306. EXPLORATION OF LEAF SHAPES

M. Key

Leaves are the primary photosynthetic organ of most higher plants. Plants have evolved a spectacular array of leaf shapes and sizes which adapt them to a wide variety of environments (POH Fig. 28.13).

Leaves are borne attached to the plant stem. Often, the leaves are attached through a **petiole**, a stalk that holds the leaf out into the light and reduces self-shading in the plant. Where self-shading is not a problem, for example in plants exposed to very bright sunlight or having long narrow leaves, petioles may be absent.

Large, thin leaves provide the maximum surface area to intercept sunlight for photosynthesis, but are highly susceptible to wind damage and are likely to exhibit high transpiration rates. In addition, large thin leaves may less effectively capture CO_2 than smaller leaves. Air moves more smoothly over large surfaces than over smaller ones, leaving a thin layer of non-moving air at the surface of a large leaf. The air over smaller leaves is better mixed, constantly bringing in a new supply of CO_2. Plants with large leaves are common in warm, wet shady areas, such as the understory of a rain forest. Plants with small leaves occur in dry deserts or cold alpine meadows (POH Fig. 29.16 - 29.20, 30.17).

Thick leaves conserve water, but at the cost of decreased photosynthesis as the top of the leaf shades its own underside. Other adaptations that conserve water include a thick cuticle, sunken stomata, and hairs that reduce air movement across the leaf surface.

Leaves also vary in overall shape, patterns of venation, and the nature of the edge, or **margin**, of the leaf. These characteristics may be used in plant identification.

An especially important structural characteristic is whether the leaf is simple or compound. The leaves of many plants are divided into leaflets, structures that superficially resemble individual leaves. These **compound** leaves are less susceptible to tearing than are undivided **simple** leaves, but have reduced photosynthetic area. Most very large leaves are compound, while small to medium-sized leaves are often simple.

The leaflets of a compound leaf are attached to the petiole or to an extension of the petiole (the **rachis**) by a stalk called the **petiolule**. If the leaflets are all attached to the end of the petiole, the leaf is **palmately compound**. If the leaflets are attached along the length of the rachis, the leaf is **pinnately compound**.

If leaflets look like leaves and petioles look like stems, how can you determine whether a leaf is compound or simple? Look for buds at the base of the stalk and at its tip. Buds are present in the leaf axil where the petiole joins the plant stem, but not where the petiolule joins the rachis or petiole. Buds are present at the ends of stems, but never at the tip of the rachis or petiole.

Even on an individual plant, leaf morphology is influenced by such factors as light intensity, water availability, winds, and predation. Many species of trees are adapted to allow sunlight to penetrate the canopy and reach interior leaves (POH Fig 30.18). It has been demonstrated experimentally that for many plants, as little as 20% of full sunlight allows maximal photosynthesis. Therefore, even leaves well within the canopy can contribute photosynthetically. For this reason, it is energetically advantageous to a tree to have deeply notched outer leaves, permitting passage of light to interior leaves for photosynthesis. If the interior leaves have smaller sinuses (notches or open spaces) than the outer leaves, they will intercept more light, and overall the energy-producing ability of the tree will be enhanced.

Text References

POH Figure 28.13, The Diversity of Leaves; p. 692-693, Adaptation to Available Sunlight

Study Questions

Explain how and why tree leaf shape changes across the canopy. How would it change from top to bottom of the tree? Describe two ways a plant can maximize light absorption by its leaves.

Purposes

To examine how leaves differ among plants and to test the prediction that the sinus to leaf ratio of tree leaves increases from the tree trunk to the perimeter of the canopy.

Materials: masking tape; marking pen; graph paper, or photocopier and balance; tree (outside); meter stick or tape measure

Find plants with the different leaf structures and arrangements described in the Coloring Book assignment. Document your discoveries by pressing and drying the leaves, making leaf rubbings, or diagramming the structures. Try to identify the plants you are using.

To determine the relationship between leaf shape and the location of the leaves in the canopy, choose a maple tree (or other species with lobed or notched leaves) with a full crown of leaves that can be reached from the ground. Run at least three collecting transects from the trunk to the perimeter of the canopy, collecting one leaf at each 1 meter interval. Collect mature leaves, as shape may vary with developmental stage in younger leaves. As you collect the leaves, label them with their canopy position by folding numbered masking tape around the petiole.

To transfer an accurate image of the leaf onto paper, you may press and dry leaves for two days. Trace the pressed leaves or photocopy fresh or pressed leaves onto paper. On your image, connect the tips of the leaf lobes with straight lines to indicate the sinus areas (Figure 1). Determine the leaf to sinus ratio of the leaves by one of the following methods:

a. Use centimeter-lined graph paper. Determine the leaf and sinus areas by counting the number of squares in each area.

OR

b. Cut out the leaf images following the straight lines from tip to tip. Then cut away and save the sinus areas. Weigh the piece of paper representing the leaf and all the pieces representing the sinus areas. To convert from paper weight to area, weigh an 8.5" by 11" (or 21.6 cm by 27.9 cm) sheet of the paper you are using. Divide the weight of the sheet of paper by its area to obtain g/cm^2 of the paper. Divide this conversion factor into the weights of your leaf images to obtain their areas:

$$cm^2 \text{ leaf image} = \frac{\text{g leaf image}}{\text{g paper}/cm^2 \text{ paper}}$$

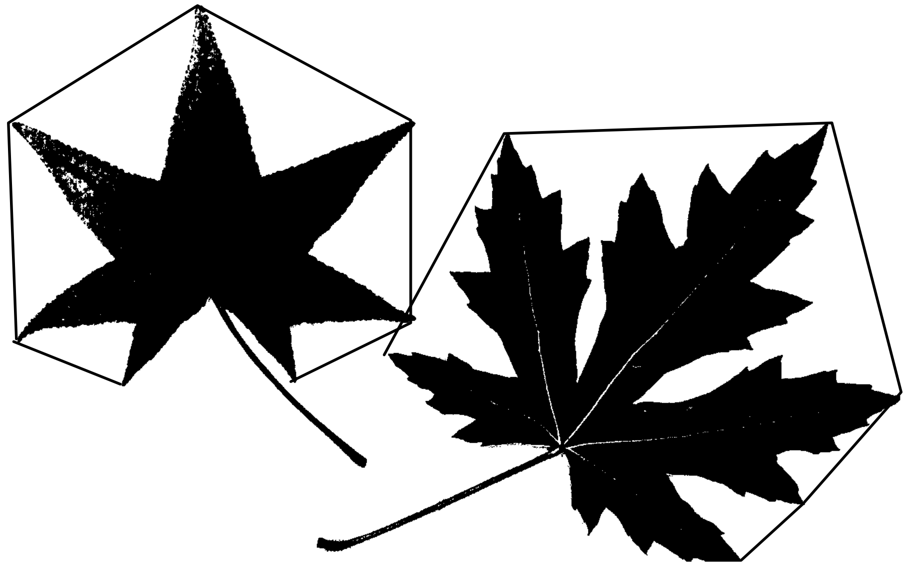

Figure 1. Leaf and sinus areas

Calculate the ratio of sinus area to leaf area for each leaf. Plot this ratio against the location in canopy (meters from the trunk).

Additional Experiments

Brighter sunlight strikes leaves at the outer edge of the canopy than those buried deep within the canopy. How would you expect light intensity to affect leaf thickness? Test your prediction by drying leaves, weighing them and dividing the leafy dry weight by the leaf area to obtain the leaf specific weight (g/cm^2). Thicker leaves will have a higher specific weight.
Investigate the mechanism that controls leaf shape or thickness.

Additional References

Horn, Henry S. 1971. The Adaptive Geometry of Trees. Princeton University Press, Princeton, New Jersey.

Pianka, Eric R. 1988. Evolutionary Ecology, 4th edition. Harper & Row, New York.

Westmoreland, David. 1989. Leaf morphology and light microenvironments: a field exercise. Amer. Biol. Teach. 51:303.

306. EXPLORATION OF LEAF SHAPES (12 PTS)

Name   Lab day and time ___________________________

PRELAB PREPARATION:

1. Procedural outline:

2. Complete Botany Coloring Book pages 68 and 69.

3. Where will you obtain leaves for determining the relationship between leaf shape and canopy location? (Describe the type of tree, its location, how you will run your transects, etc.)

4. Predict which leaves will have the largest ratio of sinus area to leaf area. Defend your predicition.

RESULTS:

5. Attach separate pages demonstrating the different leaf shapes and arrangements.

6. Describe any changes you made in the source of leaves for determining the relationship between leaf shape and canopy location after answering Question 3.

7. Record your data:

source of leaf (m from trunk)	leaf area	sinus area	ratio (in decimal form)

8. Plot the ratio of sinus area to leaf area against the location of leaf in canopy.

9. Which type of leaf would be more susceptible to damage by bacterial disease or feeding caterpillars, simple or compound? Defend your answer.

10. Did the sinus to leaf ratio have the predicted relationship with canopy location? If not, suggest possible explanations for the results you obtained.

11. Discuss possible sources of error in this experiment.