

CLAMP Leaf Character State Definitions and Scoring

Note that the scoring regime described here is for the original scoresheet. If you are using Scoresheet_2010, which simplifies much of this process, enter "1" if a character state is present or leave blank if it is absent.

The details of Based on [Wolfe \(1993\)](#).

Compound Leaves

Many leaves are compound and numerous leaflets make up the leaf. There are two types: pinnately compound (Figures A, B) and palmately compound (Figure C). Each leaflet tends to be shed separately from the others and functionally they behave as true leaves. Because of this in CLAMP leaflets are regarded in the same way as true leaves and are scored as such. Examples of pinnate and palmate compound leaves are given below.



A) Pinnately compound leaf.

Note the variation in leaflet morphology, all of which should be scored.



B) A partially pinnately lobed leaf. Here the bottom three "segments" would be scored as individual leaves.



C) Palmately compound leaf.

Lobing

In order to be **pinnately** lobed, a lamina must be incised so that a line connecting the sinuses between the lobes is approximately parallel to the midrib (Figure D); in some *Quercus* leaves, however, a line connecting the sinuses is parallel to a line connecting the apices of the lamina segments which, therefore, are classified as teeth rather than lobes (Figure E).

In **palmately** lobed leaves (Figure F), the lobes are entered by a major primary vein that originates at or near the base of the leaf.



D) Pinnately lobed leaf.



E) When a line connecting the sinuses runs parallel to the leaf margin the lamina segments are classified as teeth.



F) A palmately lobed leaf.

(NB When measuring leaf size of lobed leaves, please see note under **leaf size**)

Both pinnately and palmately lobed (Figures B-C) were scored separately but were later combined because

separate scoring appeared to produce no refinement.

A species receives a score of:

- 0 if no leaves are lobed (Figure A)
- 0.5 if some leaves are lobed and some are unlobed
- 1 if all leaves are lobed

Teeth

No Teeth

The no teeth character state is basically that of the entire margin (Figures G and I) as proposed by Bailey and Sinnott (1915, 1916); a major difference, however, is that spinose leaves (Figure H) (leaves that have a fimbrial vein forming abmedial projections) are included in the no teeth category. This is because spinose teeth are primarily an adaptation to deter browsing and therefore not related to climate.



G) Entire margin H) Spinose margin. I) Entire margin

A species receives a score of:

- 0 if teeth are present on all leaves
- 0.5 if some leaves are toothed and some are not
- 1 if no leaves are toothed

The scores, when converted to percentages, for no teeth, teeth rounded and (or) appressed, and teeth acute will total approximately 100 for a single sample.

Regularity of tooth spacing

Teeth are considered to be **regularly spaced** if the length of the basal flanks (the side of the tooth facing the leaf base) of two adjacent teeth differ by less than one-third (Figures I and J).



J) Regularly spaced teeth. K) Regularly spaced teeth L) Irregularly spaced teeth M) Irregularly spaced teeth

A species receives a score of:

- 0 if no teeth are present
- 0.25 if the teeth are both regular and irregular and some leaves have teeth and others do not
- 0.5 if the teeth are only regular and some leaves have teeth and others do not
- 0.5 if the teeth are both regular and irregular and all leaves are toothed
- 1 if all teeth are regular and all leaves are toothed.

Closeness of teeth

Teeth are considered to be **closely spaced** if the basal flanks of the teeth are no longer than three times the apical flanks (the side of the tooth facing the leaf apex) (Figures J, K), otherwise they are distant (Figures P, Q)



N) Closely spaced teeth. O) Closely spaced teeth. P) Distantly spaced teeth. Q) Distantly spaced teeth.

A species receives a score of:

- 0 if no teeth are present
- 0.25 if the teeth are both close and distant and some leaves have teeth and others do not
- 0.5 if the teeth are close and some leaves have teeth and others do not
- 0.5 if the teeth are both close and distant and all leaves are toothed
- 1 if all teeth are close and all leaves are toothed.

Teeth rounded and (or) appressed

Teeth are **rounded** if they have convex apical and basal flanks and the convexity extends to the tip of the tooth (Figures R, S).

Teeth are **appressed** if the apical flank is concave, the base of flank is convex, and the tooth is curved toward the lamina (Figures T, U); such teeth are typically glandular.



R) Rounded teeth. S) Rounded teeth. T) Appressed teeth. U) Appressed teeth.

The two states of rounded teeth and appressed teeth were originally scored and run separately, but combining the two states produced both higher eigenvalues and percent variance.

A species receives a score of:

- 0 if no teeth are present
- 0.25 if the teeth are both rounded (or appressed) and acute, and some leaves have teeth and others do not
- 0.5 if the teeth are only rounded (or appressed) and some leaves have teeth and others do not
- 0.5 if the teeth are both rounded (or appressed) and acute and all leaves are toothed
- 1 if all teeth are rounded (or appressed) and all leaves are toothed.

Teeth acute

Teeth are **acute** if the apical and basal flanks of the teeth form a sharp point (Figures V, W).

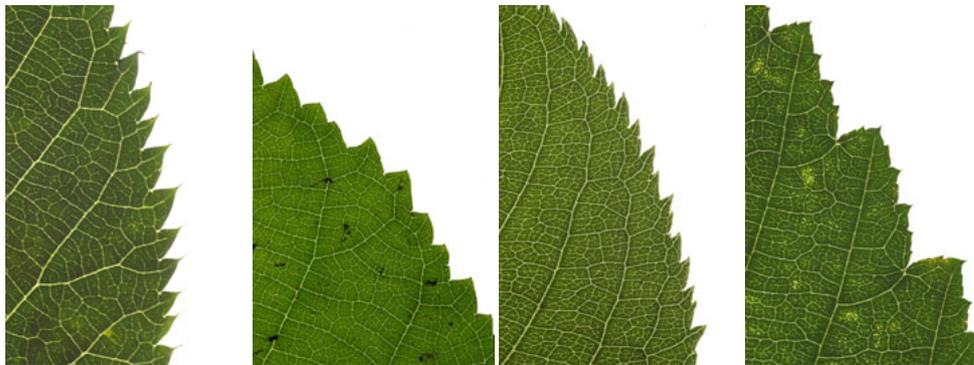
A species receives a score of:

- 0 if no teeth are present
- 0.25 if the teeth are both rounded (or appressed) and acute and some leaves have teeth and others do not

- 0.5 if the teeth are only acute and some leaves have teeth and others do not
- 0.5 if the teeth are both rounded (or appressed) and acute and all leaves are toothed
- 1 if all teeth are acute and all leaves are toothed

Teeth compound

A **compound tooth** is a tooth that has smaller teeth on (typically) its basal flank (Figures X, Y).



V) Acute teeth. W) Acute teeth. X) Compound teeth (few). Y) Compound teeth (many).

A species receives a score of:

- 0 for species that have no compound teeth
- 0.5 for species that have some, but less than 50 percent, teeth that are compound
- 1 for species that have at least 50 percent teeth that are compound

Leaf size

A species is scored for its full range of variation in leaf size. Leaf size is measured in categories using the template available here.

Note that if a **lobed leaf** is dissected more than half the distance from the apex of the lobe to the base of the lamina or to the midrib, the unit area scored is an individual lobe (Figure Z).



Z) In lobed leaves the individual size unit is the lobe. AA) Measure only the leaf lamina and not the petiole.

The leaf size (or area) categories are defined differently than the categories proposed by Raunkiaer (1934), as modified by a Webb (1959), although the division between the Microphyll III and Mesophyll I categories approximately corresponds to the division between Webb's (1959) Notophyll and Mesophyll categories. Raunkiaer's (1934) original categories were defined by him based on examination large number of herbarium specimens.

In sizing leaves early in the development of CLAMP, Wolfe observed that many species tend to have leaves concentrated in certain sizes the represent categories intermediate between two of Raunkiaer's categories, and thus Wolfe developed the system proposed here. Note that if a lobed leaf is dissected more than half the distance from the apex of the lobe to the base of the lamina or to the midrib, the unit area scored is an individual lobe.

During development of CLAMP, three additional size categories were scored. One was smaller than the Leptophyll I category and two were larger than the Mesophyll II category. In all three instances, the multivariate analysis produced character-state scores almost the same as the scores for the adjacent leaf size character-states. The similarities in scores indicated that no significant information was being added, and deletion from the database of the duplicate character states produce some what higher eigenvalues and had little effect on samples scores.

Assign scores:

- 1 if a species has leaves of only one size category it receives a score of 1 in that category
- 0.5 if a species ranges through two size categories it receives a score of 0.5 in both categories
- 0.33 if a species ranges through three size categories it receives a score of 0.33 in each category

and so forth.

Apex Form

Apex emarginate

An apex is emarginate if the most apical part of the lamina convexly curves towards the base of the lamina (Figures AB-AD).



AB) Emarginate apex. AC) Emarginate apex. AD) Emarginate apex.

Note: Insect related damage can cause a somewhat similar notched apex that tends to have irregular sides and is excluded from the emarginated category.

A species receives a score of:

- 1 if some leaves are emarginate
- 0 if no leaves are emarginate

The next three categories have a cumulative score of 1 for each species.

Apex round

An apex is round if the most apical fourth of the lamina has a margin that convexly curves and the two sides meet to form a curve (Figures AE to AH). Note that Figure AG shows a leaf with a borderline emarginate apex and could legitimately be scored as having the emarginate form.



AE) Round apex AF) Round apex AG) Round apex AH) Round apex

Apex acute

An apex is acute if the most apical fourth of the lamina has a margin that is straight and the two sides form a point (Figures AI to AL).



AI) Acute apex

AJ) Acute apex

AK) Acute apex

AL) Acute apex

Note that this definition of acute does not depend on the angle formed by the lamina sides.

Apex attenuate

An **apex** is **attenuate** if, in the most apical fourth of the lamina, the margin on both sides changes from a linear or convex margin to a concave margin and the concave margin extends for a distance of at least one centimetre (Figures AM - AP).

The necessity in the attenuate category for both sides to change curvature thus excludes many falcate laminae, which typically have a change of curvature on only one side and are considered to have acute apices.



AM) Attenuate apex

AN) Attenuate apex

AO) Attenuate apex

AP) Attenuate apex

A species can have a score of:

- 1 in one category if only one category is represented
- 0.5 in two categories if two categories are represented
- 0.33 in each category if each category is represented.

The next three categories have a cumulative score of 1 for each species.

Base Form

Base cordate

A **base** is **cordate** if the basal parts of the lamina extend basally (below) beyond the juncture of the petiole and the lamina (Figures AQ - AT).



AQ) Cordate base

AR) Cordate base

AS) Cordate base

AT) Cordate base

Base round

A **base is round** if the most basal fourth of the lamina has a convex margin (Figures AU - AY).



AU) Round base.

AV) Round base.

AW) Round base.

AY) Round base.

Base acute

A **base is acute** if the most basal fourth of the lamina has a straight or concave margin (Figures AZ to BC).



AZ) Acute base.

BA) Acute base.

BB) Acute base.

BC) Acute base.

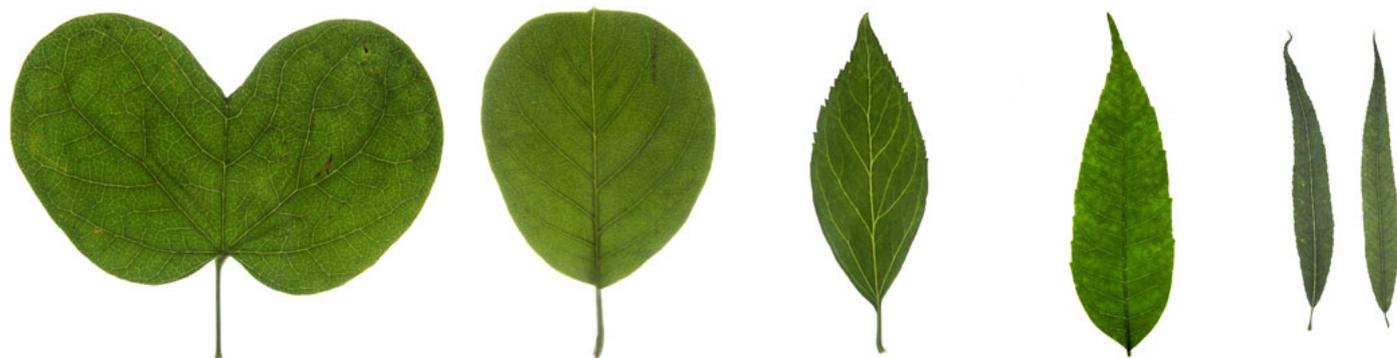
Note that this definition of acute does not depend on the angle formed by the lamina sides.

A species can have a score of:

- 1 in one category if only one category is represented
- 0.5 in two categories if two categories are represented
- 0.33 in each category if each category is represented.

Length-to-width ratio

A species is scored for its full range of variation in length to width (Figures BD - BH)



BD) Length to width less than 1:1

BE) Length to width 1-2:1

BF) Length to width 2-3:1

BG) Length to width 3-4:1

BH) Length to width greater than 4:1

A score of:

1 is given in that category to a species that has leaves of only one length-to-width category
 0.5 is given in each category if a species ranges through two categories
 0.33 is given in each category if a species ranges through three categories
 and so forth.

The next three categories have a cumulative score of 1 for each species.

Shape

Shape obovate

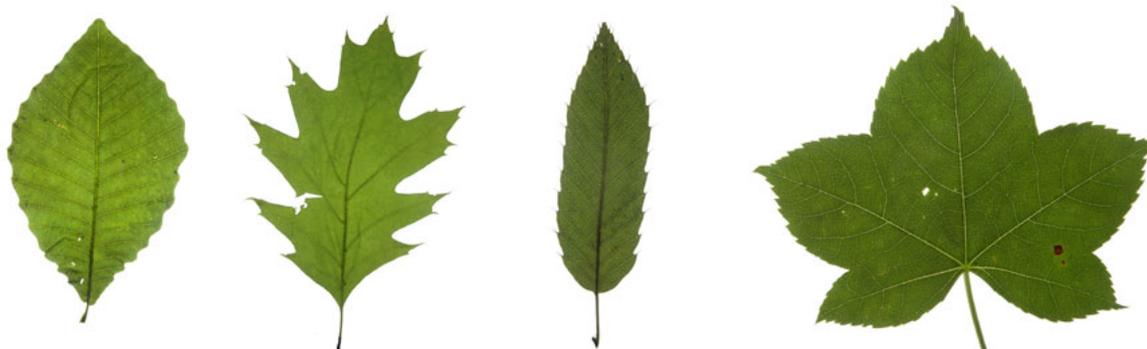
The leaf is **obovate** if it is widest in the most apical third of the lamina (Figures BI - BL).



BI) Obovate leaf. BJ) Obovate leaf. BK) Obovate leaf. BL) Obovate leaf.

Shape elliptic

A leaf is **elliptic** if it is widest in the medial third of the lamina (Figures BM - BP).



BM) Elliptic leaf. BN) Elliptic leaf. BO) Elliptic leaf. BP) Elliptic leaf.

Shape ovate

A leaf is **ovate** if it is widest in the most basal third of the lamina (Figures BQ - BS).



BQ) Ovate leaf. BR) Ovate leaf. BS) Ovate leaf.

A species can have a score of:

- 1 in one category if only one category is represented
- 0.5 in two categories if two categories are represented
- 0.33 in each category if each category is represented.

For a .pdf of these scoring instructions click [here](#).

To see how these character states and scoring criteria are entered on the "classic" score sheet [click here](#).