WATERSHED Investigations

12 Labs for High School Science

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Jennifer Soukhome, Graham Peaslee, Carl Van Faasen, and William Statema

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PREFACE

This lab manual was developed over the past three summers as a result of our efforts to study the environmental anthropogenic effects on watersheds. Most of the labs examine the ecological consequences that can happen in a watershed as urbanization increases and natural hydrology changes, while some of the labs have been included to provide necessary background information that is needed before completing later investigations.

The premise of this lab manual is that it can be used in any high school experiment-based environmental science curriculum. This manual is appropriate for upper high school students, as well as the younger grades. For example, modified laboratory procedures for this manual have been tested in a 9th grade Earth science classroom. By the nature of environmental science, the experiments cover a broad range of disciplines: geology, chemistry, Earth science, and biology and meet a wide array of state and national curricular standards. Each laboratory contains ideas to suggest in what type of class the teacher may find the laboratory useful.

There are 12 different laboratory exercises included and half of them have an extensive open-ended inquiry approach that we feel is essential for conveying some of the excitement of discovery along with the methods of scientific research and relevant examples of textbook subject material. Each laboratory could be taught in a traditional prescriptive manner, but we encourage the high school teacher to adopt some of or all of the inquiry-based learning activities included in many of the laboratories. As an example the "Allelopathy" investigation in Chapter 5 has students compare invasive and/or native plants and how their chemical components may affect the germination rate of lettuce seeds. The students develop a hypothesis and design an experiment to test the problem. They are given the methods by which to extract the chemicals from the plant material and tools for statistical testing. In another investigation, students compare the effect of stream channel morphology on the rate of sediment transport by using a Styrofoam stream table. As in the allelopathy lab, students must develop a hypothesis and design an experiment to test it.

When students in our classes are first asked to do a lab as inquiry, quite a bit of resistance is typically encountered. For most students, this will be the first opportunity for them to develop an investigation in a science class. A lot of time needs to be spent reassuring the students and repeating the steps of development and referring them back to their instruction sheet. However, after the first inquiry lab or two, future inquiry labs will be a lot less demanding on the teacher as students will be familiar with the expectations. After a term with many inquiry labs, many students are enthusiastic for more.

When conducting inquiry labs with students, it is always fascinating to see what the students develop and in what direction they take the lab. Instead of having the same lab that all students complete, the result is a variety of different lab procedures which all have been designed to examine the same problem. Since the students are responsible for the development of the lab, form their own hypothesis, and analyze their own data, they seem to have better retention of the information. Teachers can often learn from the students' results and students will teach each other in many cases.

Another advantage of having several different labs is that while there always is a chance of lab failure when there are several different labs being conducted the chances are that most of them will convey what was desired. In addition, the teacher is there guiding the students through the process, giving approval to their procedures and learning from the results just as the students do. This can often transform the teacher from a central authority figure to a coach on a shared adventure. Classroom discussion of everyone's lab about what worked and what didn't is always recommended. It does give students a chance to see that science is a process and sometime things may not work as planned. On the flip side, your students may discover new things that you had not thought of and bring in a new perspective as ours have done in almost every inquiry-based lab.

It is hard to turn over the control of your classroom to the students and give them some autonomy, but it is well worth it. Since we have been using inquiry labs and field work, we have seen students become more excited about their learning. We often have students tell us they shared what they learned with their friends or family. We have even had some students gain such an interest that they have decided to pursue a career in science. Here is an example of one such case. Stacy came into one of our classes as a senior and was decidedly going to school for culinary arts after graduation. Upon the completion of the course she wrote, "I would like to further my education in plants or animals and this hooked my interest in this type of study. I really did enjoy this class a lot."

Other labs in the manual emphasize field work and critical thinking skills. One of the field exercises teaches students how to identify plants. In a more traditional data analysis lab, students use data from the USGS website to construct a hydrograph of a river and predict the recurrence interval and probability of different flooding episodes. There is plenty of background information for teachers who may not be comfortable with these topics.

As you can see from the table below most of the labs cover the inquiry strand in the Michigan science curriculum and in the national standards.

Table 1. Michigan and National Science Standards Covered by Labs

Chapter in Lab Manual	Michigan Curriculum Objectives Covered	National Science Standards Covered
Ch 1: Modeling Glacial Features with Sand	E3.p1A E4.p3A	C.4.b.13
Ch 2: Glacial Features of a Watershed	E4.p3C	C.4.b.13
Ch 3: Plant Identification		C.2.a.2
Ch 4: Wetland Delineation	E4.p1D	C.2.b.20
Ch 5: Allelopathy	B1.1-ALL B1.2A-D B1.2f,j,k B3.4C B3.5C	C.2.a.2,3 C.2.b.14,20 C.2.c.25
Ch 6: Stream Channel Morphology	E1.1-ALL E1.2A-D E1.2f,j,k E3.p1B E4.p1C	C.4.a.3 C.4.b.19,21
Ch 7: Calculating Stream Discharge	E4.p1B	C.4.c.26
Ch 8: Flood Frequency Analysis	E4.p1C	C.4.c.26
Ch 9: Comparison of Phosphorus Levels in Stream Sediments	E1.1-ALL E1.2A-D E1.2f,j,k E4.1C	C.2.b.18,20
Ch 10: Aquatic Macroinvertebrates as Water Quality Indicators		C.4.a.12
Ch 11: Factors that Affect Eutrophication	E1.1-ALL E1.2A-D E1.2f,j,k E4.1C	C.2.b.18,20
Ch 12: Groundwater Contamination	E1.1-ALL E1.2A-D E1.2f,j,k E3.p1B E4.p1C	C.4.a.12 C.4.b.21

The labs in this manual are presented in a logical order although they do not need to be completed in this order. Furthermore, the teacher does not need to complete all of the labs and does not need to feel locked into any type of format. In certain instances the lab may fit into the class better as inquiry-based and at others only the traditional approach would work. A teacher that is not familiar with the material or inquiry learning may choose the traditional approach only for the first year until their comfort level increases. All of the investigations contain a large portion of background information whereas the student sheets contain the bare minimum, the teacher can cut and paste this background information as they see fit. Teachers should be able to use all these investigations right out of the book but also could choose to tailor any of the investigations to fit their own classroom needs.

While this laboratory manual was written with a specific watershed in mind, teachers all over the United States will be able to use the experiments. Reference information is given when appropriate for teachers to access information for their own watershed. However, teachers may wish to use the book as is and turn the watershed this book was based on into a case study for their classrooms. In that event, a brief history of the watershed has been included as an appendix at the back of this manual with a website where additional information can be obtained. In addition, teachers will also find a rubric for writing laboratory reports and the corresponding rubric in the appendix as well.

The experiments in this manual were developed, classroom tested, and written up as a result of a collaborative effort coordinated by Dr. Graham Peaslee, supported by Hope College, the National Science Foundation, the Michigan Space Grant Consortium, the Holland/Zeeland Community Foundation, and the Macatawa Coordinating Council. We would like to thank the following people in particular for their support: Dr. Winnett Murray, Dr. Cronkite, Dr. Murray, Dr. Stewart all from Hope College, Holland Michigan and Sue Higgins and Beth McDonald both from the Macatawa Area Coordinating Council, Holland, Michigan.

ABOUT THE AUTHORS

Jennifer Soukhome earned her Bachelor Degree in Education from Ferris State University in 1996 where she majored in biology and minored in general science. She then went on to earn her chemistry certification and Masters Degree in Education with an emphasis in Biology from Grand Valley State University in 2002. She has been a high school science teacher since 1997 in Zeeland, Michigan at Zeeland West High School. During that tenure, she has taught 9-12th graders subjects ranging from academic support, biology, chemistry for the community, chemistry, physical science, earth science and wetland ecology. She wrote the curriculum for the wetland ecology class as her master thesis project and was awarded the Macatawa Watershed Stakeholder of the year award for the development of the wetland ecology class which has been successfully running since 2003. Jennifer has been active in education during the summers by participating in Hope College's Howard Hughes Medical Institute Summer Research program where she has been a co-coordinator of the education scholars program for two summers. She resides in Holland, Michigan with her family.

Graham Peaslee is a professor of Chemistry and Environmental Science at Hope College, in Holland, Michigan. He received his bachelor's degree in chemistry from Princeton University, and his Ph.D. in chemical physics from SUNY Stony Brook. He is trained as a nuclear chemist and has been active in nuclear science research for more than 25 years. During this time he has published over 125 research articles. He has been at Hope College for the past 14 years and during that time has become heavily involved in undergraduate education and educational reform as well. He won the Hope Outstanding Professor and Educator award from the Hope College senior class of 2000, and has co-written several teaching cases, one on nuclear science published in the Journal of College Science Teaching. His research projects have expanded into environmental science, and he has helped to co-develop the environmental science minor at Hope College. He has been actively involved in the technical subcommittee of the Watershed Project of the Macatawa Area Coordinating Council and lives in the Macatawa Watershed with his family.

ABOUT THE AUTHORS

Carl Van Faasen was born and raised in Holland, Michigan. He graduated from Holland High School in 1987, and graduated with a B.S. from Hope College in 1992 where he majored in biology and chemistry and minored in physics and math. In 1999, he received his M.Ed from Grand Valley State University. He has been employed as a high school Chemistry teacher for the past 16 years, mostly at Holland High School. Currently he has been working to incorporate phosphorus monitoring in the curriculum by implementing a Macatawa Watershed class. He has a wife, Pamela, and two children, Neil and Cora.

William Statema was born in the small town of Zeeland, Michigan in 1984. He graduated from Zeeland High School in 2003, and earned his bachelor's degree in Chemistry Education from Hope College in 2007. After college, William moved out to the Chicagoland area where he is teaching chemistry in the Niles Township School District. William is happily married and continues to pursue further education in the sciences.

CHAPTER 3

Plant Identification

Teacher Information

Background

This investigation gives students the opportunity to view the outside world and bring science into the field. Teaching students how to identify plants gives them a greater appreciation for nature, just as learning to read words lets young students begin to appreciate literature. As older students learn to identify plants, they become educated about what lives in the watershed and they develop a greater desire to preserve it. They also become familiar with invasive species that may be invading their watershed.

Many students do not like the memorization that comes with plant taxonomy, but with modest effort everybody can successfully identify by name most of the plants in their community. By the end of this field exercise, students will feel pride in their identification abilities.

Objective

To teach students common plant species that they will encounter in the watershed.

Materials

- dichotomous key (teacher's choice)
- plant specimens (for possible species, see Table 3.1 at the end of the section "Answers to Questions in Student Handout")

Suggested Class Preparation and Format

Teaching plant identification in the field can feel overwhelming, but it does not have to be if the students are prepared for the activity. It is up to you to determine how much time to spend on plant identification; as familiarity grows, this exercise can become more extensive each year. Identification can be taught alone or with other topics. For example, plant identification most likely would be included in a biology unit on plants. Plant identification would also be useful in an ecology unit with plant population counts or in a unit on invasive species.

Preparation time for this investigation will depend on your familiarity with using dichotomous keys and existing plant knowledge. A visit ahead of time to the location that the students will explore is highly recommended. Identifying all the plants could take a relatively short time or an extended time period, depending on the degree of prior knowledge of plants.

Some counties offer plant identification programs through the parks and recreation department. For example, in Ottawa County, Michigan, this department offers basic plant identification along with Dune Ecology and Winter Botany programs. You could also check with local colleges and university extension services and contact a botany professor for recommendations and information. It is likely that a local park exists with at least some of the trees already identified along the trails.

You need to select a key or book to teach plant identification. There is a plethora of dichotomous keys on the internet (e.g., *www.for.msu.edu/extension/ExtDocs/Identkey/opening.htm*), but because books are still the most portable of field equipment, using a book with a dichotomous key is the best choice. The Peterson Field Guide Series is one option for tree identification; this series is useful because the investigation is targeted toward tree identification. Once the primary knowledge is gained, herbaceous plants could be included. A nice guide that uses a dichotomous-type key for flowers is *Newcomb's Wildflower Guide* (Newcomb 1977), which covers flowers in northeastern and north-central America.

If you need to brush up on plant terminology, refer to the plant identification book(s) selected for the investigation. These books contain definitions, explanations, and pictures. The Student Handout included in this investigation contains some definitions and illustrations of very basic terms.

Use the first class period (indoors) of the identification unit to teach students what a dichotomous key is and how to use it, as well as basic plant terminology and leaf morphology. The best way to teach the terminology is to first show students a picture from the identification book and then show them several fresh specimens in the classroom (five different specimens are enough). Additional class periods indoors may be necessary to teach the basics before taking students into the field. For a wrap-up exercise indoors, have students complete their worksheets on basic plant terminology; alternatively, you can ask them to fill out the worksheets as the material is introduced. Additional plant specimens will be needed to complete the worksheet. You should use the same specimens that students were shown in class, along with some specimens they have not seen before.

Once the students have a good grasp on how to use the dichotomous key, take them outside and have them work in pairs to "key out" the plants. To keep students who finish early engaged, assign them additional species to identify. Have students keep a field notebook of all plants identified, listing habitat and major characteristics. Give the students helpful hints along the way to aid them in their memorization; for example, the peeling bark of a sycamore tree can make it look "sick"; black cherry bark looks like burnt potato chips; and the mnemonic MAD HORSES, which stands for maples, ashes, dogwoods, and horse chestnuts, can be used to identify trees that have opposite leaves. Most other tree families commonly encountered will have alternate leaves.

Plant identification can be done anywhere. City areas may have a great number and variety of tree species, but if the opportunity exists, take a field trip to a natural area near you.

SCILINKS THE WORLD'S A CLICK AWAY
Topic: How are plants classified?
Go to: *www.scilinks.org*
Code: WAT004

Tips for Identifying Plants

1. Examine the plant and determine if the leaves are opposite or alternate.
2. Look at an individual leaf and follow the leaf stalk back until you see the bud. Is the leaf compound or simple?
3. Look at the leaf shape and margins.
4. Examine the bark.
5. Use these observations with a dichotomous key to identify the plant.

Optional Extensions

- Have your students teach basic plant identification to elementary students. This provides a great assessment for the high school student and gives the elementary student a safe and supervised encounter with nature.
- Have your students make a guided walking trail by making labels for trees and plants they have identified. Index cards with information can be laminated inexpensively at a copy center.
- Have your students make a herbarium collection, which is a collection of dried plant specimens preserved on herbarium-quality paper. Instructions for preserving plant specimens and a herbarium collection rubric are included at the end of the Teacher Information section. The collection should be limited to 25 specimens; a larger collection will require too much time and effort. The rubric gives students a list of specimens to choose from; the list includes plant species in the Midwest, but feel free to make your own list using species with which you are familiar.

Answers to Questions in Student Handout

1. alternate, opposite, whorled
2. simple, palmately compound, pinnately compound
3. serrated, entire, lobed
4. See Table 3.1 for possible species and answers to this question.

Table 3.1. Possible Species of Plants to Use in Class With Students With Answers

Species Name	Opposite, Alternate or Whorled	Blade Type: Simple or Compound	Margin of Blade: entire, serrated, undulated, lobed
Any species of Maple (except Ashleaf aka Boxelder)	Opposite	Simple	Lobed (With the different species notice the shape of the sinus. Some are "V" shaped and some are "U" shaped indicating its species.
Red, Black, White, Bur Oak	Alternate (oak leaves tend to cluster)	Simple	Lobed (With the different species notice how the lobes tip differ, each difference indicating its species.)
Bitternut Hickory	Alternate	Pinnately Compound	serrate
Any species of Ash	Opposite	Pinnately Compound	Entire to serrate depending upon species
Redbud	Alternate	Simple	Entire with leaf having a heart shape
Ohio Buckeye or Horsechesnut	Opposite	Palmately Compound	serrate

References

The leaf: parts. n.d. *www.botanical-online.com/lahojaangles.htm*

Newcomb, L. 1977. *Newcomb's Wildflower Guide*. New York: Little, Brown.

Petrides, G. A. 1973. *A field guide to trees and shrubs: Northeastern and north-central United States and southeastern and south-central Canada*. New York: Peterson Field Guides. Houghton Mifflin Harcourt.

SCILINKS THE WORLD'S A CLICK AWAY

Topic: Plant Characteristics
Go to: *www.scilinks.org*
Code: WAT005

Preserving Plant Specimens

Collecting Specimens

Select specimens for the collection that are free from any type of blemish. Use a knife or scissors to cut branches. For herbaceous plants (plants that are fleshy), cut the stem off all the way to the ground. Make sure when cutting trees or herbaceous plants that the specimen has enough leaves to determine leaf arrangement. When cutting flowers, one is sufficient. Include seeds with the specimen whenever possible. When collecting, identify the plant first before collecting it. Write the specimen's name on a piece of masking tape and wrap the tape around the stem or branch of the plant. Place the specimen in a plastic bag (such as a plastic grocery bag) with some wet paper towels. Keep the bag closed at all times. The wet paper towels keep the humidity high inside the bag to keep the plants from wilting. Plants should be pressed as soon as possible. If unable to press plants the same day, place the closed bag inside of a refrigerator. Most plants will keep for a few days.

Plant Press

Lay out the specimen on one side of a piece of a newspaper that is folded in half. Make sure the leaves are not overlapping and one leaf is turned over. Sometimes this can be tricky. Masking tape can be used to tape down branches. If using masking tape for the branches, put it on your fingers several times to take off most of the stickiness so it will not damage the specimen. Do not use masking tape on the leaves, because the tape will rip them when they are dry.

Fold the remaining half of the newspaper over the specimen. Write the species name on margin of the newspaper for later use.

Put several newspapers and, if available, a piece of corrugated cardboard in between specimens. Set heavy objects such as books on top of the stack of specimens, and wait three to five days for the specimens to dry. Try to place them in a location with little humidity, and use a fan (if available) to speed up the evaporation of the water from the plants.

Mounting Specimens

Once the plants are dry, the best thing to display them on is 11½ in. × 16½ in. herbarium paper. There are herbarium pastes that can be purchased to glue specimens to the paper, but any white glue will suffice. Never tape or staple specimens to the paper. Use your finger or a paintbrush to spread a thin layer of glue over the entire leaf surface. After covering all of the leaves on the specimen and its stem, affix the specimen to the paper. When gluing down, make sure to keep the one leaf that was turned over in the drying process so the back can be seen. Some species of plants, such as poplars or aspens, naturally turn a blackish color when dried; others tend to bubble up. These types of things are to be expected and should not cause any deduction of points on the collection. Do not cover the specimens with any type of plastic or contact paper. It is important that the viewer be able to touch the specimens for identification.

Labeling

Each specimen needs a label in the lower left corner of the herbarium paper. As shown in the sample label format below, the label should include the following information: Latin name of the plant; family name of the plant; common name of the plant; your name; date collected; city or township, county, and state where collected; specific location of collection; and habitat. The label may be typed or written in black ink.

Name of High School

Name of class, year

Latin Name ______________________________

____

Family Name ______________________________

Common Name ______________________________

Collected by ______________________________

Date of Collection ______________________________

City or Township, County, and State of Collection

____

Specific Location of Collection ______________________________

____

Habitat ______________________________

Turning in the Collection

The collection must be in alphabetical order according to family. Prepare a table of contents for the collection that consists of the family name, Latin name, common name, and page number for each specimen. Place specimens with the table of contents and the rubric on top in a brown paper bag, and turn the collection in to the teacher.

Herbarium Collection Rubric

Name______________________________

The herbarium collection is due on ____________. Every day (not class day) the collection is late, 10 points will be deducted. Two (2) points will be awarded for correctly identifying the specimen and 2 points will be awarded for quality of specimen and accuracy of information, giving a maximum of 4 points per specimen for a maximum total of 100 points.

Include 25 of any species listed below in your collection. Please check off the species included in the collection.

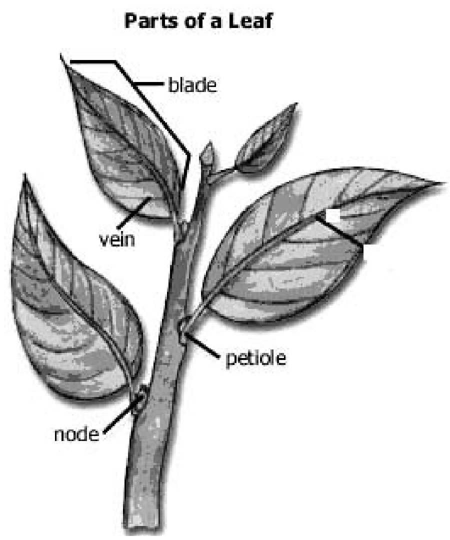
- ☐ maple (any species)
- ☐ sumac (any species)
- ☐ pawpaw
- ☐ Queen Anne's lace
- ☐ yarrow
- ☐ knapweed (any species)
- ☐ aster (any species)
- ☐ touch-me-not
- ☐ alder (any species)
- ☐ birch (any species)
- ☐ American hornbeam
- ☐ hop hornbeam
- ☐ milkweed (any species)
- ☐ dogwood (any species)
- ☐ redbud
- ☐ Kentucky coffee tree
- ☐ bird's-foot trefoil
- ☐ clover (any species)
- ☐ cow vetch
- ☐ American beech
- ☐ oak (any species)
- ☐ ginkgo
- ☐ witch hazel
- ☐ American chestnut
- ☐ Ohio buckeye
- ☐ horse chestnut
- ☐ hickory (any species)
- ☐ walnut (any species)
- ☐ catnip
- ☐ spicebush
- ☐ sassafras
- ☐ tulip tree
- ☐ black gum
- ☐ sweet gum
- ☐ ash (any species)
- ☐ sycamore
- ☐ cherry (any species)
- ☐ swamp rose
- ☐ aspen (any species)
- ☐ elm (any species)
- ☐ basswood
- ☐ blue vervain
- ☐ Virginia creeper
- ☐ boneset
- ☐ joe-pye weed
- ☐ purple loosestrife
- ☐ evening primrose

Plant Identification

Student Handout

Background

In this investigation you will identify different types of trees by learning plant morphology terms and how to use a dichotomous key. Being able to identify common plants you encounter every day will make you more aware of the diversity that exists among plants.



Typically, a leaf consists of a flattened laminar portion (the blade), and a leaf stalk (the petiole), which attaches it to the stem (see illustration). The node is the point of leaf attachment where buds can be seen. The laminar (thin and platelike) shape allows the leaf to absorb light energy and allows for gas exchange.

Although the internal construction of the many thousands of angiosperm (flowering plant) species is similar, the external form of the leaf is highly variable. This variability is often critical to the identification of the plant. There are three major features to look for when identifying the leaf of a plant:

1. the arrangement of the leaves—alternate, opposite, or whorled,
2. the type of leaf blade—simple or compound, and
3. the margin of the leaf blade.

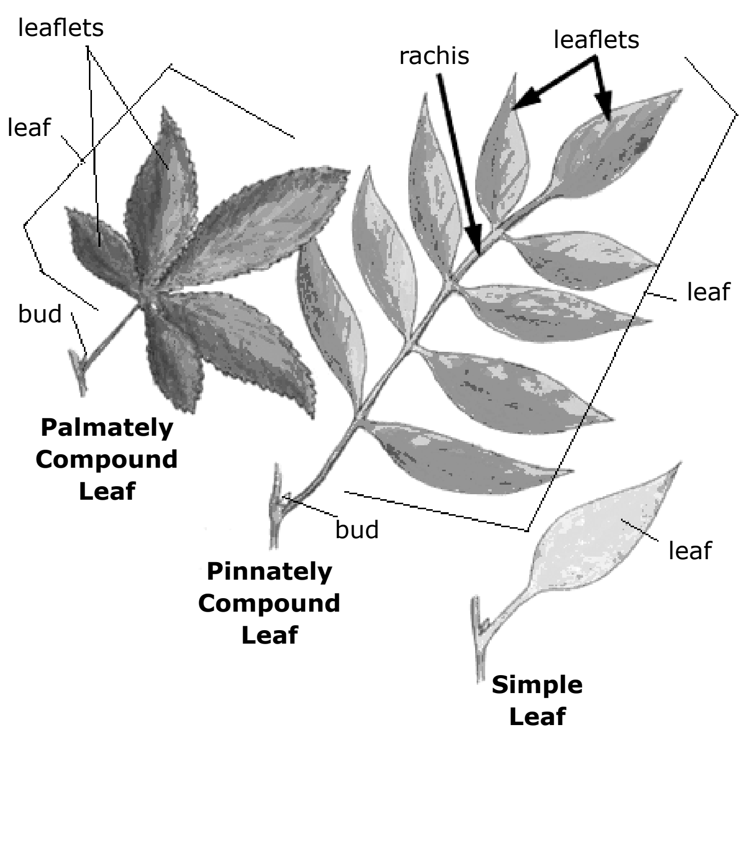
Arrangement of Leaves

The leaf may be attached directly opposite another leaf, or it may alternate attachments with leaves on the other side, or it may have many leaves that "whorl" around the stem. You can determine whether a leaf is opposite, alternate, or whorled simply by examining the arrangement of the leaves on the stem (see illustrations p. 25).

Type of Leaf

A simple leaf consists of a single blade. A compound leaf consists of a blade composed of a number of separate, leaflike parts known as leaflets. When leaflets branch off all the way along a central axis (rachis), the leaf is said to be pinnately compound. Pinnately compound leaves may be once, twice, or thrice pinnately compound depending on the number of leaflets branching off along the petiole. When the leaflets are all attached at a common point near the tip of the petiole, the leaf is said to be palmately compound. The illustration below shows simple and compound leaves.

Types of Leaves



SCILINKS
THE WORLD'S A CLICK AWAY
Topic: Plant Structure
Go to: *www.scilinks.org*
Code: WAT006

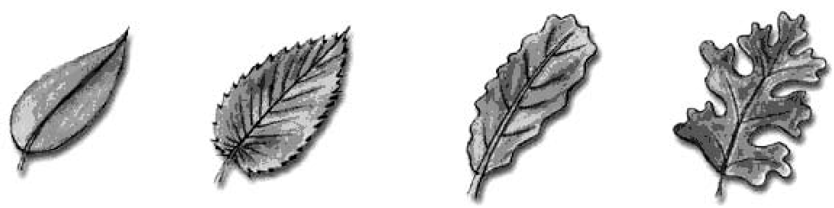
You can distinguish whether a leaf is simple or compound by examining its stem and nearest neighboring leaves. Note that buds occur on the branch at the base of the petiole of leaves and do not occur at the base of leaflets. Also, the blades of simple leaves are oriented in many different planes on the stem, whereas the blades of leaflets all occur in the same plane.

In many angiosperms, the leaf has a pair of small appendages (stipules), attached to the base of the petiole. Don't confuse these stipules with the buds.

Margin of the Leaf

The margins of the leaf blade for different species are quite variable. They can typically be described in one of four ways (see illustration below):

- Smooth/entire—the entire edge of the leaf is smooth.
- Toothed/serrated—the edge has teeth or shallow indentations along it.
- Undulated—the leaf has wavy edges.
- Lobed—the entire leaf has large indentations (e.g., an oak leaf). The indentation is referred to as the sinus and the leaf matter that juts out is the lobe.



Smooth/entire Toothed/serrated Undulated Lobed

Objective

To learn about common plant species in your watershed.

Materials

- dichotomous key
- plant specimens

Name______________________________

Plant Identification Worksheet

1. Label the illustrations below as opposite, alternate, or whorled.

2. Label the illustrations below as simple, palmately compound. or pinnately compound. On the pinnately compound leaf, label the rachis and leaflet. On the simple leaf, label the sinus and the lobe.

3. Label each of the illustrations below as smooth/entire, toothed/serrated, or lobed.

4. Use the dichotomous key to identify the specimens provided, and fill in the table below as you complete the identification.

Species Name	Opposite, Alternate or Whorled	Blade Type: Simple or Compound	Margin of Blade: Entire, Serrated, Undulated, Lobed

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Page numbers in **boldface** refer to figures.