Leaf Toughness Exercise: An activity that combines field biology, botany, and experimental design.

The following description combines my ideas with work by many others, including Jason Emry, Brad Williamson, and web exercises about "ripometers." – Helen Alexander, September 2011

The overall goal of the leaf toughness exercise is multi-fold: 1) to get people (whether K-12 students, college students, or others to ask questions and develop studies about the natural world, and 2) to encourage active engagement in science, as opposed to more passive lectures. The exercise also is excellent at showing the importance of careful experimental design (setting up a procedure, replication, variation in data, response and explanatory variables, etc.)

There are many ways this exercise could be introduced. Here is one option:

QUESTIONS

1) Ask students what they think "science" is. Students will likely make a variety of comments like "understanding the world, taking data, doing experiments, etc." One can respond with discussion of dictionary definitions (key features are: a) study of natural or material world (as opposed to ethics, religion, philosophy) and b) an organized, systematic process using observations, experiments, and/or modes). Or, more simply, one can emphasize "asking good questions and finding good ways to answer them" (T. Holmes). If doing outdoor activities, ask them about what "ecology" is (study of relationships between living organisms and their abiotic and biotic environment). Make sure they see the distinction between ecology as a science and "environmental activism."

2) A next step is to hold up a leaf and ask students to explain "what it does." Students will likely mention photosynthesis. Make sure they understand the essential ideas (carbon dioxide + water , with light, leads to sugars and oxygen) and the functional parts of a leaf (see diagrams below, as well as ideas of stomates and veins). Get them looking at the variation in leaf structure, between plants and within plants. State that there are numerous ways we could compare leaves and that today we will focus on a simple trait of "leaf toughness" --- how hard is it tear a leaf.

3) Start a conversation of "why would ecologists care about leaf toughness"? Get students to come up with their own ideas. Areas that can lead to a lot of questions include a) leaf structure/function (comparing sun/shade leaves within same plant, see below; comparing leaves exposed to different abiotic stresses), b) trophic interactions (understanding effect of insect or disease damage on leaf persistence, as well as how physical features of leaves may affect herbivore feeding), c) ecosystem ecology (leaf toughness likely to determine

how easily leaves decompose). The above areas also relate to asking whether leaf toughness varies among habitats or species.

4) State that goal of exercise is to get students to ask their own questions, but to illustrate a methodology, we'll first investigate variation in leaf toughness within a single plant. Ask if they think there is any consistent patterns in how "tough" leaves within a plant are – and get them thinking about "why. " Get them thinking about a tree, where there are leaves on the outside (exposed to a lot of sun, wind) and leaves on the inside (low sun, less wind). Do we expect different leaf sizes? Structure? Toughness? (see background information below)

METHODOLOGY

5) Tell students that there are methods that scientists use for measuring toughness (show picture from Grime *et al.* book) but that we can do a surprisingly good job with a simple apparatus (i.e. cut uniform shape from leaf blade, attach first alligator clip to one side of leaf, have bent paper clip that links first alligator clip to another alligator clip that is attached to a small paper cup). One simply holds the leaf section and counts the number of pennies that are added to the cup until the leaf blade breaks.

6) Students can do this with a single shade and sun leaf, but to promote good science, get them thinking about the need for replication (a good design would be taking one shade and one sun leaf from 20 different trees so that one can test the generality of the pattern across trees).

THEIR QUESTIONS

7) Now, encourage them to ask their own questions, come up with their own experimental design (how to choose leaves, how many leaves), and use the methodology to answer their questions. This is really the most important part of the exercise – i.e. developing their independence as researchers and scientists. Similarly, the questions they are likely to ask (i.e. should my leaf section include a vein or not) are excellent for helping them formulate their questions and develop their approaches.

BACKGROUND:

Plant functional traits allow plants to maximize their growth and reproduction under various biotic and abiotic conditions. Plants may have traits that allow them to thrive in the presence of pressure from herbivores, competition, and parasitism. Traits may also have evolved as adaptations to withstand specific abiotic environmental conditions such as water and nutrient availability, temperature, light intensity, wind exposure and soil pH.

In their review of plant biomechanics, Read and Stokes (2006) summarized the adaptive value of various functional traits. Although they detailed the anatomical basis of the traits, they also emphasized the important role that the traits play in the ecological conditions in which they occur. Traits such as leaf toughness indicate how much carbon a plant allocates towards structural protection from biotic or abiotic damage (Cornelissen et al. 2003). One measure of leaf toughness, tearability, has been implicated as a measure of palatability (Read and Stokes 2006, Wright and Cannon 2001). In a study of comparing tearability across habitats and between species within a single habitat, Dominy et al. (2008) found that the toughest leaves were those with the greatest level of exposure to damaging wind.

The morphological and anatomical differences between sun and shade leaves was documented in some of the earliest studies of plant physiological ecology, and the factors leading to these differences is still an active area of research. Morphologically, the lamina of shade leaves tend to be thinner but broader than sun leaves; anatomically, sun leaves have a more highly developed palisade mesophyll (Hanson 1917, Uemura et al. 2000) (Figure 1). One can test whether these structural differences translate into variation in the mechanical strength of sun and shade leaves. The methodology described here is a simpler version of methods that scientists use to measure leaf toughness (see, for example, Grimes et al. 1993).

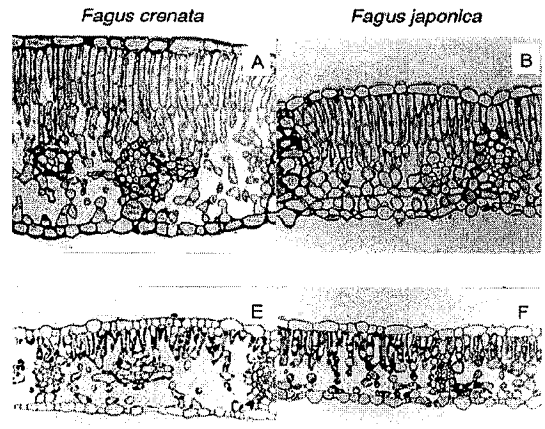

Figure 1. Sun and shade leaves from two different species of beech. The top two photomicrographs depict leaves that were grown in full sun; the bottom figures depict leaves grown in shade. Adapted from Uemura et al. (2000).

Literature cited

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