Tree Anatomy: Leaf Surfaces & Appearance

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There are many descriptions of tree leaf / leaflet surfaces. Leaves can have various surface textures and coatings which interact with light quality and quantity reflected. The overall appearance of an tree leaf surface is called its indumentum or vesture. The surface cell layer on a leaf is the epidermis which is the primary outermost layer of cells which may generate a cuticle. The epidermis is also found on buds, twigs, and over primary tissues.

Surfaces

There are a number of general surface types on tree leaves divided into eight forms: leathery, smooth, waxy, sticky, pitted, lined, rugose, and pubescent. Any one leaf may have combinations of any of these surface forms. Leaves with noticeably thick and leathery surfaces are called coriaceous. Smooth leaves lack indentations, projections, trichomes or rough surface growths. Wax coatings of various thickness and colors on leaves are its cuticle. A leaf surface is considered sticky (i.e. due to tree based materials not pest excrement), or called gluey or tacky. Pitted leaf surfaces have many indentations. Lined surfaces are marked with visible marks which are on the surface and not associated with vascular tissues beneath.

Rugose surfaces are roughened and wrinkled, and can have several different characteristics. Rugose surfaces can be: scaly and flaky with fragile projections and coatings; warty and bumpy with small rounded projections; point-covered with small pointed projections; or, wrinkled with undulations of repeating ridges and valleys. Two sub-types of rugose are rugulose which means slightly wrinkled, and ruminate meaning roughly wrinkled and appearing damaged or chewed.

Cuticle

Leaf surfaces are many times covered or coated with a cuticle. A cuticle is a three layered, non-cellular sheet of leaf-generated material covering mature portions of leaves, shoots, flowers, and trichomes. Cuticles are composed of lipids, waxes, and cutin adhered to the epidermis by pectin. The cuticle is a cutin matrix holding multiple wax layers with a surface wax layer. Cutin is a material formed by oxidation of fatty acids which act as a framework for holding and stabilizing wax.

The three layers of a leaf cuticle are a surface wax layer, and a primary and secondary layer. The most exterior layer is oxidized and photo-decayed epicuticular wax. This surface bloom on leaves and buds can have various textures and appearances. The second layer is the primary cuticle which is composed of epicuticular wax layers in a framework of cutin. The third layer (most interior layer of the cuticle) is the secondary cuticle where the cuticular layer graduates or blends into epidermal cell wall materials. Figure 1. Generally, shade leaves have thin cuticles and sun leaves have thick cuticles.

Stomates

Tree leaves have stomates for gas exchange with the environment. Carbon dioxide must reach the photosynthetic processing machinery of a leaf, and stomates actively facilitate this gas movement. Photosynthetic machinery and other life processes in a leaf must remain at or very near water vapor saturation levels (i.e. 100% relative humidity) but, stomates loose water vapor to the dry atmosphere when open. Control of stomate opening and closing is tightly controlled by leaves using water deficit levels, dissolved carbon dioxide (CO_2) content, and light sensors and triggers. Figure 2.

Tree stomates are almost always active only on the bottom / underside of a leaf (abaxial surface) There can be scattered stomates on the upper surface (adaxial surface) of a tree leaf, but they are usually

CUTICLE

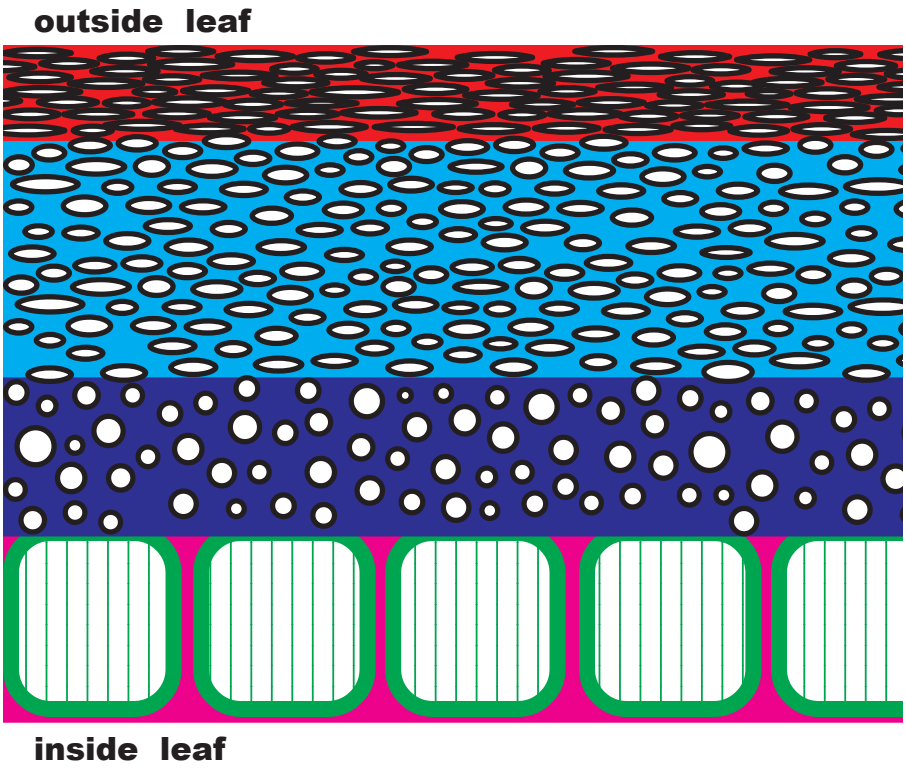

Figure 1: Leaf cuticle composed of three layers of progressively more oxidized and flattened epicuticular wax and lipids within a cutin matrix.

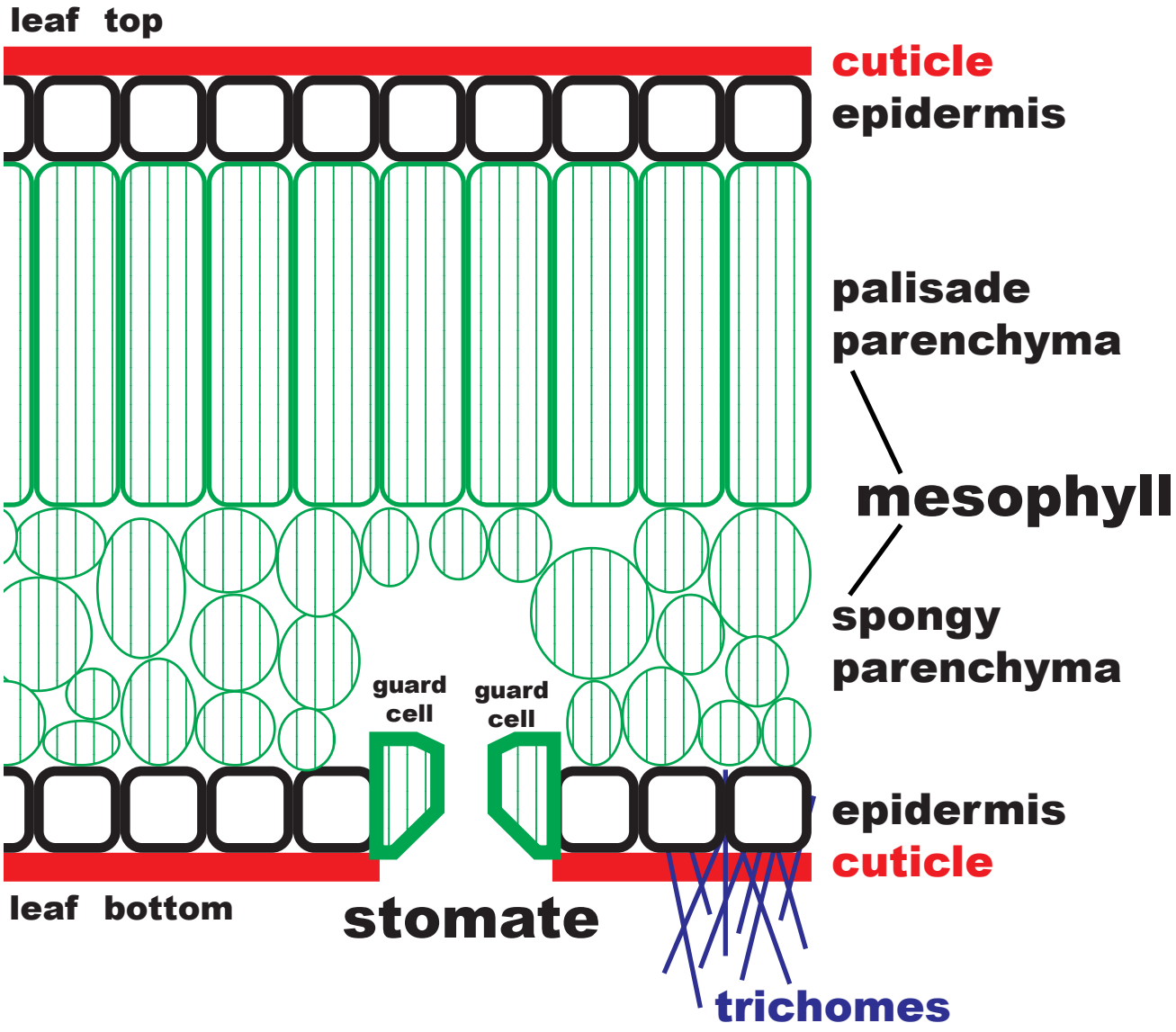

Figure 2: Idealized cross-sectional diagram of a tree leaf blade showing different non-vascular cell layers and a stomate. Cells with shading have chlorophyll. The top and bottom leaf surfaces are covered with a wax cuticle, which may or may not have tricombes protruding.

non-functional. Stomates are microscopic pores or openings in leaf epidermis surrounded and controlled by two guard cells, which are in-turn assisted by adjacent leaf cells. Guard cells are a pair of reniform chloroplast containing cells which swell to open the stomate. They are hinged at each end to allow for pore opening and closing. Figure 3.

Stomatal Counts

The number of stomates on tree leaf undersides average 309 stomates per square millimeter (mm^2) as measured from 21 North American tree species. The size of each stomate averages 28.2 microns long for the same 21 North American tree species. In other words, stomates are many and small, generating a large surface area for gas exchange in a leaf. Stomates can be arranged in lines, clustered, or randomly distributed.

Stomates can be described as hypostomatic, where functional stomates are generated only on the lower leaf surface, as in most broadleaf angiosperm trees. Stomates can also be termed hyperstomatic, where stomates are generated on upper leaf surfaces. A few broadleaf tree species generate some functional stomates on both leaf surfaces (i.e. select *Populus* (cottonwood / aspen) and *Salix* (willow) species).

Even when tree species have both upper and lower surface stomates, the larger and more numerous stomates are found on the lower surface. If few stomates are present, they are usually larger in size, and correspondingly, if many stomates are present they are usually smaller. An exception is found in *Quercus* (oak) species which tend to have many large stomates.

Textures

Tree leaf / leaflet surfaces, both cellular surfaces and cuticular materials, have many feels, appearances, and textures. Some are characteristic to genera or species. There are many surfaces which have been described. The basic surface textures include scaly, flaky, warty, bumpy, raised points, pitted, wrinkled, lined, smooth, shiny, dull, sticky, waxy, and trichomy ("hairy").

Figure 4 provides the technical terms and associated descriptors for leaf surface textures considered scaly or flaky. The scales or flakes can vary in size from flattened scales to a powder. The various terms and descriptors used for leaf / leaflet surfaces considered warty or bumpy are given in Figure 5. Bumps are rounded projections which can be short or tall. The animal term wart / warty is usually used interchangeably with the word bump / bumpy.

Figure 6 lists the technical terms and descriptors for leaf surfaces with either raised points or sunken pits. Raised points have a sharp point of various heights above the surface, which may or may not be hard or stiff. Pitted leaf / leaflet surfaces can have small, deep indentations or shallow depressions.

Figure 7 provides the terms and descriptions for leaf / leaflet surface textures considered wrinkled or lined. Wrinkled leaf surface appearance can range from ridges to smooth undulations. Lined textures can appear lined without indentations or raised lines, or can have elongated grooves. The differences between a wrinkle and a line is subjective in the tree literature. Various terms for a smooth leaf / leaflet surface is provided in Figure 8. Smooth textures are lacking in surface topography, and are usually judged upon their dull or shiny appearance.

Tree leaves can have several surface coatings which modify surface texture appearance. Figure 9 lists the technical terms and descriptors for two of the leaf / leaflet coatings. Sticky coatings are not judged by appearance, but by tactile feel. There are many environmental conditions which can deposit materials on a leaf surface which may be sticky, but this is a tree term denoting materials generated by a leaf / leaflet from its epidermal / cuticle areas, or from leaf or trichome glands. Waxy coatings are

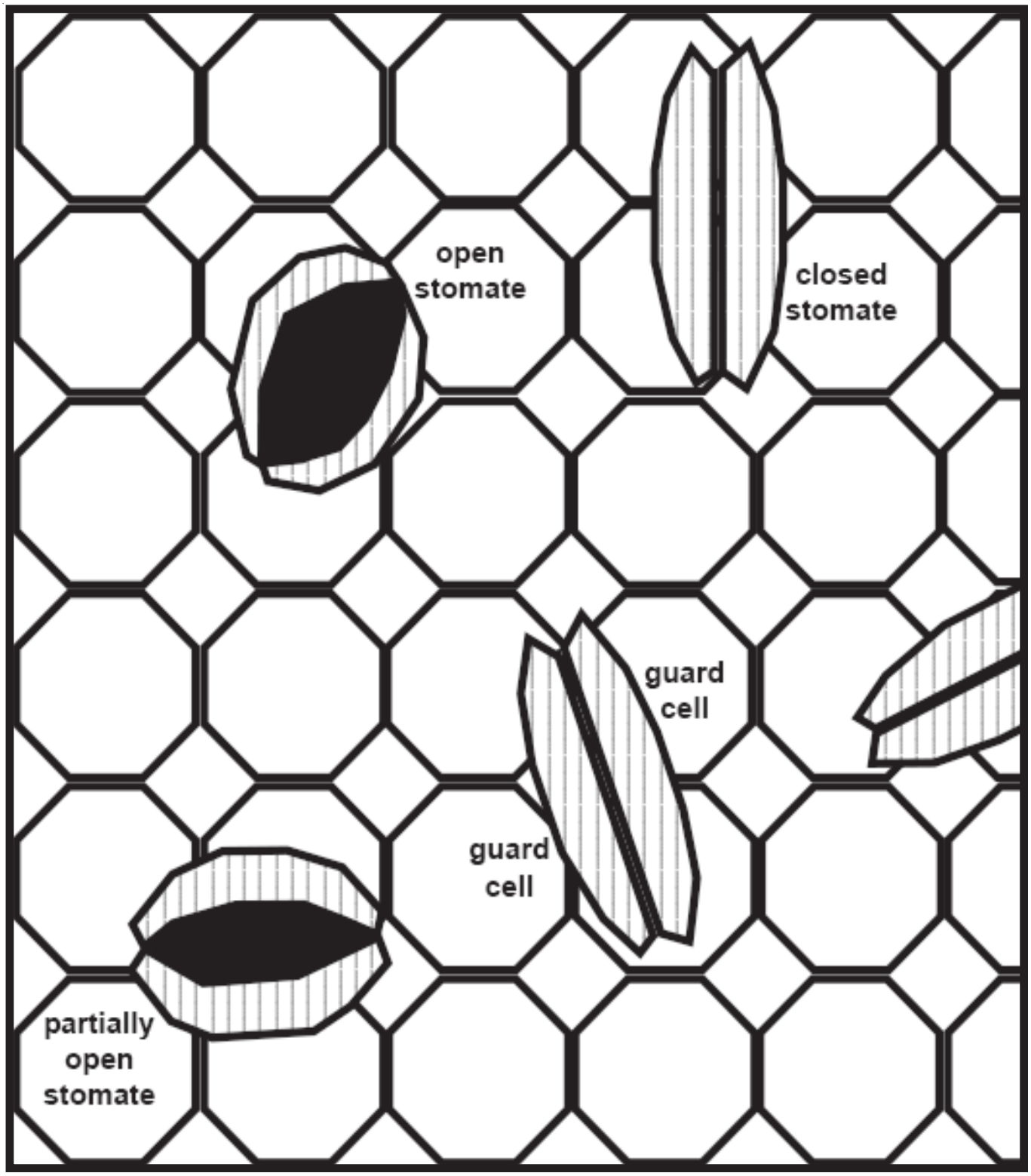

Figure 3: Diagram showing open and closed stomates on underside (abaxial surface) of a tree leaf blade. The geometric background pattern represents leaf epidermis cells covered by a waxy cuticle.

Figure 4: Various terms and descriptors used for scaly or flaky leaf / leaflet surfaces.

WARTY / BUMPY

bullate	=	**round blister projections**
granulate	=	**tiny points or warty**
mammillate	=	**nipple-like bumps**
papillate	=	**small bumps**
papillose	=	**minute bumps**
pustulose	=	**small blisters**
scaberulous	=	**slightly covered with small warts**
scabridulous	=	**minutely roughened**
scabrous	=	**rough with small warts**
strumose	=	**small bumps or swellings**
tubercularoid	=	**warty texture**
verrucose	=	**small bumps or warty outgrowths**
verruculose	=	**slightly covered with small bumps or warty outgrowths**
warty	=	**wart-like bumps**

Figure 5: Various terms and descriptors used for warty and bumpy leaf / leaflet surfaces.

RAISED POINTS

boss	=	**raised pointed projections but not prickly**
exasperate	=	**hard rough with short points**
muricate	=	**rough with small sharp projections**
muriculate	=	**roughened with minute sharp projections**
scrupose	=	**roughened with tiny hard points**
spiculate	=	**fine points**
spinulose	=	**minute points**

PITTED

fovealate	=	**minute pits**
foveate	=	**pits**
pitted	=	**small depressions**
punctate	=	**minute depressions or glandular dots**
puncticulate	=	**minute pits or sunken glands**

Figure 6: Various terms and descriptors used for either raised points or pitted leaf / leaflet surfaces.

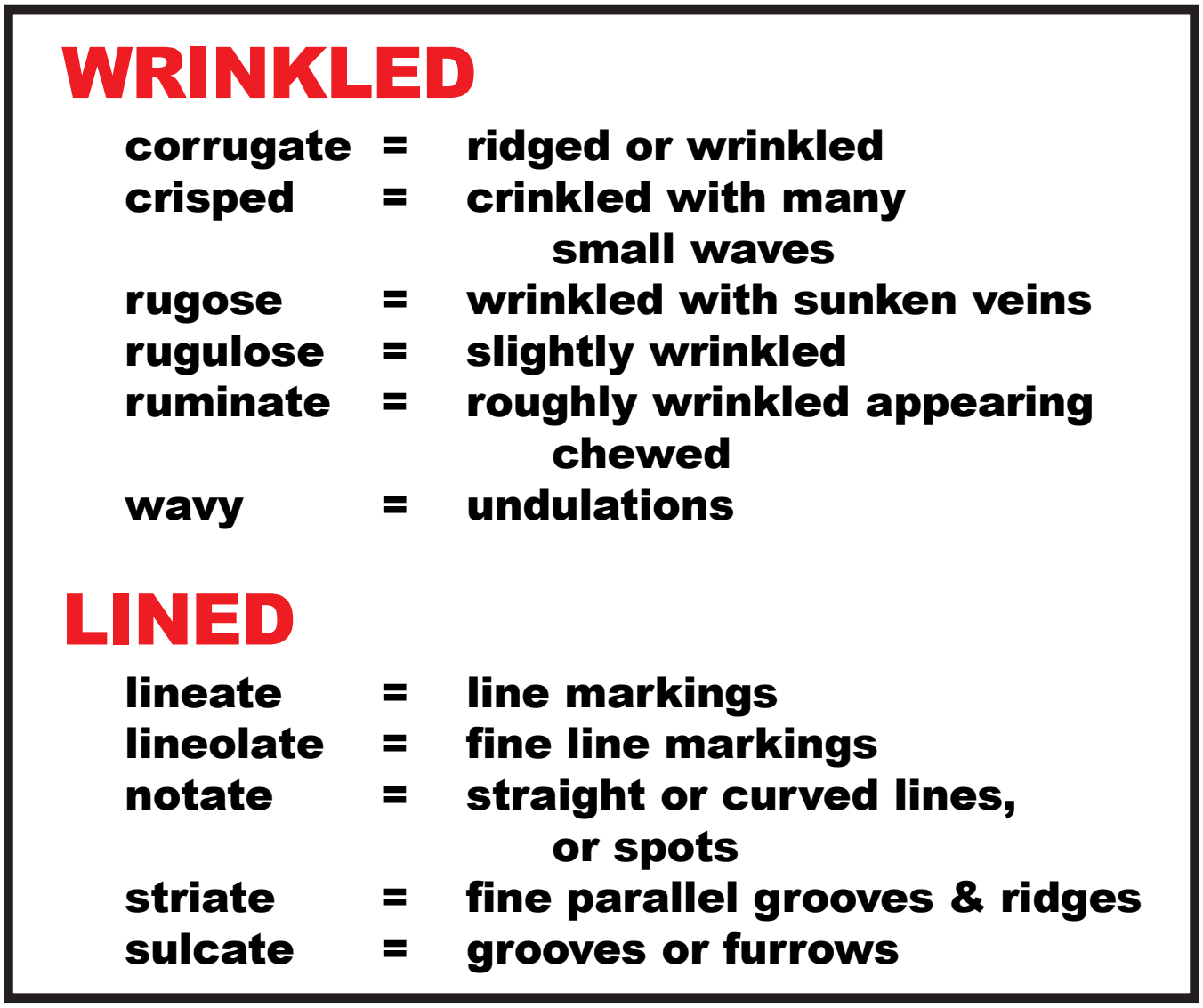

Figure 7: Various terms and descriptors used for wrinkled or lined leaf / leaflet surfaces.

Figure 8: Various terms and descriptors used for smooth and shiny leaf / leaflet surfaces.

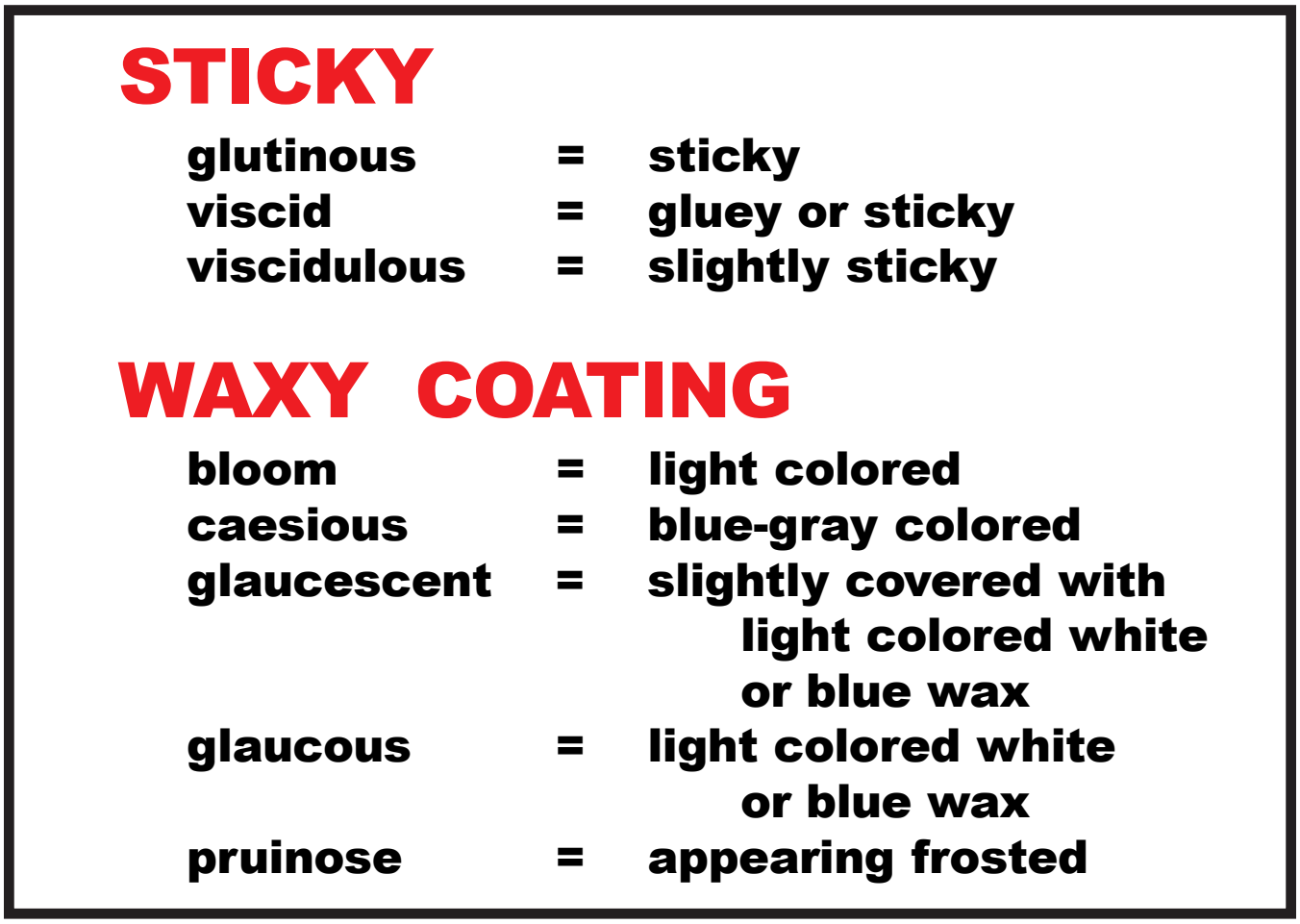

Figure 9: Various terms and descriptors used for sticky or waxy coated leaf / leaflet surfaces.

derived from cuticle sources which have been mechanically or photo-chemically degraded, and can lend a thin color layer to the leaf surface.

Trichomes

One of the most noticeable surface attributes on leaves is the presence of pubescence, which is a generic name for various types of trichomes or plant "hairs." Pubescent can also define a specific type of fine, soft trichomes covering a leaf surface. Puberulent surfaces are slightly covered with minute fine soft trichomes. Hirtose and piliferous surfaces are covered with trichomes. Tomentum denotes a surface with a covering of dense wooly, curled and matted trichomes. Figure 10 shows a variety of different trichomes.

Trichomes are unique and varied organs which are outgrowths or emergences from the epidermal region of tree structures. Generic historical terms for trichomes include plant based hair-like growths. Trichomes include epidermal generated bristles (short / stiff) and prickles (small / sharp). Trichomes also include root epidermal / sub-epidermal sourced absorbing structures (i.e. root "hairs") growing from the trichoblast, the source cells of root trichomes.

There are five primary trichome types on leaves, all with highly variable characters:

1. **papillae** which can be unicellular / multicellular & stalked / sessile;
2. **unbranched** which can be unicellular / multicellular, stalked / sessile, short / long, and thin / thick;
3. **branched** which can be unicellular / multicellular, stalked / sessile, with various number of branches, and branching forms;
4. **stellate** which are branched in a radiating or star-shape, and can be unicellular / multicellular and stalked / sessile; and,
5. **scales** which are flattened and can be unicellular / multicellular and stalked / sessile.

Other terms are associated with tree leaf surface trichomes. Piliform are surfaces with zig-zag shaped trichomes. Glochid surfaces have barbed trichomes or bristles. Stimulose surfaces have stinging trichomes, and urgent surfaces have stinging bristles. Depilation is the natural loss of trichomes as leaf tissues mature over the growing season. Erinose surfaces have abnormal development of trichomes in response to pests and injuries.

"Hair" Do

There are many types of trichomes. Usually trichomes most remarked upon for tree leaf surfaces are hair-like, elongated, and bristle forms. A three-level basic summary of tree leaf trichome descriptions and appearances are their differences in: length (short / medium / long); feel / softness (soft / intermediate / stiff); and, relative position across the leaf surface (tufted / non-tufted). Figure 11. Many trichome terms have very subtle or technical differences. Most people fall back from more technical trichome terms to more generic terms.

Figure 12 provides the technical terms and descriptors for trichomes with very short or minute lengths. These trichomes can be divided into various soft and stiff forms. Figure 13 lists terms and descriptions for leaf trichomes which are short in length, and either soft or stiff. Note the difference between short and very short / minute lengths in trichomes is not an absolute measure, but an observational choice.

Medium length trichome descriptions are given in Figure 14. Trichome descriptions are divided among soft, intermediate or medium softness, and stiff. All the terms given have been used to describe leaf / leaflet surfaces with some authors choosing one term or several to describe, in essence, the same trichomes. The more stiff a trichome, the more the terms sharp, prickly or bristly are used.

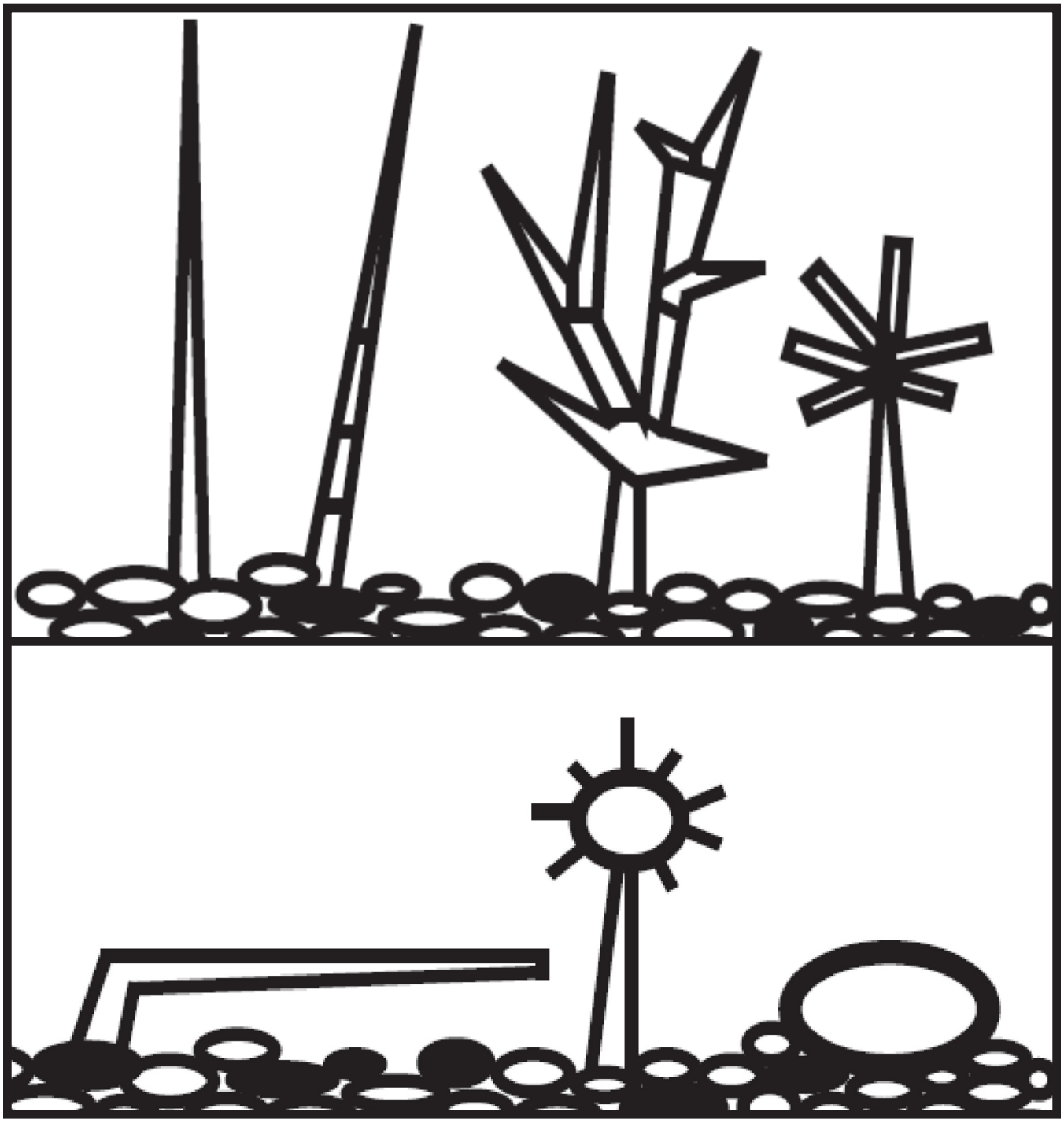

Figure 10: Diagrammatic representation of various forms of tree trichomes on leaf, bud, and root outer surfaces derived from epidermal / sub-epidermal cells.

1. LENGTH:

Very Short / Short / Medium / Long

2. FEEL or APPEARANCE:

Soft / Medium Soft / Stiff

3. POSITIONED:

Non-Tufted / Tufted

Figure 11: Various generic terms and general descriptors used for hair-like or bristle-like trichomes covering tree leaf / leaflet surfaces.

Figure 12: Various terms and descriptors used for very short length leaf / leaflet surface trichomes.

SHORT & SOFT

hoary	**=**	**dense grey-white**
lanulose	**=**	**minutely dense wooly long tangled**
pannose	**=**	**dense felt-like**
pilosulose	**=**	**minute straight distinct many scattered**
pubescent	**=**	**general term for fine whitish surface**
velutinous	**=**	**velvety spreading not matted**
villosulous	**=**	**minutely silky shagg straight unmatted fragile**

SHORT & STIFF

acanaceous	**=**	**prickly**
aculeolate	**=**	**minutely prickly**
asperulate	**=**	**minutely roughened with projections or bristles**
echinulate	**=**	**minute sharp prickles**
hirsutulous	**=**	**minutely coarse**
hirtellous	**=**	**minutely coarse**
hispidulous	**=**	**minute bristles**
setulose	**=**	**minute bristles**
strigilose	**=**	**slightly rough sharp straight appressed**
strigose	**=**	**sharp straight appressed all in same direction**

Figure 13: Various terms and descriptors used for short length leaf / leaflet surface trichomes.

MEDIUM LENGTH & SOFT

araneose	**=**	**fine**
arachoid	**=**	**fine**
downy	**=**	**fine**
lanuginose	**=**	**downy**
tomentose	**=**	**densely wooly short curled matted**
tomentulose	**=**	**slightly densely wooly short curled matted**

MEDIUM LENGTH & MEDIUM SOFTNESS

incanous	**=**	**whitish pubescence**
manicate	**=**	**thick interwoven**
pilose	**=**	**straight distinct many scattered**
stellate	**=**	**star-shaped many branched**

MEDIUM LENGTH & STIFF

aculeate	**=**	**spiny or prickly**
asperate	**=**	**rough with projections or bristles**
echinate	**=**	**sharp prickles**
setose	**=**	**bristles**

Figure 14: Various terms and descriptors used for medium length leaf / leaflet surface trichomes.

The longest trichomes are the most noticed on leaf / leaflet surfaces, and have had a number of descriptors developed. Figure 15 shows different terms for long length, soft or stiff trichomes. Wooly, cottony, silky, and cobweb-like have all been used to describe long soft trichomes. Along with length and softness, position or location relative to each other on a leaf surface are used to describe trichomes. Figure 16 shows technical terms and descriptors for trichomes in tufts, which could be long to short in length, and medium to soft.

Special Surfaces

Closely associated with leaf trichomes are leaf surface emergences. Emergences are multiple celled growths from epidermal or sub-epidermal areas, without the appearance of a trichome. Enations are general outgrowth emergences, and excrescences are warty outgrowth emergences. Another specialized surface growth on leaves are domatia, which are generated depressions, pockets, cavities or shaped trichome tufts which support occupancy of animals, like predatory mites or ants. Leaves, spines and petioles can all have these surface spaces.

Some leaf surfaces are glandular, or have secretory glands. Glands on leaves are usually described by leaf position. Glands distributed or clustered across a leaf surface are laminar glands. Marginal glands are on or near the leaf edge. Apical glands are on or near leaf apical tips, while basilaminar or basal glands are on or near the leaf base. Some trichomes are glandular / galnd tipped.

Venation

Tree leaves are usually thin enough for their larger vascular tissues or transport channels to be visible. These internal leaf / leaflet vascular bundles can be seen as patterns within a leaf which varies by genera and species, and are generically called veins. Veins are strands of vascular tissue in a leaf, with larger veins surrounded by supporting tissue, and dividing into smaller veins. The largest vein(s) are usually visible through a leaf or on the back / underside (abaxial surface) of a leaf.

The largest vein is considered the primary vein. If other visible veins are present which are nearly the same size as each other, they are all considered primary veins. A single primary vein or central vein can be called a mid-vein, mid-nerve, mid-rib, costae, or nerve. Secondary and tertiary veins branching off the primary vein(s) can form a number of patterns, eventually branching into minute vascular islands in the leaf lamina.

The largest vein and its immediate primary and secondary branches, generate patterns which can be categorized as venation types. Venation is the pattern of veins visible within a leaf lamina. Venation types include pinnate, palmate, pinnipalmate, perimarginal, parallel, dichotomous, and reticulate. Figure 17 lists the most common venation forms in native trees.

Types & Forms

Pinnate venation is when a leaf or leaflet has a single dominant vein with many smaller but equal sized lateral veins generated along its length. Pinnate venation, where secondary veins arc toward the leaf tip paralleling the leaf margin is termed arcuate venation. Penniveined is an antiquated term for a pinnately veined leaf. Figure 18.

Palmate venation describes when a leaf or leaflet has three or more main veins emulating / radiating from a single point (or nearly a single point), at or near the petiole apex / leaf laminar base. Digitate is an antiquated term for veins diverging from a central point. Trinerved venation has three primary veins all arising from near the leaf base. Triplinerved venation has three primary veins with two branching away well above the leaf base.

LONG & SOFT

arachnoid	**=**	**cob-web-like, tangled**
cottony	**=**	**fine**
eriophorous	**=**	**thick & cottony**
feathery	**=**	**branched**
gossypine	**=**	**cottony**
holosericeous	**=**	**silky moderately dense**
lanate	**=**	**dense wooly long tangled**
sericeous	**=**	**slender flattened silky sheen**
shaggy	**=**	**fragile**
silky	**=**	**slender flattened silky sheen**
tormentose	**=**	**cottony**
villose	**=**	**silky shaggy straight unmatted dense fragile**
woolly	**=**	**dense matted whitish**

LONG & STIFF

hirsute	**=**	**coarse**
hispid	**=**	**rough rigid bristly**

Figure 15: Various terms and descriptors used for long length leaf / leaflet surface trichomes.

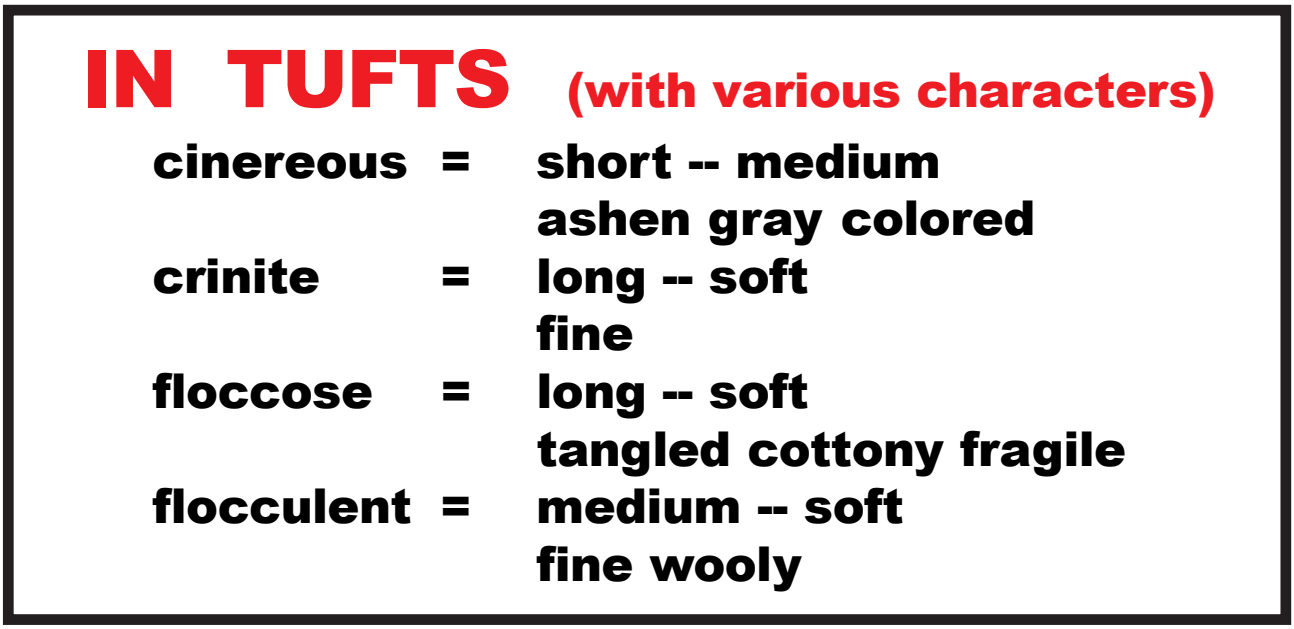

Figure 16: Various terms and descriptors used for tufted leaf / leaflet surface trichomes with various attributes.

Primary Visible Vein Forms

largest diameter vascular bundles in leaf / leaflet

pinnate = single primary vein with smaller secondary veins branching off along its length

palmate = 3 or more primary veins generated at or near the same point

- **actinodromous** = 3 or more primary veins radially from single base point
  - basal = diverge from petiole / lamina convergence
  - suprabasal = diverge farther beyond petiole connection
- **palinactinodromous** = primaries diverge in a series, not a single point
- **acrodromous** = primaries originate at one point & arc toward leaf / leaflet tip
  - basal = radiate from petiole / lamina connection
  - suprabasal = radiate farther within leaf lamina
- **flabellate** = a number of equal sized veins radiating from leaf base & branching closer to leaf edge
- **diadromous** = venation form like ribs of a fan

pinnipalmate = intermediate type between pinnate & palmate forms

Figure 17: General venation types in tree leaves.

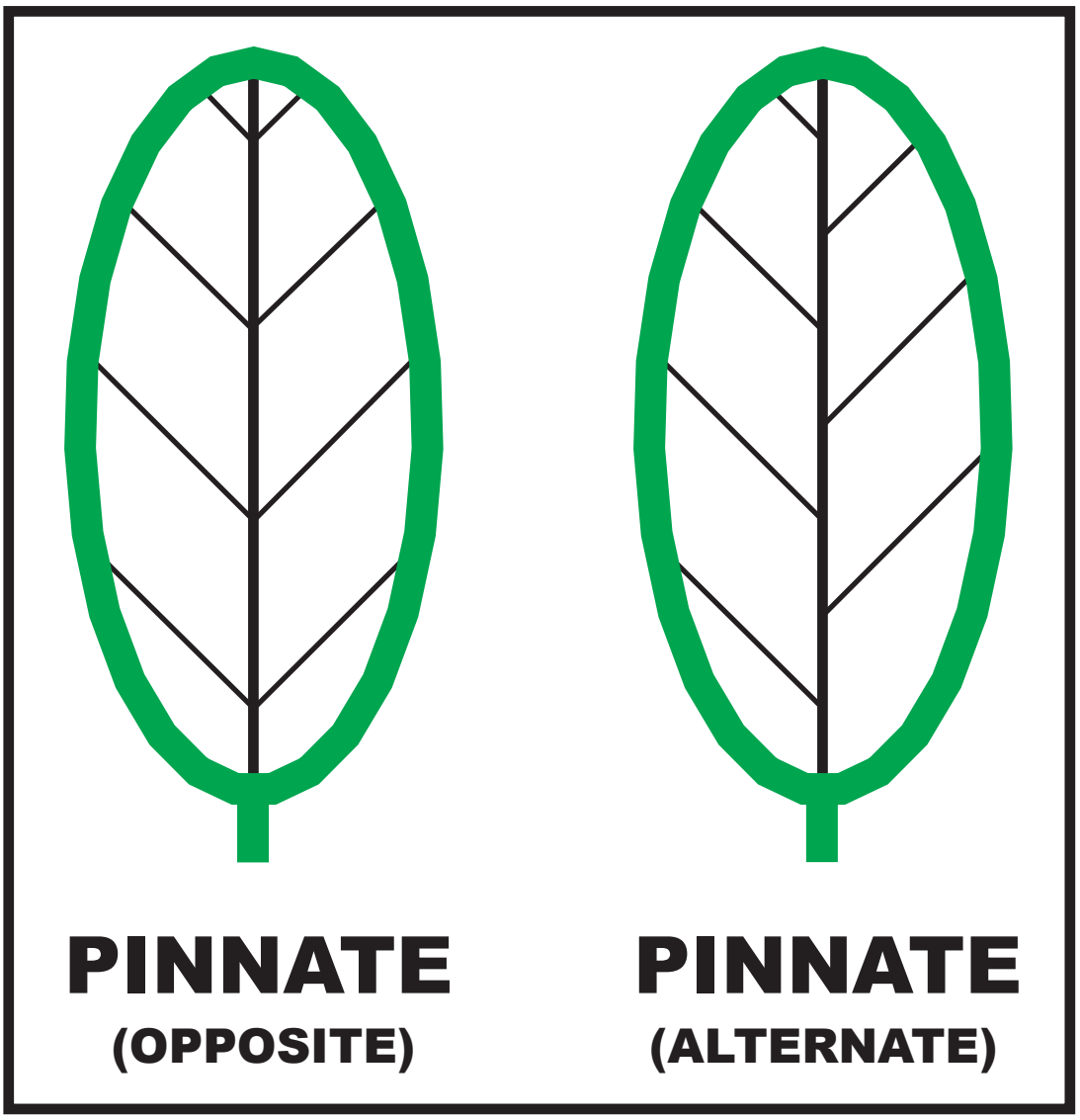

Figure 18: Pinnate venation forms in tree leaves.

Other terms have been used to define slight differences in palmate venation. Actinodromous is when three or more primary veins radiate away from single point at the leaf base. Palinactinodromous is venation where primary veins radiate near each other as series of near equal sized branches, but not from a single point. Diadromous is a palmate venation form like ribs of a fan. Acrodromous is a type of palmate venation where primary veins arise from a single point and then curve toward the apical tip. Flabellate has many small equal-sized veins radiating from a single point and branching near a leaf margin. Figure 19.

Pinnipalmate is an intermediate type between pinnate and palmate venation forms. Perimarginal venation show veins paralleling along a leaf margin. Parallel venation has many long veins parallel to each other over the length of a leaf or leaflet. Dichotomous venation is a unique type where equal Y branching of veins continue out to the edge of a leaf margin (i.e. as in ginkgo). Reticulate venation forms an interlaced vein network sometimes called net-veined.

Conclusions

Tree leaves present many textures, color variations, and light reflectance properties. These leaf / leaflet surface characteristics can suggest species, environmental conditions, or tree health. As one of two primary interfaces with a sustaining environment for a tree, leaves can all look different, but serve the same function across all trees. There are many ways to generate tree life with many types of leaves.

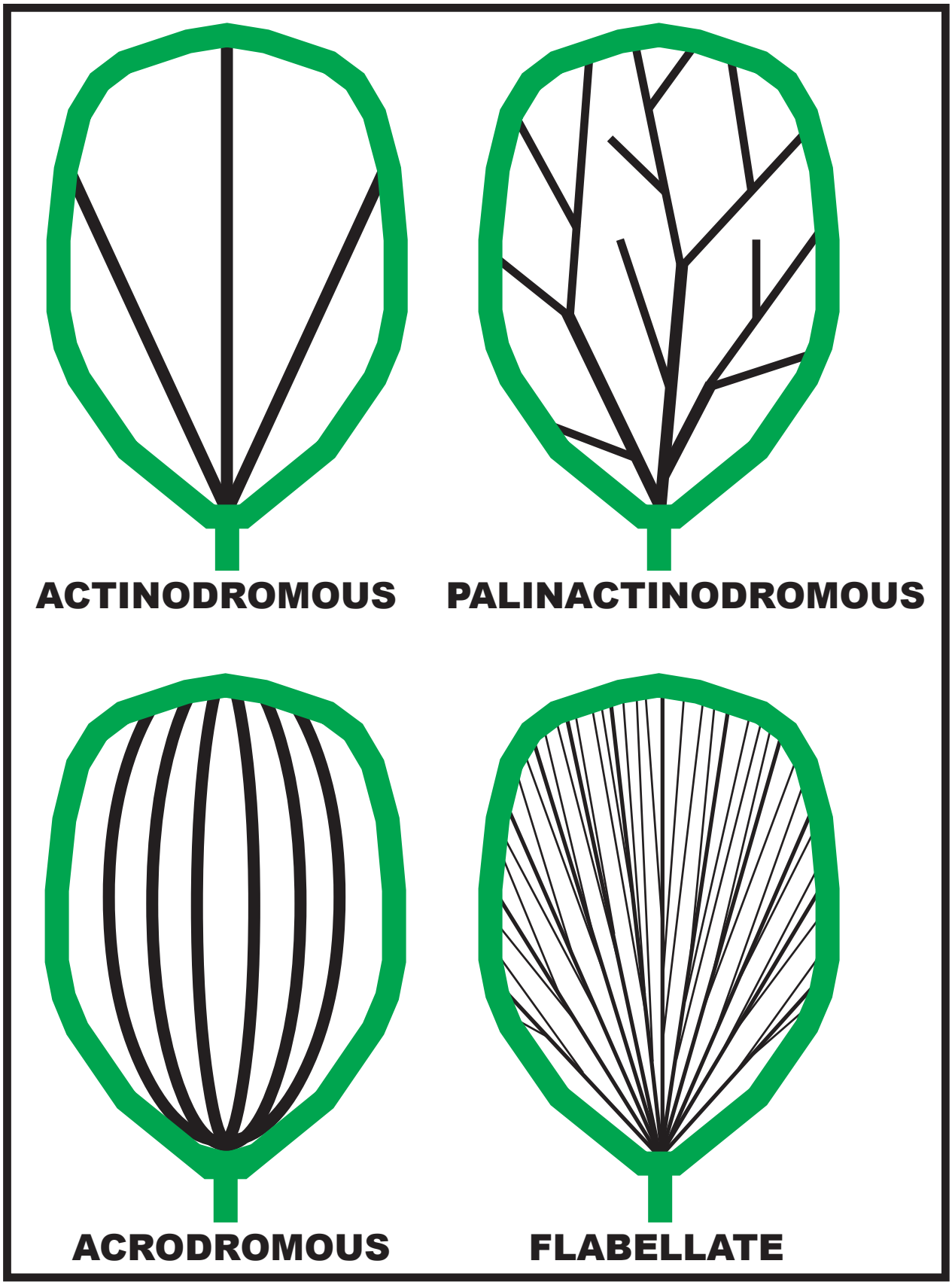

Figure 19: Palmate venation (3 or more basal main veins) patterns in tree leaves.

Outreach

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