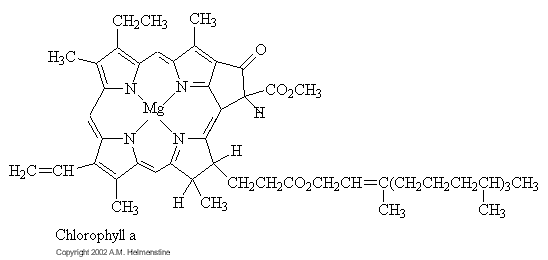
Let's take a closer look at the molecular structures and functions of the major plant pigments:

*Porphyrins*

All porphyrins have the following ring structure:

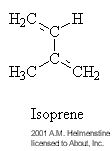


The primary porphyrin in leaves is a green pigment called chlorophyll. There are different chemical forms of chlorophyll (e.g., chlorophyll *a* and chlorophyll *b*), which are responsible for carbohydrate synthesis within a plant. Chlorophyll is produced in response to sunlight. As the seasons change and the amount of sunlight decreases, less chlorophyll is produced, and the leaves appear less green. Chlorophyll is broken down into simpler compounds at a constant rate, so green leaf color will gradually fade as chlorophyll production slows or stops.

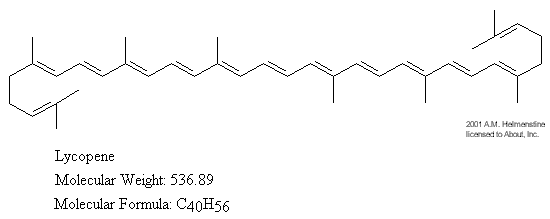


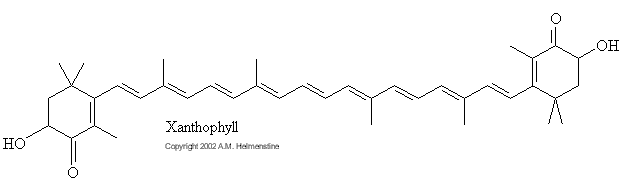
*Carotenoids*

[Carotenoids](http://chemistry.about.com/library/glossary/bldef525.htm) are [terpenes](http://chemistry.about.com/library/glossary/bldef862.htm) made of isoprene subunits.



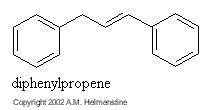
Examples of carotenoids found in leaves include [lycopene](http://chemistry.about.com/library/weekly/aa050401a.htm), which is red, and xanthophyll, which is yellow. Light is not needed in order for a plant to produce carotenoids, therefore these pigments are always present in a living plant. Also, carotenoids decompose very slowly as compared to chlorophyll.



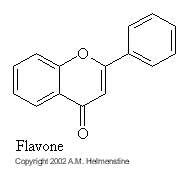
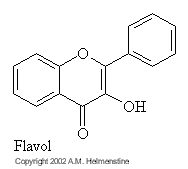


*Flavonoids*

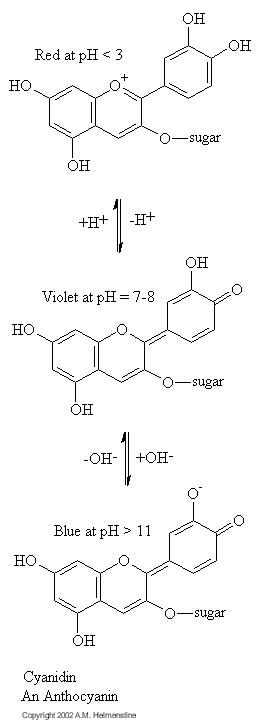
Flavonoids contain a diphenylpropene subunit.



Examples of flavonoids include flavone and flavol, which are yellow, and the anthocyanins, which may be red, blue, or purple, depending on pH.

Anthocyanins, such as cyanidin, provide a natural sunscreen for plants. Because the molecular structure of an anthocyanin includes a sugar, production of this class of pigments is dependent on the availability of carbohydrates within a plant. Anthocyanin color changes with pH, so soil acidity affects leaf color. Anthocyanin production also requires light, so sunny days are needed for the brightest fall colors!



**Autumn Color Change**

When leaves appear green, it is because they contain an abundance of chlorophyll. Chlorophyll masks other pigment colors. Anthocyanins, in turn, mask carotenoids. As summer turns to autumn, decreasing light levels cause chlorophyll production to slow. However, the decomposition rate of chlorophyll remains constant, so the green color will fade from the leaves. At the same time, anthocyanin production in leaves increases, in response to surging sugar concentrations. Leaves containing primarily anthocyanins will appear red. Leaves with good amounts of both anthocyanins and carotenoids will appear orange. Leaves with carotenoids but little or no anthocyanins will appear yellow. In the absence of these pigments, other plant chemicals also can affect leaf color. An example includes tannins, which are responsible for the brownish color of some oak leaves.

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**Hickory Environmental Education Center**

**Chemistry ALTERNATE Activity**

**NOTE:** If student was absent for any classroom activities associated with the HEEC activity, those activities must also be provided and completed by the student.

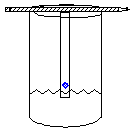
**Concepts:** Most materials in our world are mixtures. Very few materials are pure substances. The art of separating mixtures is important because it enables one to isolate pure substances. Paper chromatography is a modern method used to separate mixtures. Paper chromatography uses paper as the stationary phase and a liquid solvent as the mobile phase. Paper chromatography can be used to test leaves for different pigments.

**Materials:**

* coffee filters or paper towel
* 50 mL of each of the following liquids.
  + Isopropyl alcohol (90% rubbing alcohol from drug store)
  + acetone (finger nail polish remover)
  + Water
* clear plastic cups
* graduated cylinder
* tape
* 4 pencils
* scissors
* colored pencils
* 1 shallow pan
* 4 small jars with lids
* leaves (spinach, red leaved tree, yellow leaved tree, conifer)

**Procedure:**

1. Find leaves of three different colors/species (red leaved tree, yellow leaved tree, conifer) and a sample of spinach leaves from the store. Use the following website to identify species of leaves. <http://harvardforest.fas.harvard.edu/research/leaves/Autumn_leaves.html>
2. Take 4-5 large leaves (or the equivalent with smaller leaves), tear them into tiny pieces, and place them into small jars with lids.
3. Add enough alcohol to just cover the leaves.
4. Loosely cover the jars and set them into a shallow pan containing an inch or so of hot tap water.
5. Let the jars sit in the hot water for at least a half hour. Replace the hot water in the shallow pan as it cools and swirl the jars from time to time.
6. While you are waiting for the pigments to steep, start the Modeling of Organic Pigments Activity.
7. The pigment extraction is finished when the alcohol has picked up color from the leaves. The darker the color, the brighter the chromatogram and the better the results will be.
8. Cut a strip of coffee filter paper (or paper towel) 2 to 3 cm wide and long enough to reach from the bottom of the jar to the top. Lay one pencil horizontally and tape the paper strip vertically to the pencil so that the bottom of the paper just touches the top of the liquid in the jar when the pencil is placed across the opening of the jar (see diagram).



1. Repeat step 7 so there is one strip attached to a pencil for each of the four jars of pigments.
2. Place one strip of paper into each jar by resting the pencil across the opening of the jar.
3. As the alcohol evaporates, it will pull the pigment up the paper, separating pigments according to size (largest will move the shortest distance).
4. After 30-90 minutes (or until the desired separation is obtained), remove the strips of paper and immediately mark the height that the solvent (alcohol) has traveled. Allow the strips to dry.
5. Circle the color bands, with pencil, after the paper is dry.
6. Calculate the reference fronts for each band on the developed filter paper for each sample tested using the formula below.

distance solute center of gravity moved

Rf =

distance solvent front moved

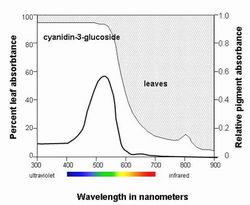
Record your results in the data table below.

**Reference Front Values with Alcohol**

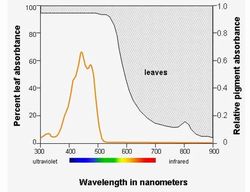
|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Spinach** | **Species 1**  **\_\_\_\_\_\_\_\_\_\_\_\_\_** | **Species 2**  **\_\_\_\_\_\_\_\_\_\_\_\_\_** | **Species 3**  **\_\_\_\_\_\_\_\_\_\_\_\_\_** |
| **Band 1** |  |  |  |  |
| **Band 2** |  |  |  |  |
| **Band 3** |  |  |  |  |
| **Band 4** |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
| **Pigment/s Visible** |  |  |  |  |

**Discussion:**

1. Can you identify which pigments are present? If so, which one/s are present?
2. Does the season in which the leaves are picked affect their colors? Explain your answer.
3. Does the season that the leaves are picked affect the pigments? Explain your answer.
4. Explain how paper chromatography works.
5. The following pictures show the color change in two tree species commonly found in Garrett County. The graph to the right of each picture shows the absorbance of light wave lengths by the leaf and its pigments.

Red Oak

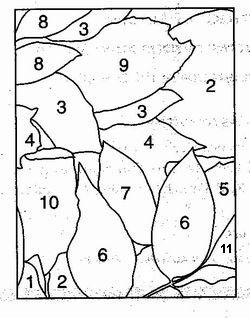
Witch Hazel

**NOTE:** The graphs above for percent leaf absorbance show the percentage of light by wavelength that is being absorbed by the leaf. A higher absorbance percentage for a wavelength of light means this wavelength is not as visible in the reflected wavelengths of light seen by the naked eye.

1. What is the apparent color of each species of leaf?
2. What colors of light are being reflected by each species of leaf?
3. What colors of light are being absorbed by each species of leaf?
4. Based on the wavelength graphs for each species, identify the wavelength (in nm) which is being absorbed at the highest percentage. Do both species absorb light at the same wavelength? Explain your answer.
5. What is the significance of your answer in part d?

# The Plants of Autumn Foliage Color

**NOTE:** All of the specimens below are on the HEEC property.

[Conifers](http://harvardforest.fas.harvard.edu/research/leaves/plants.html#conifers), [yellow](http://harvardforest.fas.harvard.edu/research/leaves/plants.html#yellow) and [red](http://harvardforest.fas.harvard.edu/research/leaves/plants.html#red) leaved flowering shrubs and trees are the most important plants in providing color during the autumn at the Harvard Forest. For the most part, these are the plants that we have studied, and information about them will be provided in the [science sections](http://harvardforest.fas.harvard.edu/research/leaves/science.html). The above photograph provides a look at their leaves together in mid-October, when the colors are at their peak.

The species in the photograph are:

1. [witch hazel](http://harvardforest.fas.harvard.edu/research/leaves/plants/witchhazel.html)
2. [hobble bush](http://harvardforest.fas.harvard.edu/research/leaves/plants/hobblebush.html)
3. [northern wild-raisin](http://harvardforest.fas.harvard.edu/research/leaves/plants/raisin.html)
4. [sugar maple](http://harvardforest.fas.harvard.edu/research/leaves/plants/sugar_maple.html)
5. [red maple](http://harvardforest.fas.harvard.edu/research/leaves/plants/red_maple.html)
6. [ash](http://harvardforest.fas.harvard.edu/research/leaves/plants/white_ash.html)
7. [black cherry](http://harvardforest.fas.harvard.edu/research/leaves/plants/black_cherry.html)
8. [high bush blueberry](http://harvardforest.fas.harvard.edu/research/leaves/plants/blueberry.html)
9. [Yellow birch](http://harvardforest.fas.harvard.edu/research/leaves/plants/yellowbirch.html)
10. [beech](http://harvardforest.fas.harvard.edu/research/leaves/plants/beech.html)
11. [Striped Maple](http://harvardforest.fas.harvard.edu/research/leaves/plants/striped_maple.html)

## CONIFERS

Conifers provide the green backdrop during the autumn color changes in New England forests. These are principally white pine and hemlock, although other pines may be introduced in plantations. Larches are the only conifers in these forests which lose their needles completely during the fall. These trees produce an autumn show of bright yellow in the swampy areas where they grow. The European larch may be introduced in plantations or in landscaping, to provide more autumn yellow color.

* [American Larch](http://harvardforest.fas.harvard.edu/research/leaves/plants/american_larch.html)
* [Eastern Hemlock](http://harvardforest.fas.harvard.edu/research/leaves/plants/eastern_hemlock.html)
* [White Pine](http://harvardforest.fas.harvard.edu/research/leaves/plants/white_pine.html)

## Red-leaved Flowering Shrubs and Trees

All of these shrubs and trees produce varying amounts of anthocyanins during senescence. Sometimes these pigments are produced uniformly in the leaves, but often distinct patterns.

* [Alternate-Leaved Dogwood](http://harvardforest.fas.harvard.edu/research/leaves/plants/alt_leaf_dogwood.html)
* [Black Cherry](http://harvardforest.fas.harvard.edu/research/leaves/plants/black_cherry.html)
* [Black Chokeberry](http://harvardforest.fas.harvard.edu/research/leaves/plants/black_chokeberry.html)
* [High-Bush Blueberry](http://harvardforest.fas.harvard.edu/research/leaves/plants/blueberry.html)
* [Hobblebush](http://harvardforest.fas.harvard.edu/research/leaves/plants/hobblebush.html)
* [Northern Wild Raisin](http://harvardforest.fas.harvard.edu/research/leaves/plants/raisin.html)
* [Red Maple](http://harvardforest.fas.harvard.edu/research/leaves/plants/red_maple.html)
* [Red Oak](http://harvardforest.fas.harvard.edu/research/leaves/plants/red_oak.html)
* [Red-Osier Dogwood](http://harvardforest.fas.harvard.edu/research/leaves/plants/osier_dogwood.html)
* [Scarlet Oak](http://harvardforest.fas.harvard.edu/research/leaves/plants/scarlet_oak.html)
* [Juneberry (Serviceberry, Shadbush)](http://harvardforest.fas.harvard.edu/research/leaves/plants/serviceberry.html)
* [Black (Sour) Gum](http://harvardforest.fas.harvard.edu/research/leaves/plants/sourgum.html)
* [Sugar Maple](http://harvardforest.fas.harvard.edu/research/leaves/plants/sugar_maple.html)
* [Stag-horn Sumac](http://harvardforest.fas.harvard.edu/research/leaves/plants/sumac.html)
* [White Ash](http://harvardforest.fas.harvard.edu/research/leaves/plants/white_ash.html)
* [White Oak](http://harvardforest.fas.harvard.edu/research/leaves/plants/white_oak.html)

## Yellow-Leaved Flowering Shrubs and Trees

All of these species turn yellow during the autumn, due to the breakdown of chlorophyll and the retention of some carotenoid pigments in their plastids. In a few cases, small amounts of anthocyanins may be produced, sometimes only in a few individuals in a population.

* [American Beech](http://harvardforest.fas.harvard.edu/research/leaves/plants/beech.html)
* [American Chestnut](http://harvardforest.fas.harvard.edu/research/leaves/plants/chestnut.html)
* [Big-Toothed Aspen](http://harvardforest.fas.harvard.edu/research/leaves/plants/bigtooth_aspen.html)
* [Gray Birch](http://harvardforest.fas.harvard.edu/research/leaves/plants/gray_birch.html)
* [Quaking Aspen](http://harvardforest.fas.harvard.edu/research/leaves/plants/quaking_aspen.html)
* [Striped Maple](http://harvardforest.fas.harvard.edu/research/leaves/plants/striped_maple.html)
* [Tulip Poplar](http://harvardforest.fas.harvard.edu/research/leaves/plants/tulip.html)
* [Winterberry Holly](http://harvardforest.fas.harvard.edu/research/leaves/plants/holly.html)
* [Witch Hazel](http://harvardforest.fas.harvard.edu/research/leaves/plants/witchhazel.html)
* [Yellow Birch](http://harvardforest.fas.harvard.edu/research/leaves/plants/yellowbirch.html)

**NOTE:** For additional help identifying the above species the following website provides links to the identification. <http://harvardforest.fas.harvard.edu/research/leaves/plants.html>

**Hickory Environmental Education Center**

**Strange Planets Activity 5**

**Day 1 – Activity** - Astronomy and spectral analysis “Strange Planets”(Planetarium)

Questions:

1. How are the different ways that light can be measured?
2. How are a light’s frequency, wavelength and energy related?
3. What are the units for a light’s frequency, wavelength and energy?
4. What are the assigned symbols for a lights frequency and wavelength?
5. What is the difference between and absorption spectrum and emission spectrum?
6. How can spectrums be used to identify different elements?
7. How can the shifting of wavelengths of light be used to determine if an object in space is coming toward or away from Earth?
8. How can the bending of light due to gravity be used to determine the size of ex planets and how far they are away from their sun?

**Chemistry ENVIRONMENTAL LITERACY LESSON**

**(Teacher Edition)**

**GARRETT COUNTY, MARYLAND**

Composed by:

Brian Price, Northern High School

2011

**School-based Engagement Activity 1**

**Paper Chromatography of Inks Used in Markers**

**Concepts:** Most materials in our world are mixtures. Very few materials are pure substances. The art of separating mixtures is important because it enables one to isolate pure substances. Paper chromatography is a modern method used to separate mixtures. Paper chromatography uses paper as the stationary phase and a liquid solvent as the mobile phase. Paper chromatography can be used to test markers to see if the color results from a single dye or mixture of dyes.

**Time and Location:** This activity should be done in the classroom the day before the HEEC field trip. It should take 30 to 45 minutes.

**Materials:** (assuming 6 groups of 4)

* 18 chromatography tape strips
* 6 chromatography tape strip prepared by the teacher
* 300 ml of water
* 24 clear plastic cups
* 6 metric ruler
* 6 tape
* 6 sets of water soluble colored markers (2 markers of same color but different brand per set)
* 6 sets of water soluble black markers (3 black markers of each brand *- vis-à-vis, crayola, sharpie*-to include the marker used to write the note)
* blank sheet of paper
* pencil
* paper towels
* calculator

**Procedure**:

1. Use the colored markers to write a word or phrase on a sheet of paper. Be sure to label with a pencil which marker was used for each phrase.
2. Sprinkle water on the written phrases on the paper.
3. Answer the following questions:
   * What happened to the paper when it got wet?
   * What is happening to the marker ink as it gets wet?
   * What colors did you see?
   * What do the different colors tell us about the markers?
   * How do we get so many different colors of markers?
   * Why are some markers green while others are purple?

**Scenario:** You have found a piece of paper with a note written on it “Adam love Eve”. Andy, Bill

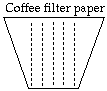
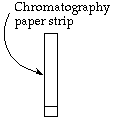
and Charles all possessed black markers. What method can be used to determine who wrote the note?

* From this point allow discussion on how to determine which marker wrote the note.
* Now have the students do the paper chromatography for the three black markers. While the students are preparing their chromatograms, prepare 6 chromatograms for the marker used to write the note.
* Prepare a test strip with the actual marker that wrote the note on chromatography paper for each group.
* Make sure to remind students to handle all chromatography paper or filer paper by the edges to prevent placing oils from your hands on the paper. These oils may interfere with the solvent movement.

**Procedure**

1. Cut chromatography tape into 15 cm length. If using coffee filters or filter paper, cut a strip 3

cm wide by 15 cm long.



2. On each chromatography tape, measure 1 cm from the bottom and the top. The top line will be

your ending point, mark this line with a pencil. The bottom line will be marked with the marker

you will be testing (each filter paper should represent a different marker).

3. Add 10 mL of water to the cup.

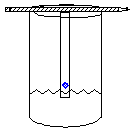
4. Trace the bottom pencil line with the tested marker.

5. Place the tested marker in front of you horizontally. Tape the chromatography tape to the marker it

is testing. It will look like the tape is dangling from the marker (see picture below). Repeat steps

2-5 for each sample being tested including the sample provided by the teacher. Use the pencil to

hang the teacher sample.



6. Place the marker across the cup so the chromatography tape is touching the water (but not so deep

that the marker line is touching the water…refer to above picture).

7. Allow the water to wick until it reaches the top pencil line. Remove the tape by lifting the pen off

of the cup. The top pencil line now represents the distance the solvent front moved.

8. Place the chromatography tapes on the paper towel to dry.

9. Circle the color bands, with pencil, after the paper is dry.

10. Calculate the reference fronts for each band on the developed chromatography tape for each

sample tested.

distance solute center of gravity moved

Rf =

distance solvent front moved

11. Record results in data table below.

**Reference Front Values**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Marker 1** | **Marker 2** | **Marker 3** | **Unknown Marker** |
| **Band 1** |  |  |  |  |
| **Band 2** |  |  |  |  |
| **Band 3** |  |  |  |  |
| **Band 4** |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |

**Evaluation:** Compare the Rf values for the chromatography tapes including the teacher prepared tape in order to determine which marker was used to write the note. Based on your data, which marker wrote the note? Defend your answer below. Use additional paper as needed.

Answers will vary but should include that the unknown marker has equal numbers of bands with the same Rf value for each of the bands of one of the three markers tested.

**Hickory Environmental Education Center**

**Exploration Activity 2**

**Paper Chromatography of Pigments in Leaves**

**NOTE:** Collect samples of leaves for students who are absent.

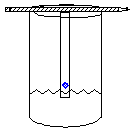
**Concepts:** Most materials in our world are mixtures. Very few materials are pure substances. The art of separating mixtures is important because it enables one to isolate pure substances. Chromatography is a modern method used to separate mixtures. Paper chromatography uses paper as the stationary phase and a liquid solvent as the mobile phase. Paper chromatography can be used to test leaves for different pigments.

**Materials:** (assuming 6 groups of 4)

* chromatography tape
* 500 ml of each of the following liquids.
  + water
  + isopropyl alcohol
  + acetone
* 30 clear plastic cups
* tape
* 30 pencils
* paper towels
* 24 Chromatography activity worksheets
* 24 “How Fall Colors Work” article
* 24 – 30 leaves of each species (spinach, conifer, red leaf, yellow leaf)
* 24 capillary tubes
* calculator

**Procedure:**

1. Collect 12 leaf samples (or the equivalent with smaller leaves) from one species in each of the three categories (conifer, red leaved trees, and yellow leaved trees). Refer to the category list.
2. Prepare four chromatography strips following the same method as used previously in the marker investigation.
3. Take 4 to 5 large leaves (or the equivalent with smaller leaves) and tear them into small pieces. Place leaf pieces into a mortar. Add 1 to 2 mL of water to the mortar. Grind with pestle. Grind until the leaf pieces are no longer identifiable (approximately 2 minutes).
4. Using a capillary tube to transfer sample, make a small dot in the center of the pencil line on the chromatography paper. Let the dot dry and then reapply another small dot on top of the first one. Repeat this transfer eight (8) times. NOTE: The dot should be small and dark…not wide.
5. Attach a chromatography tape strip to a pencil like in the diagram below.
6. Add 10 mL water to the cup and label cup with the name of the sample. Place the pencil across the cup so the chromatography tape is touching the water (but not so deep that the dot is touching the water…refer to picture below). Repeat steps 3 - 6 for all leaf and spinach samples.



1. Allow the water to wick until it reaches the top pencil line. Remove the tape by lifting the pen off of the cup. The top pencil line now represents the distance the solvent front moved.
2. Place the chromatography tapes on the paper towel to dry.
3. Circle the color bands, with pencil, after the paper is dry.
4. Calculate the reference fronts for each band on the developed chromatography tape for each sample tested

distance solute center of gravity moved

Rf =

distance solvent front moved

11. Record results in data table below.

**Reference Front Values with Water as Solvent**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Spinach** | **Species 1**  **\_\_\_\_\_\_\_\_\_\_\_\_\_** | **Species 2**  **\_\_\_\_\_\_\_\_\_\_\_\_\_** | **Species 3**  **\_\_\_\_\_\_\_\_\_\_\_\_\_** |
| **Band 1** |  |  |  |  |
| **Band 2** |  |  |  |  |
| **Band 3** |  |  |  |  |
| **Band 4** |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
| **Pigment/s Visible** |  |  |  |  |

**Discussion:**

1. Can you identify which pigments are present? If so, which one/s are present?

Students should be able to at least see bands for anthocyanins pigments.

1. Does the season in which the leaves are picked affect their colors? Explain your answer.

Yes…answer should include at least that green pigments are visible during spring, summer, and early fall noting that leaves change color in the fall of the year.

1. Does the season that the leaves are picked affect the pigments? Explain your answer.

No…pigments (except chlorophyll) are present throughout the year but are not visible when chlorophyll is present.

1. Does the water solvent separate pigments that would be present in the leaves? Explain your answer.

Answers will vary based on the pigments that are water soluble and available in the leaves. Students should at least be able to identify that the green pigments in the spinach did not separate.

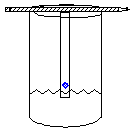
**Hickory Environmental Education Center**

**Exploration Activity 3**

**Paper Chromatography of Pigments in Leaves**

**Procedure:**

1. Prepare four chromatography strips following the same method as used previously in the marker investigation (Activity 1).
2. Take 4 to 5 large leaves (or the equivalent with smaller leaves) and tear them into small pieces. Place leaf pieces into a mortar. Add 1 to 2 mL of solvent assigned by your teacher (acetone or isopropyl) to the mortar. Grind with pestle. Grind until the leaf pieces are no longer identifiable (approximately 2 minutes).
3. Using a capillary tube to transfer sample, make a small dot in the center of the pencil line on the chromatography paper. Let the dot dry and then reapply another small dot on top of the first one. Repeat this transfer eight (8) times. NOTE: The dot should be small and dark…not wide.
4. Attach a chromatography tape strip to a pencil like in the diagram below.
5. Add 10 mL assigned solvent to the cup and label cup with the name of the sample. Place the pencil across the cup so the chromatography tape is touching the water (but not so deep that the dot is touching the solvent…refer to picture below).
6. Repeat steps 2 - 5 for all leaf and spinach samples.



1. Allow the water to wick until it reaches the top pencil line. Remove the tape by lifting the pen off of the cup. The top pencil line now represents the distance the solvent front moved.
2. Place the chromatography tapes on the paper towel to dry.
3. Circle the color bands, with pencil, after the paper is dry.
4. Calculate the reference fronts for each band on the developed chromatography tape for each sample tested

distance solute center of gravity moved

Rf =

distance solvent front moved

11. Record results in data table below.

**Reference Front Values with Alternate Solvent**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Solvent Used  \_\_\_\_\_\_\_\_\_\_\_\_\_ | **Spinach** | **Species 1**  **\_\_\_\_\_\_\_\_\_\_\_\_\_** | **Species 2**  **\_\_\_\_\_\_\_\_\_\_\_\_\_** | **Species 3**  **\_\_\_\_\_\_\_\_\_\_\_\_\_** |
| **Band 1** |  |  |  |  |
| **Band 2** |  |  |  |  |
| **Band 3** |  |  |  |  |
| **Band 4** |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
| **Pigment/s Visible** |  |  |  |  |

**Discussion:**

1. Can you identify which pigments are present? If so, which one/s are present?

Answers will vary based on the alternate solvent chosen.

1. Does the season in which the leaves are picked affect their colors? Explain your answer.

Yes…answer should include at least that green pigments are visible during spring, summer, and early fall noting that leaves change color in the fall of the year.

1. Does the season that the leaves are picked affect the pigments? Explain your answer.

No…pigments (except chlorophyll) are present throughout the year but are not visible when chlorophyll is present.

1. Did the alternate liquid work better or worse than the water that was used first and how?

Answers will vary but students should find that the alternate solvent were able to dissolve more pigments than the water due to the solubility properties of the pigments.

1. Explain how paper chromatography works.

The solvent dissolves the pigment and moves it up the strip as the solvent travels up the strip. Pigments will be deposited along the strip based on the size of the molecule. Larger molecules will be found closed to the bottom of the strip.

**Explanation Activity 4**

**Modeling of Organic Pigments**

**Concepts:** In science we attempt to model nature in order to understand natural phenomena. Modeling can be used to help students bridge the gap between the abstract two dimensional structural formulas and a more realistic three dimensional representation.

**Time and Location:** This activity should be done during the Exploration Activity and should take approximately 30 minutes.

**Materials:** per group

* “How Fall Colors Work” article
* Organic Chemistry models

**Procedure**: Each group is to choose one of the structural formulas of an organic pigment from the “How Fall Colors Work” article. They should then build a three dimensional representation of the molecule with the organic chemistry models. Take a photograph to compare the two dimensional structure with the 3D model structure. Include the photo, as well as a 2D representation of the model chosen in your lab report.

**Evaluation:**

What are some of the problems associated with trying to visualize what a larger organic molecule looks like from a two dimensional representation?

Students can’t see the curves and bending of the bonds formed between the atoms.

How did building the molecules help your understanding of what the molecule looks like?

Answers will vary based on students’ visual perception.

Look up your molecule at <http://www.drugbank.ca/> and find its 3D model and compare it to yours. How are they similar? How are they different?

Answers will vary but students may find that the orientation of atoms in the model may differ from the actual 3D shape.

Do the organic molecules have areas of polarity?

Answers will vary depending on the molecule studied.

Does the presence or lack of polarity on the pigment molecules have anything to do with how well the pigments were separated in the different liquids? Explain.

Yes…polar molecules will dissolve in polar solvents while non-polar molecules will dissolve in non-polar solvents.

**How Fall Colors Work**

**Leaf Colors**

The color of a leaf results from an interaction of different pigments produced by the plant. The main pigment classes responsible for leaf color are porphyrins, carotenoids, and flavonoids. The color that we perceive depends on the amount and types of the pigments that are present. Chemical interactions within the plant, particularly in response to acidity (pH) also affect the leaf color.

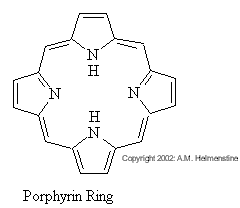
|  |  |  |
| --- | --- | --- |
| Pigment Class | Compound Type | Colors |
| Porphyrin | **chlorophyll** | green |
| Carotenoid | **carotene** and lycopene  xanthophyll | yellow, orange, red  yellow |
| Flavonoid | flavone  flavonol  **anthocyanin** | yellow  yellow  red, blue, purple, magenta |

**Chemistry of Plant Pigments**

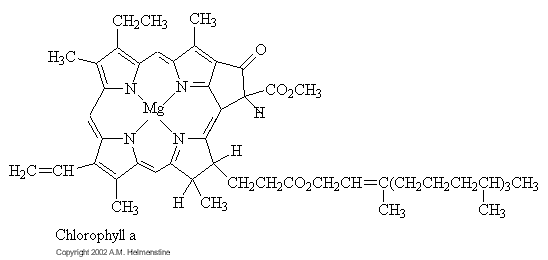
Let's take a closer look at the molecular structures and functions of the major plant pigments:

*Porphyrins*

All porphyrins have the following ring structure:

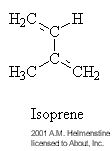


The primary porphyrin in leaves is a green pigment called chlorophyll. There are different chemical forms of chlorophyll (e.g., chlorophyll *a* and chlorophyll *b*), which are responsible for carbohydrate synthesis within a plant. Chlorophyll is produced in response to sunlight. As the seasons change and the amount of sunlight decreases, less chlorophyll is produced, and the leaves appear less green. Chlorophyll is broken down into simpler compounds at a constant rate, so green leaf color will gradually fade as chlorophyll production slows or stops.

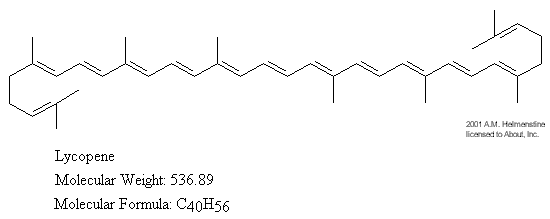


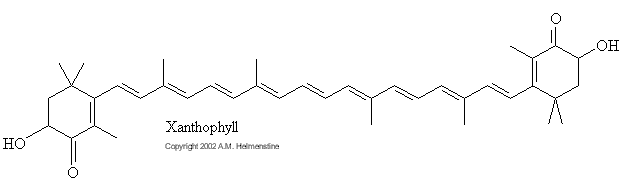
*Carotenoids*

[Carotenoids](http://chemistry.about.com/library/glossary/bldef525.htm) are [terpenes](http://chemistry.about.com/library/glossary/bldef862.htm) made of isoprene subunits.



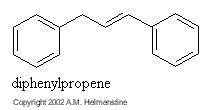
Examples of carotenoids found in leaves include [lycopene](http://chemistry.about.com/library/weekly/aa050401a.htm), which is red, and xanthophyll, which is yellow. Light is not needed in order for a plant to produce carotenoids, therefore these pigments are always present in a living plant. Also, carotenoids decompose very slowly as compared to chlorophyll.



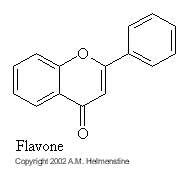
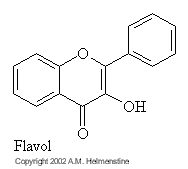


*Flavonoids*

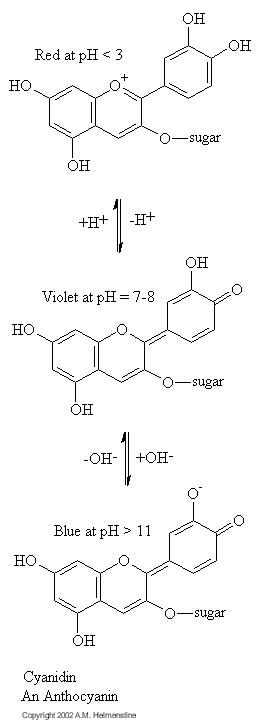
Flavonoids contain a diphenylpropene subunit.



Examples of flavonoids include flavone and flavol, which are yellow, and the anthocyanins, which may be red, blue, or purple, depending on pH.

Anthocyanins, such as cyanidin, provide a natural sunscreen for plants. Because the molecular structure of an anthocyanin includes a sugar, production of this class of pigments is dependent on the availability of carbohydrates within a plant. Anthocyanin color changes with pH, so soil acidity affects leaf color. Anthocyanin production also requires light, so sunny days are needed for the brightest fall colors!



**Autumn Color Change**

When leaves appear green, it is because they contain an abundance of chlorophyll. Chlorophyll masks other pigment colors. Anthocyanins, in turn, mask carotenoids. As summer turns to autumn, decreasing light levels cause chlorophyll production to slow. However, the decomposition rate of chlorophyll remains constant, so the green color will fade from the leaves. At the same time, anthocyanin production in leaves increases, in response to surging sugar concentrations. Leaves containing primarily anthocyanins will appear red. Leaves with good amounts of both anthocyanins and carotenoids will appear orange. Leaves with carotenoids but little or no anthocyanins will appear yellow. In the absence of these pigments, other plant chemicals also can affect leaf color. An example includes tannins, which are responsible for the brownish color of some oak leaves.

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**Hickory Environmental Education Center**

**Chemistry ALTERNATE Activity**

**NOTE:** If student was absent for any classroom activities associated with the HEEC activity, those activities must also be provided and completed by the student.

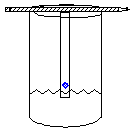
**Concepts:** Most materials in our world are mixtures. Very few materials are pure substances. The art of separating mixtures is important because it enables one to isolate pure substances. Paper chromatography is a modern method used to separate mixtures. Paper chromatography uses paper as the stationary phase and a liquid solvent as the mobile phase. Paper chromatography can be used to test leaves for different pigments.

**Materials:**

* coffee filters or paper towel
* 50 mL of each of the following liquids.
  + Isopropyl alcohol (90% rubbing alcohol from drug store)
  + Water
* clear plastic cups
* graduated cylinder
* tape
* 4 pencils
* scissors
* colored pencils
* 1 shallow pan
* 4 small jars with lids
* leaves (spinach, red leaved tree, yellow leaved tree, conifer)

**Procedure:**

1. Find leaves of three different colors/species (red leaved tree, yellow leaved tree, conifer) and a sample of spinach leaves from the store. Use the following website to identify species of leaves. <http://harvardforest.fas.harvard.edu/research/leaves/Autumn_leaves.html>
2. Take 4-5 large leaves (or the equivalent with smaller leaves), tear them into tiny pieces, and place them into small jars with lids.
3. Add enough alcohol to just cover the leaves.
4. Loosely cover the jars and set them into a shallow pan containing an inch or so of hot tap water.
5. Let the jars sit in the hot water for at least a half hour. Replace the hot water in the shallow pan as it cools and swirl the jars from time to time.
6. While you are waiting for the pigments to steep, start the Modeling of Organic Pigments Activity.
7. The pigment extraction is finished when the alcohol has picked up color from the leaves. The darker the color, the brighter the chromatogram and the better the results will be.
8. Cut a strip of coffee filter paper (or paper towel) 2 to 3 cm wide and long enough to reach from the bottom of the jar to the top. Lay one pencil horizontally and tape the paper strip vertically to the pencil so that the bottom of the paper just touches the top of the liquid in the jar when the pencil is placed across the opening of the jar (see diagram).



9. Repeat step 7 so there is one strip attached to a pencil for each of the four jars of pigments.

10. Place one strip of paper into each jar by resting the pencil across the opening of the jar.

11. As the alcohol evaporates, it will pull the pigment up the paper, separating pigments according to

size (largest will move the shortest distance).

12. After 30-90 minutes (or until the desired separation is obtained), remove the strips of paper and

immediately mark the height that the solvent (alcohol) has traveled. Allow the strips to dry.

13. Circle the color bands, with pencil, after the paper is dry.

14. Calculate the reference fronts for each band on the developed filter paper for each sample tested

using the formula below.

distance solute center of gravity moved

Rf =

distance solvent front moved

Record your results in the data table below.

**Reference Front Values with Alcohol**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Spinach** | **Species 1**  **\_\_\_\_\_\_\_\_\_\_\_\_\_** | **Species 2**  **\_\_\_\_\_\_\_\_\_\_\_\_\_** | **Species 3**  **\_\_\_\_\_\_\_\_\_\_\_\_\_** |
| **Band 1** |  |  |  |  |
| **Band 2** |  |  |  |  |
| **Band 3** |  |  |  |  |
| **Band 4** |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
| **Pigment/s Visible** |  |  |  |  |

**Discussion:**

1. Can you identify which pigments are present? If so, which one/s are present?

Answers will vary but should include chlorophyll, caroteniods, and flavonoids.

1. Does the season in which the leaves are picked affect their colors? Explain your answer.

Yes…answer should include at least that green pigments are visible during spring, summer, and early fall noting that leaves change color in the fall of the year.

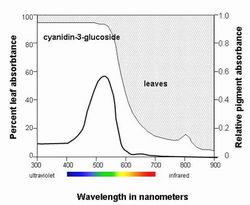
1. Does the season that the leaves are picked affect the pigments? Explain your answer.

No…pigments (except chlorophyll) are present throughout the year but are not visible when chlorophyll is present.

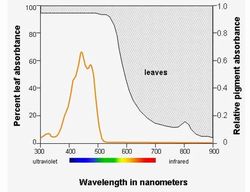
1. Explain how paper chromatography works.

The solvent dissolves the pigment and moves it up the strip as the solvent travels up the strip. Pigments will be deposited along the strip based on the size of the molecule. Larger molecules will be found closed to the bottom of the strip.

1. The following pictures show the color change in two tree species commonly found in Garrett County. The graph to the right of each picture shows the absorbance of light wave lengths by the leaf and its pigments.

Red Oak

Witch Hazel

**NOTE:** The graphs above for percent leaf absorbance show the percentage of light by wavelength that is being absorbed by the leaf. A higher absorbance percentage for a wavelength of light means this wavelength is not as visible in the reflected wavelengths of light seen by the naked eye.

1. What is the apparent color of each species of leaf?

Red Oak-red

Witch Hazel-yellow

1. What colors of light are being reflected by each species of leaf?

Red Oak-red

Witch Hazel-yellow

1. What colors of light are being absorbed by each species of leaf?

Red Oak-all colors but red

Witch Hazel-all colors but yellow

1. Based on the wavelength graphs for each species, identify the wavelength (in nm) which is being absorbed at the highest percentage. Do both species absorb light at the same wavelength? Explain your answer.

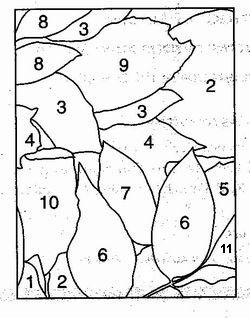
No…red oaks absorb most light at approximately 530 nm; witch hazels absorb most light at approximately 430 nm.

1. What is the significance of your answer in part d?

Percentages of reflected light at each wavelength determine the light which is picked up by the human eye and is interpreted as a specific combined color and not white due to some wavelengths being absorbed by the leaf.

# The Plants of Autumn Foliage Color

**NOTE:** All of the specimens below are on the HEEC property.

[Conifers](http://harvardforest.fas.harvard.edu/research/leaves/plants.html#conifers), [yellow](http://harvardforest.fas.harvard.edu/research/leaves/plants.html#yellow) and [red](http://harvardforest.fas.harvard.edu/research/leaves/plants.html#red) leaved flowering shrubs and trees are the most important plants in providing color during the autumn at the Harvard Forest. For the most part, these are the plants that we have studied, and information about them will be provided in the [science sections](http://harvardforest.fas.harvard.edu/research/leaves/science.html). The above photograph provides a look at their leaves together in mid-October, when the colors are at their peak.

The species in the photograph are:

1. [witch hazel](http://harvardforest.fas.harvard.edu/research/leaves/plants/witchhazel.html)
2. [hobble bush](http://harvardforest.fas.harvard.edu/research/leaves/plants/hobblebush.html)
3. [northern wild-raisin](http://harvardforest.fas.harvard.edu/research/leaves/plants/raisin.html)
4. [sugar maple](http://harvardforest.fas.harvard.edu/research/leaves/plants/sugar_maple.html)
5. [red maple](http://harvardforest.fas.harvard.edu/research/leaves/plants/red_maple.html)
6. [ash](http://harvardforest.fas.harvard.edu/research/leaves/plants/white_ash.html)
7. [black cherry](http://harvardforest.fas.harvard.edu/research/leaves/plants/black_cherry.html)
8. [high bush blueberry](http://harvardforest.fas.harvard.edu/research/leaves/plants/blueberry.html)
9. [Yellow birch](http://harvardforest.fas.harvard.edu/research/leaves/plants/yellowbirch.html)
10. [beech](http://harvardforest.fas.harvard.edu/research/leaves/plants/beech.html)
11. [Striped Maple](http://harvardforest.fas.harvard.edu/research/leaves/plants/striped_maple.html)

## CONIFERS

Conifers provide the green backdrop during the autumn color changes in New England forests. These are principally white pine and hemlock, although other pines may be introduced in plantations. Larches are the only conifers in these forests which lose their needles completely during the fall. These trees produce an autumn show of bright yellow in the swampy areas where they grow. The European larch may be introduced in plantations or in landscaping, to provide more autumn yellow color.

* [American Larch](http://harvardforest.fas.harvard.edu/research/leaves/plants/american_larch.html)
* [Eastern Hemlock](http://harvardforest.fas.harvard.edu/research/leaves/plants/eastern_hemlock.html)
* [White Pine](http://harvardforest.fas.harvard.edu/research/leaves/plants/white_pine.html)

## Red-leaved Flowering Shrubs and Trees

All of these shrubs and trees produce varying amounts of anthocyanins during senescence. Sometimes these pigments are produced uniformly in the leaves, but often distinct patterns.

* [Alternate-Leaved Dogwood](http://harvardforest.fas.harvard.edu/research/leaves/plants/alt_leaf_dogwood.html)
* [Black Cherry](http://harvardforest.fas.harvard.edu/research/leaves/plants/black_cherry.html)
* [Black Chokeberry](http://harvardforest.fas.harvard.edu/research/leaves/plants/black_chokeberry.html)
* [High-Bush Blueberry](http://harvardforest.fas.harvard.edu/research/leaves/plants/blueberry.html)
* [Hobblebush](http://harvardforest.fas.harvard.edu/research/leaves/plants/hobblebush.html)
* [Northern Wild Raisin](http://harvardforest.fas.harvard.edu/research/leaves/plants/raisin.html)
* [Red Maple](http://harvardforest.fas.harvard.edu/research/leaves/plants/red_maple.html)
* [Red Oak](http://harvardforest.fas.harvard.edu/research/leaves/plants/red_oak.html)
* [Red-Osier Dogwood](http://harvardforest.fas.harvard.edu/research/leaves/plants/osier_dogwood.html)
* [Scarlet Oak](http://harvardforest.fas.harvard.edu/research/leaves/plants/scarlet_oak.html)
* [Juneberry (Serviceberry, Shadbush)](http://harvardforest.fas.harvard.edu/research/leaves/plants/serviceberry.html)
* [Black (Sour) Gum](http://harvardforest.fas.harvard.edu/research/leaves/plants/sourgum.html)
* [Sugar Maple](http://harvardforest.fas.harvard.edu/research/leaves/plants/sugar_maple.html)
* [Stag-horn Sumac](http://harvardforest.fas.harvard.edu/research/leaves/plants/sumac.html)
* [White Ash](http://harvardforest.fas.harvard.edu/research/leaves/plants/white_ash.html)
* [White Oak](http://harvardforest.fas.harvard.edu/research/leaves/plants/white_oak.html)

## Yellow-Leaved Flowering Shrubs and Trees

All of these species turn yellow during the autumn, due to the breakdown of chlorophyll and the retention of some carotenoid pigments in their plastids. In a few cases, small amounts of anthocyanins may be produced, sometimes only in a few individuals in a population.

* [American Beech](http://harvardforest.fas.harvard.edu/research/leaves/plants/beech.html)
* [American Chestnut](http://harvardforest.fas.harvard.edu/research/leaves/plants/chestnut.html)
* [Big-Toothed Aspen](http://harvardforest.fas.harvard.edu/research/leaves/plants/bigtooth_aspen.html)
* [Gray Birch](http://harvardforest.fas.harvard.edu/research/leaves/plants/gray_birch.html)
* [Quaking Aspen](http://harvardforest.fas.harvard.edu/research/leaves/plants/quaking_aspen.html)
* [Striped Maple](http://harvardforest.fas.harvard.edu/research/leaves/plants/striped_maple.html)
* [Tulip Poplar](http://harvardforest.fas.harvard.edu/research/leaves/plants/tulip.html)
* [Winterberry Holly](http://harvardforest.fas.harvard.edu/research/leaves/plants/holly.html)
* [Witch Hazel](http://harvardforest.fas.harvard.edu/research/leaves/plants/witchhazel.html)
* [Yellow Birch](http://harvardforest.fas.harvard.edu/research/leaves/plants/yellowbirch.html)

**NOTE:** For additional help identifying the above species the following website provides links to the identification. <http://harvardforest.fas.harvard.edu/research/leaves/plants.html>

**Hickory Environmental Education Center**

**Strange Planets Activity 5**

**Day 1 – Activity** - Astronomy and spectral analysis “Strange Planets” (Planetarium)

Questions:

1. How are the different ways that light can be measured?
2. How are a light’s frequency, wavelength and energy related?
3. What are the units for a light’s frequency, wavelength and energy?
4. What are the assigned symbols for a lights frequency and wavelength?
5. What is the difference between and absorption spectrum and emission spectrum?
6. How can spectrums be used to identify different elements?
7. How can the shifting of wavelengths of light be used to determine if an object in space is coming toward or away from Earth?
8. How can the bending of light due to gravity be used to determine the size of ex planets and how far they are away from their sun?