**Michigan
Technological
University**

Michigan Technological University
Digital Commons @ Michigan Tech

Dissertations, Master's Theses and Master's Reports

2018

THE DYNAMIC NATURE OF FORAGE PREFERENCE AND MICROHISTOLOGICAL ATLAS

John J. Henderson

Michigan Technological University, jjhender@mtu.edu

Copyright 2018 John J. Henderson

Recommended Citation

Henderson, John J., "THE DYNAMIC NATURE OF FORAGE PREFERENCE AND MICROHISTOLOGICAL ATLAS", Open Access Dissertation, Michigan Technological University, 2018.
<https://doi.org/10.37099/mtu.dc.etdr/584>

Follow this and additional works at: <https://digitalcommons.mtu.edu/etdr>

Part of the [Other Ecology and Evolutionary Biology Commons](#)

THE DYNAMIC NATURE OF FORAGE PREFERENCE
AND MICROHISTOLOGICAL ATLAS

By

John J. Henderson

A DISSERTATION

Submitted in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

In Forest Science

MICHIGAN TECHNOLOGICAL UNIVERSITY

2018

© 2018 John J. Henderson

This dissertation has been approved in partial fulfillment of the requirements for the
Degree of DOCTOR OF PHILOSOPHY in Forest Science.

School of Forest Resources and Environmental Science

Dissertation Advisor: *Andrew J. Storer*

Committee Member: *Joseph K. Bump*

Committee Member: *David J. Flaspohler*

Committee Member: *John J. Durocher*

School Dean: *Terry L. Sharik*

Dedication

Dedicated to the
Conservation and Preservation
of Moose

Contents

	Dedication	vi
	Preface	vi
	Definitions	viii
	Abstract	ix
1	Introduction	1
1.1	Early history	1
1.2	Advancements in microhistology	2
1.3	Microhistological atlas	2
1.4	Application of microhistology	3
2	The dynamic nature of forage preference in a generalist herbivore	5
2.1	Introduction	6
2.2	Study system	8
2.3	Methods	10
2.3.1	Field methods	10
2.3.2	Laboratory methods	12
2.3.3	Statistical analysis of empirical data	13
2.4	Results	15
2.5	Discussion	16
	Acknowledgements	19
	Supplemental material 2.1: Years and sites of data collection	25
	Supplemental material 2.2: Relative forage availability	26
	Supplemental material 2.3. Interspecific variation in digestibility	28
	Supplemental material 2.4. Effect of categorization scheme	30
	Supplemental material 2.5. Relationship between forage availability and dietary frequency	33
3	Microhistological Atlas of Greater Yellowstone Elk Browse	34
3.1	Introduction	34
3.1.1	Dietary selection	35
3.1.2	Forage availability	36
3.1.3	Nomenclature	36
3.1.4	Microscopic examination	37
3.2	Materials and Methods	37
3.2.1	Plant collection	37
3.2.2	Epidermal peel	37

3.2.3	Microscope.....	38
3.3	Results	38
3.4	GYE elk forage: Gymnosperms	61
3.5	GYE elk forage: Graminoids.....	80
3.6	GYE elk forage: forbs, non-graminoid monocots and woody dicots.....	129
4	Microhistology of some preferred North American woody plants	374
4.1	Introduction	374
4.1.1	Background	374
4.1.2	Nomenclature	376
4.1.3	Microscopic examination.....	376
4.2	Materials and Methods	377
4.2.1	Plant collection.....	377
4.2.2	Epidermal peel	377
4.2.3	Equipment	378
4.3	Results	378
4.4	Description and Photographic Plates.....	408
5	Microhistology of Plant Fragments in Herbivore Diets.....	873
5.1	Introduction	875
5.2	Cellular Structures	876
5.3	Inclusions.....	877
5.4	Surface Growths	877
5.5	Plant Identification	878
5.6	Discussion	879
6	Permissions, permits and related documents.	905

Preface

Chapters 2 and Chapter 5 of this work represent peer-reviewed journal articles in various stages of review and publication. Chapters 3 and 4 of this work represent books that will be self-published for scientific reference by laboratories and analysts conducting microhistological analysis. Contribution of authors and status of each chapter are provided below:

Chapter 2: The dynamical nature of forage preference in a generalist herbivore was prepared and submitted to *Ecology*; manuscript was rejected and is currently being revised for resubmission to another journal.

Author Contributions: John A. Vucetich (JAV) conceived the research with input from John J. Henderson (JJH). JAV and Rolf O. Peterson (ROP) collected field samples and data with assistants over the past 13 years. Microscopic analysis was conducted by JJH and Grace L. Parikh (GLP) and JJH conducted statistical analysis with guidance from JAV. JJH and JAV wrote the manuscript; JAV provided guidance through all stages of this project. JAV and ROP reviewed manuscript in preparation for publication.

Chapter 3: Microhistological Atlas of Greater Yellowstone Elk Browse has been prepared for self-publication as a scientific reference book for microhistological analysis.

Author Contributions: JJH conceived the research and collected field samples; permission to collect samples within Grand Teton National Park was granted by the National Park Service (Chapter 7). JJH performed the microscopic analysis, recorded the photomicrographs and wrote the manuscript. Andrew J. Storer (AJS) provided guidance through all stages of this project.

Chapter 4: Microhistology of some Preferred North American Woody Plants has been prepared for self-publication as a scientific reference book for microhistological analysis.

Author Contributions: JJH conceived the research and collected field samples; permission to collect samples within Grand Teton National Park was granted by the National Park Service (Chapter 7). Herbarium samples were supplied courtesy of University of

Nebraska at Kearney and Michigan Technological University School of Forest Resources and Environmental Science. JJH performed the microscopic analysis, recorded the photomicrographs and wrote the manuscript. Andrew J. Storer (AJS) provided guidance through all stages of this project. Fifty plant descriptions and plates are reproduced from Chapter 3 for inclusion as they are woody plants. Portions of the methods, dichotomous key and spreadsheet description are reproduced from Chapter 3.

Chapter 5: Microhistology of Plant Fibers in Herbivore Diets, © 2016 *The Microscope Journal*; special permission to republish was granted by managing editor in author's dissertation (Chapter 7). JJH conceived the topic and wrote the manuscript. JAV provided guidance and reviewed manuscript in preparation for publication.

Definition of Selected Terms

Abaxial:	lower surface of the leaf
Adaxial:	upper surface of the leaf
Anomocytic:	a stoma that lacks differentiated subsidiary cells
Anticlinal:	external cell wall of epidermal cells
Brachyparacytic:	a stoma with opposing subsidiary cells to the stoma guard cells, a pair of subsidiary cells flanking the guard cells
Druses:	calcium or silica compounds found in the epidermal matrix of some plants
Globular:	spherical or globe-shaped
Microhistology:	the microscopical analysis of fecal pellets for the determination of diet
Phytolith:	silica mineral inclusions in epidermal tissue, phytoliths are also referred to as druses
Raphide:	calcium oxalate needle-shape crystals, frequently in large consolidate bundles
Rhombohedral:	three-dimensional crystals with angled faces
Sinuuous:	many turns and curves with a low amplitude
Stoma:	pore in the epidermal layer for the exchange of gasses
Stomata:	multiple stoma, pores in the epidermal layer for the exchange of gasses
Tetracytic:	a stoma with four subsidiary cells surrounding the guard cells
Trichomes:	hair or bristle outgrowths of the epidermal layer
Verrucate:	uneven wavy anticlinal wall of epidermal cells
Wavy:	multiple undulating or waveline curves with higher amplitude than sinuous

Abstract

Moose, *Alces alces*, are among the most iconic species in the northern circumpolar temperate forests. Multiple factors influence moose density. Winter is a time of severe dietary stress for moose because deciduous trees are leafless and available forage is limited to conifers with high plant secondary metabolites or low-energy deciduous twigs. Forage preference depends on the intrinsic forage properties, abundance of forage and environmental stressors. These stressors include predation risk and severity of climate that affect forage efficiency. We examined forage preference of moose on Isle Royale National Park during winter over a ten-year period. Diet was divided into two categories, coniferous and deciduous. Preference varied relative to abundance of coniferous and deciduous, winter severity and predation risk. As forage abundance increased, coniferous preference decreased. Preference for coniferous forage was weaker during severe winters and predation weakens the negative frequency dependence. Analysis was facilitated with microhistology

Microhistological analysis is typically conducted at commercial laboratories and few individuals are trained in this discipline. Furthermore, each forage study entails collection and analysis of reference specimens representative of forage available. This results in additional costs for the research that could be alleviated if published documents were available outlining the characteristics and providing a dichotomous key for the identification of these forage items. Two microhistological atlases, with dichotomous keys, are presented. One covers elk forage of the Greater Yellowstone Ecosystem and the second covers a range of woody plant material across North America. We hope that these atlases will act as a springboard for additional publications extending the microhistological database of available material to additional plant material, not only in North America but in other regions as well.

1 Introduction

1.1 Early history

The first experiments with microscope design date back to 1590 when two Dutch opticians, Zacharias and Hans Jansen, experimented with lenses mounted at opposite ends of a draw tube. Galileo Galilei also experimented with a microscope design in 1609 and Robert Hook documented a range of microscopic observations. However, these early attempts were very crude microscopes with a magnification range of 30X or less. It was Anton van Leeuwenhoek, in 1674 that achieved the first microscope of sufficient magnification (200 x) to observe single-celled plants and animals (Clay 1932).

Leeuwenhoek was largely excluded from the scientific community because he was an uneducated tradesman (draper) however he is credited as the Father of Microscopy. It was his diligence in observing nearly anything he could that distinguished him from others. Leeuwenhoek was unable to draw and he hired an illustrator to help document his discoveries. Drawings of the microscopic structure of plants were among the first discoveries. Over the next two hundred and fifty years, optical microscopy saw rapid growth and became firmly established as a serious scientific discipline. However, optical microscopy took a backseat to electron microscopy in the 1930's until the 1960's.

Through the efforts of Walter C. McCrone, Jr., the Father of Modern Microscopy, optical microscopy again returned to its rightful place. Walter McCrone established the McCrone Research Institute (McRI) in Chicago, Illinois in 1960. Thousands of students and professionals funneled through McRI from 1960 through present; each received training in the use and application of polarized light microscope for identification of fibers, particles, paint and biological materials.

The first reference to microhistology is a journal article about histological brain lesions (Wertham 1933). Early fecal pellet analysis techniques were termed plant histology or plant microtechniques (Baumgartner and Martin 1939, Dusi 1947, Davis 1951 and Garrigus and Rusk 1939). Hansen et al. (1976) were among the first to apply the term

microhistology to plant histology. Soon, microhistology came to mean microscopic analysis of fecal material, and tissue analysis become histology.

1.2 Advancements in microhistology

Jerry Holechek significantly advanced the science in the early 1980's by addressing the need for standardized techniques, training, and calculations (Holechek 1982, Holechek and Gross 1982a, Holechek and Gross 1982b, Holechek et al. 1982a, Holechek et al. 1982b, Holechek et al. 1982c, Holechek and Vavra 1981, Holechek et al. 1995 and Vavra and Holechek 1980). Training of new analysts and continued training of experienced analysts requires a database of known plant materials (Holechek and Gross 1982a). A few manuscripts have been published that document microhistological characteristics however most of these manuscripts have been limited in geographic scope (Henderson, Grainger and Springer 2013, Howard and Samuel 1979, Hurst and Beck 1988, and Lindstrom et al. 1998). Carriere's (2002) Arctic vascular plants manuscript was the first ecosystem-wide identification guide, but her identification criteria focused on trichomes and inclusions. Henderson et al. (2013) published the first atlas in book form and although it was region specific, it highlighted the need for more documentation.

1.3 Microhistological atlas

There is one commercial laboratory in the United States and one in Scandinavia offering microhistological services. Both labs have an extensive proprietary database of plant characteristics. A few universities have attempted microhistology. However, it is difficult to train oneself without the guidance of an experienced teacher or an atlas of characteristics. The McCrone Research Institute (McRI) in Chicago offers the only related course on the analysis of botanical traces, but this course does not cover the needs of a microhistologist in sufficient detail. Nevertheless, it is an excellent primer and should be considered by anyone new to the field. Coupling the McRI class with a detailed atlas would enable an inexperienced analyst to learn the techniques and become proficient. In this document, two atlases for microhistological studies are presented.

Chapter 3 covers elk forage in the Greater Yellowstone Ecosystem (155 plants) and chapter 4 is a microhistological atlas of some North American woody browse (233 plants). It is hoped that these documents, along with Henderson et al. (2013), will be a springboard to further documentation and sharing of this essential information. These guides can be used by the beginning analyst to learn the techniques and characteristics of fecal plant material.

1.4 **Application of microhistology**

Dietary preference of moose living on Isle Royale National Park was studied using microhistology. Isle Royale National Park is a 544 km² island in Lake Superior. Moose arrived on the island around 1910 (Peterson 1995). Moose abundance has been monitored annually since 1958, as part of the ongoing continuous predator-prey study, using aerial surveys and cohort analysis (Vucetich and Peterson 2004). During this timeframe, abundances peaked at 2450 in 1995 (Vucetich and Peterson 2004). Summer diets consist of deciduous browse and aquatic plants, while winter diets consist of deciduous twigs and conifers. Balsam fir (*Abies balsamea*) and northern white-cedar (*Thuja occidentalis*) are believed to be preferred winter browse (Belovsky 1981, Parikh et al. 2016). Parikh et al. (2016) reported that moose winter diet consisted of 47% balsam fir and 15% cedar; the balance of the diet is deciduous twigs.

Moose are un-hunted and wolves are the only predator of moose on the island. Winter is a period of stress for moose. Wolves prey on young, sick, and injured moose. Climatic stress in the form of winter severity is another factor that is expected to influence forage preference. With increasing snow depth, moose and other ungulates become more sedentary (Parker et al. 1984, Moen 1976). Vegetative composition is different between the western and eastern regions of the island (Brandner et al. 1990). Cedar abundance is greater and woody browse is more diverse on the western side of the island (Sanders and Grochowski 2011). These differences are attributed to differences in soil and glacial history (De Jager et al. 2009 and Brandner et al. 1990).

Fecal pellets were collected over a 10-year period. Pellets were analyzed using microhistology and moose forage preference for conifers was calculated as Manly's alpha (Chesson 1978). Using mixed-effect models, preference was measured as a function of forage availability, predation rate, winter severity and region.

2 The dynamic nature of forage preference in a generalist herbivore

Abstract. Preference of a consumer for various kinds of forage is a basic behavioral phenomenon with important consequences for the dynamics of populations and communities. Foraging preferences depend on intrinsic properties of the forage, such as nutritional content. Preference for a kind of forage may also depend on the relative abundance of that forage as well as other environmental contexts, such as predation risk (against the consumer) and climatic conditions that affect foraging efficiency. While those influences are believed to be important, they are not often examined. We assessed preference of a large browsing herbivore, moose (*Alces alces*), foraging on its natural diet during winter over a ten-year period. Their diet is usefully categorized as being comprised of two forage types, coniferous and deciduous. We assessed how preferences varied over space and time in relation to relative frequency of coniferous and deciduous forage as well as winter severity and predation risk by wolves (*Canis lupus*). The analysis was facilitated by ascertaining the diet of moose through microhistological analysis of fecal pellets. Preference decreased greatly with increasing relative abundance. Preference varied more with relative abundance than it varied due to the intrinsic difference in properties of the forage types. Negative frequency dependence is associated with increased diet diversity and the minimization of plant-specific defensive compounds. Both are at the cost of limiting the rate of intake. Preference for conifers was slightly weaker during more severe winters. Increasing predation risk had a tendency to weaken the strength of the frequency dependence.

Key words: *Alces alces*, consumer-resource dynamics, context-dependent decision-making, diet diversity, foraging preference, Isle Royale National Park, Manly's alpha, predation risk, risk-sensitive foraging

2.1 Introduction

Preference for any forage is believed to depend on the properties of the forage type. For example, preference for prey by predators is determined by body size (Clement et al. 2014). Among herbivores, preference is influenced by plant qualities such as the concentration of nutrients and toxins (Marsh et al. 2006).

Preference may also depend on environmental context, especially the relative frequency of a particular forage type. Three preference forage strategies are recognized: positive frequency-dependence, frequency independence, and negative frequency-dependence (Fig. 2.1). Positive frequency-dependent foraging (Fig. 2.1A) results when forage is consumed in relation to its environmental frequency or abundance. As environmental frequency of a forage item increases, dietary frequency increases. Prey switching occurs when preference for a forage type increases with its relative frequency (Murdoch 1969). Because forage items are consumed in proportion to their rate of encounter, this strategy maximizes dietary intake rate.

Frequency independent foraging (Fig. 2.1B) results when food is consumed independent of environmental frequency. This strategy can maximize gross energy consumption or maximize particular nutrients. This strategy can lower intake rate as search time is increased. Alternatively, negative frequency dependence (Fig. 2.1C) is a foraging strategy that tends to maintain a certain diversity of diet under a range of frequencies (Di Stefano and Newell 2008). With negative frequency dependence, as a forage item becomes more common in the environment, preference for that forage item decreases. For example, northern white cedar is rare in abundance and preferred forage when it occurs. Because rare items are favored, negative frequency-dependent foraging results in a mixed diet. This may be important for herbivores restricted to a diet that includes plants with toxins. Intake of a mixed diet tends to dilute the effects of plant secondary metabolites.

Frequency-dependent forage preferences are important not only as a behavioral phenomenon, but also for their potential influence on population- and community-level

dynamics. For example, positive frequency dependence can favor stability (in predator-prey interactions) and coexistence (among prey species) by favoring rare species and disfavoring common species (Murdoch and Oaten 1975). Conversely, negative frequency dependence could favor instability. The precise outcome almost certainly depends on the precise nature, strength, and linearity of the frequency dependence (e.g., Garrott et al. 2007).

In spite of its importance, frequency-dependent forage preference dynamics are notoriously difficult to study (Hassell 2000) and have only rarely been studied among mammalian herbivores. Collectively, the studies that exist, do not provide adequate understanding. Some studies have found frequency independence (Lundberg et al. 1990, Chevallier-Redor et al. 2001). Other studies suggest that frequency dependence is mediated by the forage types, with positive frequency dependence being exhibited when the forage categories differ importantly in tannin concentration, but not otherwise (Bergvall and Leimar 2005). Those studies were semi-controlled experiments and may not reflect the kind of choices that herbivores experience in more natural environments. Among studies conducted under more natural conditions, there have been several reports of negative frequency dependence (e.g., Edenius et al. 2002, Di Stefano and Newell 2008). However, another field study observed positive frequency dependence and frequency independence, depending on the forage species, time of year, and spatial scale of observation (Fortin et al. 2003).

Foraging preference may be influenced not only by relative frequency of forage types, but also by other environmental conditions such as predation risk. Predation risk is widely appreciated to influence other aspects of foraging behavior in herbivores (Verdolin 2006), such as vigilance, movement, and habitat selection (Fortin et al. 2004, Pierce et al. 2004, Fortin et al. 2005). Predation risk may also be associated with foraging strategies that minimize the amount of time spent foraging. For this reason, we hypothesize that increased predation rate is associated with a greater tendency for positive frequency dependence. Positive frequency dependence is associated with maximizing intake rate thereby reducing foraging time and possible predation.

A time-minimizing strategy for browsing ungulates could also correspond to consuming forage characterized by larger bite size (Cohen et al. 1999; Shipley 2007). For the system we investigate here, i.e., the moose (*Alces alces*) of Isle Royale National Park, coniferous forage is associated with larger bite size and increased intake rate than deciduous forage (Risenhoover 1987, Parikh et al. 2016), and it is plausible that increased predation risk would lead to increased preference for coniferous forage.

Another environmental condition that might influence preference is climatic stress. For ungulates living in north temperate ecosystems, winter severity is an important aspect of climatic stress. Because the energetic cost of locomotion increases with snow depth, ungulates tend to become more sedentary as snow depth increase (Parker et al. 1984, Jingfors 1982, Moen 1976). Increased snow depth has also been shown to alter the foraging strategy of grazing ungulates from being more rate-limited to more encounter-limited (Robinson and Merrill 2011). These circumstances represent reasons to think that winter severity could affect forage preferences and mediate the nature of frequency dependence.

Here we report on the diet preference of a free-ranging population of moose on Isle Royale National Park (ISRO) during the winter over a 10-year period (2004-2013) during which there was considerable inter-annual variation in predation risk and winter severity. We evaluate how the preference for two types of forage (i.e., conifers and deciduous, which differ importantly with respect to forage quality) is influenced by relative frequency, predation risk, and winter severity.

2.2 Study system

We assessed dietary preference for moose living on Isle Royale National Park (48°00'N, 89°00'W), an island (544 km²) in Lake Superior. During the study period, moose density varied between 1.7 km⁻² and 2.1 km⁻². These densities are high compared to many North American sites, but near the long-term annual average for this particular site.

The moose population is not hunted by humans and its dynamics are influenced by predation (Vucetich et al. 2011). In particular, predation rate accounts for approximately 60% of the variance in annual growth rate of the moose population. During the study period, predation rate ranged from 0.02 yr⁻¹ to 0.24 yr⁻¹ (interquartile range = [0.07, 0.19]).

The primary components of winter diet for Isle Royale moose are two species of conifer, balsam fir (*Abies balsamea*) and northern white cedar (*Thuja occidentalis*). On average, balsam fir comprised about 47% of the diet and cedar represents about 15% of the diet (Parikh et al. 2016). The balance of the diet is a variety of deciduous twigs. Of these deciduous species, the most common are sugar maple (*Acer saccharum*), trembling aspen (*Populus tremuloides*), and redosier dogwood (*Cornus stolonifera*), each representing about 5% of the diet (Risenhoover 1987). The remainder of the diet is comprised of about 18 other deciduous species, each representing less than a percent of the diet composition. While those averages are useful, considerable diversity exists among any particular fecal sample (Parikh et al. 2016). For example, balsam fir can be as low as 20% and as high as 80% of any particular sample.

The eastern and western regions of Isle Royale are distinguished by significant differences in vegetative composition and herbivory (Brandner et al. 1990; Parikh et al. 2016). The western region is characterized by increased relative abundance of cedar (Sanders and Grochowski 2011), greater browsing damage to balsam fir (Brandner et al. 1990) and smaller bite size of balsam fir (Vucetich and Peterson 2014). The western region is also characterized by more abundant and more diverse woody browse than the eastern region (Sanders and Grochowski 2011). These differences are less likely attributable to differences in moose density, which is similar in both regions (Montgomery et al. 2012); and more likely the result of differences in soil (De Jager et al. 2009) and glacial history (Brandner et al. 1990).

The climate is characterized by warm summers and cold, snowy winters. During the study period, mean daily snow depth for each of winter throughout the study period (measured daily from mid-January to early March) ranged from 18 cm to 72 cm (interquartile range = [34, 54]).

2.3 Methods

2.3.1 Field methods.

From 2004 to 2013, we re-visited ten sites each year in late May where we estimated the relative availability of different forage types and collected moose pellets (for estimating diet composition). From 2006-2013, we re-visited an additional four sites (Fig. 2.2; see Supplemental material 2.1 for details). The sites were marked and relocated by GPS. The sites were selected to represent habitat types where moose commonly forage and a range of relative availability of balsam fir, the dominant forage species.

Relative availability of different forage types was estimated at each site by a modified point-quarter method. In particular, we identified the species of moose forage along three, 100 meter transects radiating from the site center. Each of the three transects was separated by 120°, except in a few instances where geography (e.g., a lake) made such spacing impossible. Every three meters along each transect we temporarily placed a stake in the ground and recorded the species of the nearest available winter forage.

The end of the transects traced a circle whose area was equal to 3.1 ha. That area is comparable to the area within which a moose would forage over a two- or three-day period (Dussault et al. 2005). This consideration is important because the fecal pellets resulting from a particular meal are produced two or three days after consumption (Franzmann and Schwartz 1987).

The relative availability of woody vegetation changes slowly and gradually, and we estimated relative abundance at each site on two occasions (at the beginning and end of the study period). Some sites exhibited negligible change between the time periods and other sites exhibited larger differences (Supplemental material 2.2). In those later cases, differences may have been due to sampling error or due to plant succession. To ensure that our conclusions were robust to that uncertainty, we conducted two analyses. In one analysis, we assumed all of the difference was due to sampling error and we estimated relative frequency for each year as an average of the two measurements. In the other

analysis, we assumed the changes were successional and we estimated relative frequency each year (in each plot) as a linear trend marked by the two end-point observations. We present the results of the latter analyses in the main paper and results of the former analysis in Supplemental material 2.2. The results of both analyses were qualitatively identical.

These estimates of relative availability are coarse. If we had failed to find any statistically significant relationships between relative availability and preference, then large sampling error would likely have been the explanation. But we did not fail to find patterns (see *Results*). For similar reasons, the success we had in detecting patterns is likely the result of considerable variance in relative availability among sites (see Fig. 2.3).

From each site, we also collected 7-10 pellets from each of three piles of fecal pellets. They were collected from as near the GPS location as possible, typically within ten meters. Pellets were deposited sometime during the previous winter. The 14 sites were sufficiently spaced that one moose is unlikely to have browsed two sites in the same winter. We do not have any way of knowing whether the pellets collected from a site were or were not the same individual. Some of the unexplained variance in our results (see below) is likely attributable to differences in foraging behavior among individual moose.

Visiting every site in every year would have yielded 140 plot-year combinations. While logistical constraints prevented us from visiting every site in every year, we visited most sites in most years resulting in 113 plot-year combinations (Supplemental material 2.1).

The wolf and moose populations of Isle Royale have been studied intensively each winter. That study includes estimating predation rate (*pr*) each winter according to methods described in Vucetich et al. (2011). Because predation rate is the proportion of moose killed each year, it is an approximate indication of predation risk. We measured snow depth on a daily basis each year from mid-January to early March. From those

measurements, we calculated mean snow depth for each winter and used that value as an index of winter severity (*ws*).

2.3.2 Laboratory methods.

To assess diet composition, we conducted microhistological analyses of pellet samples (Holechek 1982). Shortly after pellets were collected they were dried in a drying oven and stored in brown paper bags. Prior to microhistological analysis each sample was re-dried, ground in a food processor, passed through two sieves (1 mm and 0.2 mm), rinsed with tap water, and drained. Samples are ground so that they pass through the sieves. Afterward, we incubated the sample for five minutes with 5 mL nitric acid to bleach the sample. The sample was agitated three times during the incubation period. The sample was poured into a flask with 45 mL distilled water and the incubation tube was rinsed with 45 mL distilled water. We brought the mixture of 90 mL distilled water, nitric acid, and sample to a boil for five minutes. After allowing the sample to cool, we decanted it and placed the processed sample in a vial. Using forceps and a probe, we spread a small amount of processed sample on a microscope slide and allowed it to dry for 24 hours. After drying, we applied three to four drops of Permount® (Fisher Scientific, Fairlawn, New Jersey), covered the sample with an 18x18 mm coverslip, and allowed it to dry for another 24 hours.

We prepared three slides for each of the three samples of fecal pellets that were collected. We viewed each slide at 100x magnification under polarized light and identified the plant fragments located closest to the center of the field of view for 100 stations on each of three slides. These stations were arranged in a grid, 10 columns and 10 rows, across the slide. Diet composition for each plot, each year, was based on the identification of 900 fragments (i.e., three hundred fragments from each of three fecal samples collected from each site, each year).

We identified each plant fragment on the basis of the structure of stomata and other distinguishing cells. Identifying structures were determined from a reference collection that we prepared, representing the plant species that Isle Royale moose are

known to eat (Risenhoover 1987). These reference samples were ground and processed in the same manner as moose pellet samples. Prior to microhistological analysis, each analyst passed blind tests based on a reference collection. Because many deciduous species are indistinguishable under a microscope, we pooled all deciduous species into one category. Every item identified as deciduous, balsam fir, or cedar was correctly identified 100% of the time.

Of the fragments examined in the fecal samples collected from the field sites, 7.2% were classified as unknown. Ninety percent of the fragments classified as unknown during blind tests were deciduous species and the remainder were cedar. Thus, we calculated diet composition after re-assigning 90% of the unknown fragments in each sample as deciduous and re-assigning 10% as cedar. Diet composition was also corrected to account for interspecific differences in digestibility (Supplemental material 2.3).

Finally, the items identified as cedar or balsam fir were pooled into a single category, i.e., conifer. This classification is supported by two considerations. First, the nutritional properties of the two-coniferous species are similar compared to the nutritional properties of the deciduous species (Risenhoover 1987). Second, a binary-choice model is often more appropriate than a multiple-choice model when a choice is context dependent and when relatively little is known about the psychology and evolutionary ecology of the choice being analyzed (Tversky and Simonson 1993; Carson et al. 1994). For further justification and assurance that our results are not a spurious artifact of this categorization, see Supplemental material 2.4.

2.3.3 Statistical analysis of empirical data.

For each year at each site, we calculated preference for conifers as Manly's alpha (Chesson 1978):

$$\alpha_c = \frac{f_c}{n_c} \left(\frac{f_c}{n_c} + \frac{1-f_c}{1-n_c} \right)^{-1} \quad [\text{Eqn 1}]$$

where n_c represents the relative availability (proportion) of coniferous forage in the environment, and f_c represents the relative frequency (proportion) of coniferous forage in the diet. By definition, the availability and preference of deciduous forage is equal to $n_d = 1 - n_c$ and $\alpha_d = 1 - \alpha_c$. Manly's alpha is proportional to the probability of taking a bite given that it was encountered (Manly et al. 1992, Edenius et al. 2002). Manly's alpha is also related in a precise manner to the attack rate in the functional response of a consumer-resource model (Chesson 1983).

In total, we have estimates of α_c for 113 site-year combinations. Our goal was to assess how α varied with relative availability in the environment (n), predation rate (pr), winter severity (ws), and region (rg), where region is a dichotomous variable representing the eastern or western region of Isle Royale (See *Study System* and Fig. 2.2). We conducted our assessment in R (R Core Team, 2014) and began by evaluating mixed models to determine whether the observations were influenced by plot or year effects that were not captured by our characterization of the plots (n and rg) or year (pr). Following the procedures developed by Zuur et al. (2009), we constructed a full model, *i.e.*, all main (fixed) effects, all pairwise interactions, and random intercepts for years and plots. We compared that full model to models that included: (i) all fixed effects, but no random effects, (ii) all of the fixed effects plus random intercepts for plot, and (iii) all of the fixed effects plus random intercepts for year. We evaluated these models on the basis of Akaike Information Criterion (AIC) and p -values for the random effect terms. The performance of these models indicated that random-effects can be ignored.

Because α is constrained to the range $[0,1]$, the relationship between n and α is best modelled by logit-transforming the values of α . To understand what combination of fixed effects best predict α , we used the step function in R (forward option). In particular, we used the step function where all four main effects (n , pr , ws , rg) and $pr:ws$, the interaction term most likely to be important given the complicated relationship between winter severity and predation risk for ungulates (Jedrzejewski et al. 1992, Mech et al. 2001). To test the hypothesis that frequency dependence is mediated by predation risk or

winter severity, we also tested the interaction terms, $n:pr$ and $n:ws$. The coefficient for those terms would represent the influence of pr and ws on the slope of the relationship between n and α .

2.4 Results

Our evaluation of mixed-effects models indicated that random effects for years and plots were not important. In particular, the model with only fixed effects had a dAIC of 0.04 compared to the best performing model with random effects (which included random intercepts for plots, $p=0.15$).

The regression algorithm that we used indicated that the most parsimonious model explains 71% of the variation in preference and includes main effects for n ($p<0.001$), rg ($p=0.004$) and ws ($p=0.04$) as well as interaction term, $n:pr$ ($p<0.001$) (Table 2.2). The sign of the coefficient for n was negative (-4.9 ± 0.4 SE; Fig. 2.4), indicating that moose foraging exhibits strong negative frequency dependence. The significance of region (rg) means that conifers were more preferred in the western region compared to the eastern region of Isle Royale (Fig. 2.2B).

The sign of the ws coefficient is negative ($-7.8\times10^{-3} \pm 3.9\times10^{-3}$), indicating that years of greater winter severity were associated with a slightly weaker preference for conifers (Fig. 2.3C). The sign of the $n:pr$ interaction ($+7.3\pm1.7$) indicated that years with increasing predation risk were associated a weakening of negative frequency dependence (Fig. 2.3A) – a result that is consistent with our hypothesis.

While frequency dependence was important and explains much of the variance in preference, moose also exhibited taxon-specific patterns in preference. In a year with average predation risk and winter severity, the preference for conifers was considerably greater than 0.5 in foraging patches where the relative frequency of conifers is 0.5 (Fig. 2.3). The statistical significance of the interaction terms also means that preference for conifers was strengthened during years with higher predation and lower winter severity.

The relationship between n and α (Fig. 2.3) has built-in a dependency because α is a function of n (Eqn 1). For this reason, p -values associated with the relationship between n and α may be biased. The statistical significance of the relationship between n and α can be assured by the relationship between f_c and n_c (Supplemental material 2.5).

Supplemental material 2.2 demonstrates that inferences pertaining to the influence of rg , n , and $n:pr$ are unaffected by details of how we handled estimation of n (as described earlier). However, the alternative handling of n (as shown in Supplemental material 2.2) suggested that the strength of ws was not constant, but rather mediated by the influence of pr (as indicated by the significance of the $pr:ws$ interaction term). The two approaches for handling f also indicated that the influence of ws was relatively weak (as shown in Fig 2.3C).

Supplemental material 2.4 demonstrates that the primary inferences pertaining to the influence of n and $n:pr$ were unaffected by the details of how food items are categorized. However, when forage was categorized as balsam fir and other forage (Supplemental material 2.4), rather than conifer and deciduous (Fig. 2.3, Table 2.2), then regression results indicated that preference was also affected by ws and $ws:pr$ (see Supplemental material 2.4 for additional details).

2.5 Discussion

We observed strong negative frequency dependence that would have the effect of maintaining diet diversity (Fig. 2.3). Such strategies are expected to maximize energy intake under certain circumstances (Pyke et al. 1977). Negative frequency dependence (and the more diverse diet that results from such a strategy) is also expected when forage is of low nutritional value or high in plant secondary metabolites (Bergvall and Leimar 2005). A diverse diet minimizes the concentration of any particular secondary metabolite that is specific to a particular species of forage. These circumstances would seem to characterize moose herbivory in Isle Royale (Parikh et al. 2016).

In contrast to our findings, two studies involving manipulated diets and controlled

trials found browsing ungulates to exhibit frequency independence or positive frequency dependence (Lundberg et al. 1990, Bergvall and Leimar 2005). One of those studies involved captive moose selecting between downy birch (*Betula pubescens*) or European mountain ash (*Sorbus aucuparia*) during late winter. Moose in the one study (Lundberg et al. 1990) lived in Sweden where, for example, Scots pine is a regular part of a moose diet, but not included as part of that experiment. The other study involved fallow deer choosing between pellets (artificial food) that differed with respect to the concentration of tannins. The results of both studies may have been a consequence of the artificial setting or focusing on selection among forage items that do not represent the full range of choices typically available to free-ranging ungulates. This idea is consistent with Edenious et al. (2001), who reported negative frequency dependence in free-ranging moose that could choose to forage from any of several stands in a manipulated forest that contained the diversity of forage species that is typical for moose.

Our results also contrast with observed patterns of foraging in bison, a grazing ungulate, that was found to exhibit frequency independence during the summer with a strong preference for wheat sedge (*Carex atherodes*) over wheatgrass (*Agropyron* spp.) (Fortin et al. 2003). This strategy is expected to maximize the short-term rate of energy intake, because availability of wheat sedge was greater than the higher energy wheatgrass (Fortin et al. 2002). By contrast, when forage detection was limited because of deep snow cover, bison exhibited positive frequency dependence (Fortin et al. 2003).

While moose foraging in this study exhibited negative frequency dependence on the whole, predation risk appears to weaken the strength of negative frequency dependence (Fig. 2.3A). A weakening of negative frequency dependence would be associated with reducing the time required for an ungulate to fill its rumen and thereby reduce the duration of a feeding bout. Forage search time is reduced with a weakening of negative frequency dependence. Weakening of frequency dependence was also associated with an increased preference for conifers. An increased preference for conifers would also tend to reduce the time to fill the rumen because the coniferous forage of Isle Royale is associated with a larger bite size than deciduous forage (Parikh et al. 2016) and bite

size is the most important predictor of intake rate within a patch for a browsing ungulate, in general (Shipley 2007) and on Isle Royale (Renecker and Schwartz 1997). Ungulates are also known to increase vigilance when predation risk is greater (Fortin et al. 2004). As such, our result is expected, inasmuch as a moose may be less able to be vigilant while foraging.

Prior research indicates that large ungulates exposed to predation tend to select foraging patches with increased cover or ready escape routes (Ripple and Beschata 2003, Fortin et al. 2005, Wirsing et al. 2007, and Montgomery et al. 2012). Those investigations have tended to focus on assessing how risk-sensitive foraging influence selection among foraging patches. By contrast, our analysis is distinctive for evaluating how risk sensitive foraging influences the selection of forage within a patch. Studies of selection between patch have shown various patterns, such as dugongs preferring to forage in microhabitats allowing for escape from, rather than avoidance of, predators (Wirsing et al. 2007). Prime-aged moose tend to make greater use (as compared to senescent moose) of habitat farther from the shoreline of Isle Royale, i.e., areas tending to provide better foraging but also increased predation risk (Montgomery et al. 2012; see also Ripple and Beschta 2003, Fortin et al. 2004). Our analysis of foraging within patches adds to such insights by suggesting that preference for conifers increases with increases in predation risk (Fig. 2.3A).

Winters characterized by deeper snows were associated with a slight weakening of preference for conifers, which would tend to increase the frequency of deciduous forage in the diet (Table 2.1, Fig. 2.3C). Deeper snows limit locomotion and increase the energy expenditure associated with locomotion (Parker et al. 1984). With increasing snow depth, moose become more sedentary and forage less widely (Moen 1976, Jingfors 1982). Similarly, grazing elk switch from being limited by handling time (digestive efficiency) to being limited by encounter rate as snow depth increases – a result that is expected given the effect of snow on locomotion (Robinson and Merrill 2011). The increase in preference for deciduous forage that we observed ought to increase intake rate in the encounter-limited circumstances that characterizes winters with deeper snows. This

is expected because deciduous forage is somewhat more abundant than coniferous forage (Fig. 2.3).

The effect of region on preference (Fig. 2.3B) may be associated with cedar being more common than balsam fir in the forest and in the diet on the western region of Isle Royale (Parikh et al. 2016). This result demonstrated that significant variation in foraging dynamics can occur over relatively small spatial scales, in this case that regions separated by about 40 km.

Acknowledgements

This work was also supported in part by the U.S. National Science Foundation (DEB-0918247 to JAV), Isle Royale National Park (CESU Task Agreement No. P11AC90808), the Robbins chair in Sustainable Management of the Environment for ROP at MTU, and a McIntyre-Stennis Grant (USDANifa #224870 and USDA-Nifa#1004363).

Fig. 2.1. Three preference forage strategies are recognized: positive frequency-dependence (panel A), frequency independence (panel B), and negative frequency-dependence (panel C). Positive frequency-dependent foraging results when forage is consumed in relation to its environmental frequency or abundance. Frequency independent foraging results when food is consumed independent of environmental frequency. With negative frequency dependence, as a forage item becomes more common in the environment, preference for that forage item decreases (Di Stefano and Newell 2008).

Table 2.1. Performance of models predicting preference (i.e., $\text{logit}[\alpha]$) from the following candidate predictors, relative forage availability in the environment (n), predation rate (pr), region (rg), winter severity (ws), and several selected interaction terms (see Methods). The models are those that result from the step function of R. Numbers in square parentheses are *p-values*.

Covariate(s) [<i>p-values</i>]	dAIC	R ²
n [<0.001]	20.37	0.64
n [<0.001], n:pr [<0.001]	8.53	0.68
n [<0.001], n:pr [<0.001], rg [0.0048]	2.24	0.70
n [<0.001], n:pr [<0.001], rg (0.0045), ws [0.045]	0.00	0.71

Fig. 2.2. The distribution of sites in Isle Royale National Park where forage preferences were estimated. The eastern and western regions of Isle Royale, which differ with respect to forest composition, are separated by the boundaries of a historic forest fire in the central portion of the island. Sites 1-10 collected in 2004-2013 are represented by crosses and sites 11-14 collected in 2006-2013 are represented with closed circles.

Fig. 2.3. Preference for coniferous forage (α) in relationship to relative availability of forage in the environment (n), predation risk (pr), geographic region (rg), and winter severity (ws) for moose on Isle Royale National Park. Blue lines depict the best fitting regression model for coniferous forage (Table 2), $\text{logit}[\alpha] = 2.78 - 4.94n + 0.32rg + 7.3(n \times pr) - 0.008(ws)$. Red lines depict deciduous forage and were calculated from the knowledge that $\alpha_d = 1 - \alpha_c$ and $n_d = 1 - n_c$. In panel (A), solid lines represent the 20th percentile of pr , dashed lines represent the 80th percentile of pr , $rg = 1$, and ws is set to the mean value. In panel (B), solid lines depict the western region of Isle Royale, dashed

lines depict the eastern region, $ws = 41.4$ and $pr = 0.146$, which represent the mean values for the study period. In panel (C), solid lines represent the 20th percentile of ws , dashed lines represent the 80th percentile of ws , $rg = 1$, and pr is set to the mean value.

Supplemental material 2.1: Years and sites of data collection

Table 2.A1. Years and sites during which we estimated relative forage availability (*n*) and diet composition (*f*). The site locations are shown in Figure 2.2. While logistical constraints prevented us from visiting every site in every year, we visited most sites in most years resulting in 113 plot-year combinations. Although we conducted a relative availability field survey in 2014, no moose pellets were collected.

Year	Site													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
2004	<i>f, n</i>	<i>f, n</i>	<i>f, n</i>	<i>f, n</i>	<i>f, n</i>	<i>f, n</i>	<i>f, n</i>	<i>f, n</i>	<i>f, n</i>	<i>f, n</i>				
2005	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>				
2006	<i>f</i>		<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>	<i>f, n</i>	<i>f, n</i>	<i>f, n</i>	<i>f, n</i>
2007	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>		
2008		<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>					<i>f</i>				<i>f</i>
2009	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>
2010		<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>		<i>f</i>	<i>f</i>		<i>f</i>	<i>f</i>		<i>f</i>
2011	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>
2012	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>		<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>		<i>f</i>
2013	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>		<i>f, n</i>	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>	<i>f</i>		<i>f</i>
2014	<i>n</i>	<i>n</i>	<i>n</i>	<i>n</i>	<i>n</i>			<i>n</i>	<i>n</i>	<i>n</i>	<i>n</i>	<i>n</i>	<i>n</i>	<i>n</i>

Supplemental material 2.2: Relative forage availability

Fig. 2.A2. Of the 14 plots that we observed, nine exhibited small differences (<9%) in the relative frequency of coniferous forage over the decade-long study period. Three plots exhibited moderate differences (14-21%) and two plots exhibited larger differences (32%).

When changes are attributed to plant succession (see *Field Methods*), the random effects are unimportant to the model structure (see *Results*). In particular, the model with only fixed effects had a dAIC of 0.04 compared to the best performing model with random effects (which included random intercepts for plots, $p=0.15$). When the changes are attributed to sampling error and the two measured values of relative availability are averaged and used as an estimate for each year, then it is also the case that random effects are unimportant to the model structure.

Table 2.A2 (next page) demonstrates that the most important conclusions that we draw in this paper – about the importance of forage availability and predation rate – are apparent for models created under the two assumptions (plant succession and sampling error). The different results (with respect to ws and $pr:ws$) between the two sets of assumptions are highlighted in the *Results* section.

Table 2.A2. Comparison of coefficients and *p-values* (in parentheses) for the best model of logit [α] under two assumptions. The assumption of plant succession is that assumption taken for results presented in the main paper. The covariate abbreviations are the same as given in Table 2.2.

Covariate	Coefficients [<i>p-values</i>]		
	Assumption: plant succession	Assumption: sampling error	% error between coefficients
n	– 4.94 [<0.001]	– 4.89 [<0.001]	1.0%
rg	0.32 [0.004]	0.33 [0.009]	-3.1%
n:pr	7.30 [<0.001]	7.52 [<0.001]	-3.0%
ws	– 7.8x10 ⁻³ [0.04]	–	–
pr:ws	–	-4.3x10 ⁻² [0.02]	–

Supplemental material 2.3. Interspecific variation in digestibility

The forage species vary with respect to digestibility. In particular, cedar is 42.1% digestible, balsam fir is 36.2% digestible, and deciduous species are 26.2% ($\pm 2.2\%$, standard error for 15 species) digestible (Risenhoover 1987). We do not have an estimate of digestibility for white pine, which represents only a very small portion of diet (i.e., $<0.5\%$). We adjusted proportion of diet for each of those three food categories as:

$$\frac{p_i/d_i}{\sum_i(p_i/d_i)}$$

where p_i is the unadjusted proportion and d_i is digestibility of food category i .

When interspecific differences in digestibility are taken into account, the random effects were unimportant to the model structure (see Results). When those differences were not taken into account, then it was also the case that random effects were unimportant to the model structure. In particular, the best performing model included only fixed effects whereas the second best performing model with random effects had a dAIC of 0.05 (which included random intercepts for plots, $p=0.16$).

Table 2.A3 (next page) demonstrates that the basic conclusions (significant and magnitude of effect) were similar for models where the data were and were not corrected for digestibility.

Table 2.A3. Comparison of coefficients and *p-values* (in parentheses) for the best model of logit [α] under two assumptions. The assumption of corrected for digestibility is that assumption taken for results presented in the main paper. The covariate abbreviations are the same those as given in Table 2.2.

Covariate	Coefficients [<i>p-values</i>]		
	Assumption: corrected for digestibility	Assumption: uncorrected	% error between coefficients
n	– 4.94 [<0.001]	– 4.94 [<0.001]	0.0%
rg	0.32 [0.004]	0.29 [0.011]	– 9.4%
ws	– 7.8×10^{-3} [0.04]	– 8.1×10^{-3} [0.04]	– 3.8%
n:pr	7.30 [<0.001]	7.36 [<0.001]	0.8%

Supplemental material 2.4. Effect of categorization scheme

In the main text we presented results based on the assumption that diet was usefully categorized as deciduous forage and coniferous forage (mostly balsam fir and some cedar). To increase assurance that our results were not overly sensitive to that categorization, we re-ran our analyses based on categorizing forage as balsam fir versus other kinds of forage (cedar and deciduous). Table 2.A4 (below) demonstrated that the most important conclusions in this paper – about the importance of forage availability (n) and its interaction with predation rate (n:pr) – were also apparent when the diet was categorized in this alternative manner.

Under this alternative categorization, we also found that preference was affected by winter severity (ws) and its interaction with predation risk (ws:pr), but not when it was categorized as coniferous and deciduous (Table 2.A4). The other apparent difference between these categorizations pertains to the importance of region (rg). When forage was categorized as coniferous or deciduous, then preference for conifers was greater in the western region (Fig. 2.3A). However, when forage was categorized as balsam fir or other forage, then preference for other forage (non-balsam fir) was greater in the western region (Fig. 2.A4). While the regression coefficient resulting from these two categorization schemes are quite different, they both point to a similar ecological circumstance. Recognizing that circumstance begins by acknowledging that balsam fir (a conifer) was more prevalent in the eastern region of Isle Royale (40% and 19% occurrence in the eastern and western regions, respectively), but cedar (also a conifer) was more prevalent in the western region of Isle Royale (15% and 2% occurrence in the western and eastern regions respectively).

Table 2.A4. Comparison of coefficients and *p-values* (in parentheses) for the best model of logit [α] under two assumptions. The assumption of coniferous versus deciduous is that assumption taken for results presented in the main paper. The covariate abbreviations are the same as given in Table 2.2.

Covariate	Coefficients [<i>p-values</i>]		
	Assumption:	Assumption:	% error
	coniferous vs.	balsam fir vs.	between
	deciduous	other forage	coefficients
n	– 4.94 [<0.001]	– 6.24 [<0.001])	– 26.3%
rg	0.32 [0.004]	– 0.87 [<0.001]	370%
n:pr	7.30 [<0.001]	13.1 [<0.001]	80.8%
ws	– 7.8×10^{-3} [0.04]	–	–
pr:ws	–	-5.6×10^{-2} [<0.001]	–

Fig. 2.A4. Preference (α) for balsam fir and non-balsam fir forage in relationship to relative availability of forage in the environment (n) and geographic region (rg) for moose on Isle Royale National Park. Blue lines depict the best fitting regression model for balsam fir (Table 2.A4), $\text{logit}[\alpha] = 2.84 - 6.24n - 0.87rg + 13.1(n \times pr) - 0.056(pr \times ws)$, where pr is predation risk and ws is winter severity (ws). We set $ws = 41.4$ and $pr = 0.146$, which represent mean values for the study period. Solid lines depict the western region of Isle Royale, and dashed lines depict the eastern region, Red lines depict non-balsam fir forage and were calculated from the knowledge that $\alpha_{nbf} = 1 - \alpha_{bf}$ and $n_{nbf} = 1 - n_{bf}$.

Supplemental material 2.5. Relationship between forage availability and dietary frequency.

Fig. 2.A5. Relationship between availability of coniferous forage (n_c) and frequency in the diet (f_c). The solid line is the fitted regression line between n_c and f_c , which has a slope that is significantly less than 1. In particular, the 99.5% confidence interval is [0.10, 0.50] for the slope and [0.40, 0.58] for the intercept. The dashed line is the line of equality (i.e., slope = 1, intercept = 0). If the observations were appropriately characterized by the dashed line (or any line with a slope of 1), then Manly's alpha (α_c) would not tend to increase or decrease with changes in n_c . The slope and intercept of the fitted regression is evidence for the statistical significance of a negative relationship between n_c and α_c that is shown in Figure 2.3.

3 Microhistological Atlas of Greater Yellowstone Elk

Browse

3.1 Introduction

The elk of the Greater Yellowstone Ecosystem (GYE) belong to the subspecies *Cervus elephus nelsoni* (Rocky Mountain Elk). Twenty-two subspecies of *Cervus elephus* are recognized that range in the north circumpolar regions of North America, Europe and Asia with *Cervus elephus barbarus* extending into Northern Africa. *Cervus elephus* have also been introduced to New Zealand. Six subspecies of elk are endemic to North America with *C. e. canadensis* (Eastern elk) and *C. e. merriami* (Merriam's elk) extinct since the introduction of Europeans in North America (Toweill and Thomas 2002).

Cervus elephus roosevelti (Roosevelt or Olympic elk) are considered the largest extant elk with bull average weight approximately 254 kg and cows 215 kg (Toweill and Thomas 2002). The current range of Roosevelt elk is isolated to the coastal areas of Humboldt and Del Norte, California and northward through western Oregon, Washington and into British Columbia. *C. e. nanodes* (Tule elk) is the smallest of the North America subspecies with bulls approximately 250 kg (McCullough 1969). Tule elk are isolated to the grass and marshlands of the Central Valley of California. *C. e. manitobensis* (Manitoba elk) bulls average 353 kg whereas cows average 275 kg (Toweill and Thomas 2002). Manitoban elk range formerly covered areas of Manitoba and Saskatchewan however current range is now central Manitoba. Manitoban elk have also been transplanted into the former range of *C. e. canadensis* (Eastern elk) on the eastern side of Smoky Mountain National Park. *Cervus elephus nelsoni* (Rocky Mountain elk) bulls average 333 kg whereas cows average 259 kg (Flook 1970). The historic range of Rocky Mountain elk extended from the 35th parallel to the 55th parallel of the Rocky Mountains and adjacent ranges (Bryant and Maser 1982). The near eradication of the elk herds from North America between the late 1600's and the early 1900's with subsequent reintroductions of the Yellowstone herd and the Manitoban herd has dulled much of the

subspecies differences (Murie 1951). Elk are classified as intermediate feeders with a diet that ranges from graminoids, forbs (succulents) and woody plants such as shrubs and trees (Robbins et al. 1995).

3.1.1 Dietary selection

Elk, members of the suborder Ruminantia (ruminants), are herbivores with a four-chambered stomach. Along with deer (*Odocoileus* sp.), moose (*Alces alces*) and caribou (*Rangifer taranus*), elk are part of the family Cervidae. Unlike deer and moose, elk and caribou are primarily grazers (graminoids and forbs) however elk are classified as intermediate feeders because of their penchant for also consuming shrubs and trees (Baker and Hobbs 1987). Elk diets show considerable plasticity and are largely determined by forage availability (Jenkins and Wright 1988, Merrill 1994). In winter, elk are primarily grazers as deciduous plants are leafless, however conifers become part of the winter diet. Conifers are higher in available energy and nutrients than dormant graminoids, however they are also higher in plant secondary metabolites such as tannins and phenolics (Parikh et al. 2017, MacArthur et al. 1993). Elk will migrate from summer upland habitats to less snow-covered lowland winter habitats such that access to graminoids is continuous throughout the winter period. Non-winter diets concentrate more on high-energy woody deciduous plants and less on graminoids. The goal of most ruminates is maximizing nutrient and net energy intake (Hanley et al. 1989).

The mechanisms used by ruminates for forage selection is not clearly understood but Provenza (1995) documented that the primary mechanism for diet selection involved postingestive feedback loops. Through experience, herbivores establish a link between forage that is responsible for discomfort and food items that satiate. Herbivores will avoid overconsumption of discomfort foods and concentrate on the items that provide higher energy and satiate their hunger (Provenza 1995). Herbivores will return to these favorable forage patches repeatedly (Gillingham and Bunnell 1989, Provenza 1995). Elk food habits are varied with over 150 species of forbs, lichens and ferns; approximately 100 species of graminoids and approximately 150 species of woody plants documented as

predominant to occasional forage items (Cook, part of Elk Book, pg 288). Approximately 450 forage items are scattered throughout the differing habitats of elk with some items available to Tule elk and similar or different items available to Manitoba or Rocky Mountain elk.

3.1.2 Forage availability

Within the Greater Yellowstone Ecosystem, the National Park Service documents 224 graminoids, forbs and woody plants that match the aforementioned forage items. For this study, we collected 155 forage items. An additional 39 forage items were previously collected and documented (Henderson, Granger and Phillips 2013). Of the 194 collected forage items, 31 were graminoids, ferns and mosses, 73 were forbs and 90 were woody plants. Samples of bark, seeds, fruits or other possible forage items were not collected and are not a part of this study. Table 3.1 contains a plant class column in order to differentiate graminoids, ferns, mosses, forbs and woody (shrubs) plants. Additional forage items, collected as part of a different study, are presented in Henderson, Granger and Phillips (2013). However, these forage items add to the study providing a more complete representation of forage availability within the Greater Yellowstone Ecosystem.

3.1.3 Nomenclature

Scientific plant names are relatively uniform however occasionally names are adjusted as research shows different genetic or other derivations. Many times, plants are known by many different common names. For this document, we used the USDA PLANTS database: A synonymized checklist of the vascular flora of the United States, Canada, and Greenland for scientific and common names (USDA, NRCS 2018). Stomata nomenclature is in accordance with Prabhakar (2004) and phytolith inclusions are in accordance with the ICPN Working Group (Madella, Alexandre and Ball 2005). Cellular structures and other epidermal features are in accordance with Metcalfe and Chalk (1979).

3.1.4 Microscopic examination

Microscopic examination of epidermal surfaces and surface features was in accordance with Henderson and Vucetich (2016) and Henderson, Phillips, and Springer (2014) (chapter 5). Diagnostic features include the morphology and structure of epidermal cells, surface growths (trichomes and scales), inclusions (phytoliths, calcium carbonate, calcium oxalate, starch, etc), stomata and surrounding subsidiary cells, etc. Many diagnostic features are family and/or genera specific; the collection consists of 46 families and 116 genera. Families and genera are summarized in table 3.1.

3.2 Materials and Methods

3.2.1 Plant collection

Plant collection was conducted between May and August 2017. Within park boundaries, collection was conducted under United States Department of Interior, National Park Service scientific research and collecting permit number “GRTE-2017-SCI-0078” (chapter 7). A representative clipping of each plant was obtained with pruning shears and stored in a one-gallon plastic bag with approximately 100 ml of water to prevent desiccation. After field collection, plants were pressed a minimum of a fortnight in a Bioquip 30X46 cm standard plant press. Each clipping was then pressed between sheets of newsprint and stored in a 12.5X23 cm envelope; site collection information was recorded for each clipping. Each plant clipping was viewed under a stereoscope and surface characteristics recorded.

3.2.2 Epidermal peel

Each plant clipping was viewed under a Bausch & Lomb 1X stereoscope and a pair of 10X W.F. oculars that was illuminated with a Bausch & Lomb 35-watt light source. Two additional lenses, 0.5 and 2X, were attached to the stereoscope objective yielding an effective magnification of 0.5-20X. Surface features such as hairs, texture, and morphology were recorded; epidermal peels were mounted of both surfaces. Many times,

abundances of stomata and trichomes differ on the adaxial (top) and abaxial (bottom) surfaces; however once digested, it is not possible to differentiate adaxial from abaxial (Steward, 1965). A leaf was boiled for 10 minutes in a distilled water bath to soften the epidermal surface (Carriere, 2002). Epidermal sections were peeled using fine-tipped forceps and a #10 scalpel blade. Epidermal sections were soaked in household bleach (3-8% sodium hypochlorite) for five minutes followed by a five-minute soak in distilled water. The outer leaf surface of the epidermal peel was mounted toward the coverslip on microscope slides (Holechek 1982). Epidermal peels and tape samples were mounted using Hoyer's mounting medium (Hempstead Halide) to standard 25x75x1 mm microscope slides with 18X18 mm cover slips.

3.2.3 Microscope

An Olympus BH-2 BHS trinocular microscope coupled with a BH2-KP polarizing attachment was employed for microscopic examinations. An Omax 18-megapixel USB3.0 microscope camera was used for photomicrographs and Toup View software by ToupTek Photonics was used for image capture. The Omax camera was calibrated using a 0.1mm stage micrometer slide. The Omax camera was mated to a MSI 6QF Apache Pro i7 quad-core PC computer with NVIDIA GTX970M video card. Adobe Lightroom CC and Adobe Photoshop CC software were used for processing of digital images. Images were cropped and converted to JPEG format; no digital enhancement or alterations were performed. To preserve image detail, images were saved uncompressed at maximum resolution. Digital images were stored on a 1 terabyte hard drive and backed-up on a second hard drive.

3.3 Results

Each of the 155 plants includes a written description of macroscopic and microscopic characteristics. Plants are divided into three groups; graminoids, conifers and angiosperms. Laboratory specimens have the advantage of being larger and more intact

than masticated specimens. Masticated specimens are typically smaller, however epidermal structures, stomatal morphology and structure, and inclusions such as phytoliths and surface growths are typically evident (Carriere 1999, Larter 1999). Sufficient characteristics are typically present to permit identification; at times to the genus level and other times to species.

Similar plant characteristics are combined into a series of eight groups identified as Groups A-H. The groups can be used like a dichotomous key to identify similar plants and occasionally individual species. The primary characteristic that should be used for any microhistological identification scheme is availability. A field biologist should always provide a listing of forage available for the study area.

Identification key for GYE elk forage

- Ia Epidermal cells square, rectangular or parallelogram shape; epidermal cells stacked brick-like; stomata in rows, stomata guard cells bilobal, isotropic silica phytoliths typically present (**Group A**-Graminoids)
- Ib Stomata guard cells not bilobal (go to II)
- IIa Epidermal cells square, rectangular, or parallelogram shape; epidermal cells stacked brick-like, stomata in rows, stomata tetracytic (**Group B**-Gymnosperms)
- IIb Epidermal cells square, rectangular, parallelogram, polygonal or irregular shape; stomata in rows or random; stomata not tetracytic; druses present or absent (go to III)
- IIIa Stomata in rows; epidermal cells square, rectangular, parallelogram, polygonal or irregular shape; stomata not tetracytic; druses present or absent (**Group C**-Monocots other than graminoids)

- IIIb Stomata randomly arranged; epidermal cells square, rectangular, parallelogram, polygonal or irregular shape; stomata not tetracytic; druses present or absent (go to IV)
- IVa Stomata brachyparacytic, epidermal cells square, rectangular, parallelogram or polygonal shaped, anticlinal walls straight, straight-curved or sinuous, stomata randomly arranged; druses present or absent (**Group D**)
- IVb Stomata not brachyparacytic or tetracytic (go to V)
- Va Trichomes double-ended, multi-branched or stellate; stomata anomocytic and randomly arranged; epidermal cells square, rectangular, parallelogram, polygonal or irregular shaped, anticlinal walls straight, straight-curved, sinuous or wavy; druses present or absent (**Group E**)
- Vb Trichomes segmented; stomata anomocytic and randomly arranged; epidermal cells square, rectangular, parallelogram, polygonal or irregular shaped, anticlinal walls straight, straight-curved, sinuous or wavy; druses present or absent (**Group F**)
- Vc Trichomes absent or unbranched; stomata anomocytic and randomly arranged; epidermal cells square, rectangular, parallelogram, polygonal or irregular shaped, anticlinal walls straight, straight-curved, sinuous or wavy; druses present or absent (go to VI)
- VIa Trichomes unbranched; stomata anomocytic and randomly arranged; epidermal cells square, rectangular, parallelogram, polygonal or irregular shaped, anticlinal walls straight, straight-curved, sinuous or wavy; druses present or absent (**Group G**)
- VIb Trichomes absent; stomata anomocytic and randomly arranged; epidermal cells square, rectangular, parallelogram, polygonal or irregular shaped, anticlinal walls straight, straight-curved, sinuous or wavy; druses present or absent (**Group H**)

Group A-Graminoids: Stomata guard cells bilobal, epidermal cells square, rectangular or parallelogram shape; epidermal cells stacked brick-like; stomata in parallel rows.

- a. Silica present
 - b. trichomes present
 - c. silica orbicular, oblong to ovate
Agropyron cristatum,
Elymus canadensis, *E.*
trachycaulus, *Poa alpina*
 - c. silica polylobate
Dactylis glomerate, *Poa*
secunda
 - c. silica rectangular
Bromus tectorum, *Trisetum*
spicatum
 - b. trichomes absent
 - c. silica ovate to oblong
Deschampsia cespitosa
Festuca ovina, *Koeleria*
macrantha
 - c. silica bilobate
Aristida basiramea
 - c. silica polylobate
Phleum alpinum, *Poa*
bulbosa
 - c. silica barrel-shaped
Bouteloua gracilis,
Muhlenbergia frondosa
 - c. silica rectangular
Bromus inermis,
Calamagrostis canadensis
 - c. silica scutiform
Phleum pretense
 - c. silica trapeziform
Poa compressa, *Poa*
pratensis
- a. Silica and trichomes absent
 - b. anticlinal walls straight
Juncus arcticus
 - b. anticlinal walls wavy to verrucate
Carex haydeniana, *Carex*
raynoldsii

Group B-Gymnosperms: Epidermal cells square, rectangular, or parallelogram;
epidermal cells stacked brick-like, stomata in parallel rows and tetracytic

- a. Stoma rectangular or parallelogram
 - b. LWL-UWL wide, polar stem narrow *Abies lasiocarpa*
 - b. LWL-UWL narrow, polar stem narrow *Juniperus communis*, *J. scopulorum*
 - b. LWL-UWL wide, polar stem wide *Pinus albicaulis*, *P. contorta*, *P. flexilis*
- b. Stoma rounded
 - b. LWL-UWL narrow, polar stem wide *Picea engelmannii*
 - c. chloroplast in guard cells *Picea pungens*
- c. Stoma circular
 - b. LWL-UWL moderate, polar stem wide *Pseudotsuga menziesii* var. *glauca*

Group C-Non-graminoid Monocots: Stomata in parallel rows and not tetracytic;
epidermal cells stacked or aligned.

- a. Trichomes unbranched
 - b. calcium oxalate, calcium carbonate, bilobate silica inclusions *Allium textile*
 - b. calcium oxalate, calcium carbonate absent
 - c. silica inclusions *Maianthemum stellatum*
 - c. silica absent *Maianthemum racemosum*, *Lycopodium annotinum*
- a. Trichomes absent
 - b. stomata brachyparacytic *Typha latifolia*
 - b. stomata not brachyparacytic

- c. silica inclusions
 - d. anticlinal walls wavy or verrucate *Equisetum arvense*,
E. hyemale
 - d. anticlinal walls straight or straight-curved *Iris missouriensis*
- c. silica absent
 - d. epidermal morphology irregular *Pteridium aquilinum*
 - d. epidermal morphology polygonal *Camassia quamash*
 - d. epidermal morphology rectangular, square or parallelogram *Equisetum fluviatile*

Group D: Stomata brachyparacytic, stomata and epidermal cells randomly arranged.

- a. trichomes unbranched
 - b. calcium oxalate inclusions
 - c. calcium carbonate inclusions *Salix fragilis*
 - c. calcium carbonate absent *Populus balsamifera*
 - b. calcium oxalate absent
 - c. silica inclusions *Oenothera macrocarpa*
 - c. silica absent *Galium boreale*
- a. trichomes absent
 - b. calcium oxalate inclusions
 - c. calcium carbonate inclusions *Populus angustifolia*
 - c. calcium carbonate absent *Liquidambar styraciflua*
 - b. calcium oxalate absent
 - c. calcium carbonate inclusions *Populus tremuloides*
 - c. calcium carbonate absent *Vaccinium angustifolium*

Group E: Trichomes double-ended, multi-branched or stellate, stomata and epidermal cells randomly arranged.

- a. trichomes double-ended, calcium oxalate present
 - b. starch inclusions *Cornus sericea*
 - b. starch absent *Cornus canadensis*
- a. trichomes stellate
 - b. epidermal morphology irregular *Elaeagnus commutata*
 - b. epidermal morphology polygonal, brachyparacytic *Mahonia repens*

Group F: Trichomes segmented, stomata and epidermal cells randomly arranged.

- a. trichomes unbranched present
 - b. silica inclusions *Artemisia ludoviciana, A. tridentata*
 - b. silica absent *Achillea millefolium, Antennaria parvifolia, Antennaria rosea, Artemisia tridentata*
- a. trichomes unbranched absent
 - b. calcium oxalate inclusions *Erigeron sp., Mitella diphylla, Rubus parviflorus*
 - b. calcium oxalate absent
 - c. silica present *Arnica cordifolia*
 - c. silica absent
 - d. anticlinal walls wavy to verrucate *Agoseris glauca*
 - d. anticlinal walls straight-curve *Rudbeckia occidentalis, Solidago canadensis,*

Taraxacum officinale,
Xanthium strumarium

Group G: Trichomes unbranched, stomata and epidermal cells randomly arranged.

a. calcium oxalate present

b. calcium carbonate present

c. epidermal morphology irregular

Amelanchier alnifolia

c. epidermal morphology polygonal

Acer negundo,

Cercocarpus ledifolius,

Fragaria virginiana, *Malus*

pumila, *Vaccinium*

membranaceum

b. calcium carbonate absent

c. trichomes textured or striated

Lonicera involucrate,

Potamogeton gramineus,

Potentilla gracilis

c. trichomes attached to veins

Rosa woodsia

c. trichomes smooth

d. epidermal morphology irregular

Arenaria serpyllifolia,

Sambucus racemosa

d. epidermal morphology polygonal

e. stoma polar stem narrow

Betula occidentalis,

Ceanothus velutinus,

Eriogonum heracleoides,

Myriophyllum spp., *Ribes*

viscosissimum

e. stoma polar stem wide

Ribes inerme, *Ribes lacustre*,

Ribes oxycanthoides spp.

	<i>cognatum</i> , <i>Rubus idaeus</i> ssp. <i>trigosus</i> , <i>Symphoricarpos</i> <i>albus</i> , <i>Purshia tridentate</i> , <i>Viola nuttallii</i>
a. calcium oxalate absent	
b. calcium carbonate present	
c. silica present	<i>Lonicera utahensis</i>
c. silica absent	<i>Hedysarum boreale</i>
b. calcium carbonate absent	
c. trichome textured	<i>Actaea rubra</i> , <i>Medicago</i> <i>sativa</i> , <i>Myosotis alpestris</i> , <i>Oxytropis lambertii</i> , <i>Zizia</i> <i>aptera</i>
c. trichome smooth	
d. silica anisotropic	<i>Trifolium pretense</i> , <i>T. repens</i> , <i>Artemisia cana</i>
d. silica isotropic	
e. polar stem narrow	<i>Artemisia frigida</i> , <i>A.</i> <i>tripartite</i> , <i>Astragalus</i> <i>crassicaulus</i> , <i>Delphinium</i> <i>bicolor</i> , <i>Eriogonum</i> <i>umbellatum</i> , <i>Phacelia</i> <i>heterophylla</i>
e. polar stem wide	<i>Aquilegia flavescens</i> , <i>Balsamorhiza sagittata</i> , <i>Cirsium vulgare</i> , <i>Crepis</i> <i>runcinate</i> , <i>Eriogonum</i> <i>ovalifolium</i> , <i>Geum</i> <i>canadense</i> , <i>Glycyrrhiza</i> <i>lepidota</i> , <i>Lithospermum</i>

e. polar stem unknown	<i>incisum, Senecio plattensis,</i> <i>Wyethia amplexicaulis</i> <i>Heracleum maximum,</i> <i>Lupinus sericeus</i>
d. silica absent	<i>Dasiphora fruticose,</i> <i>Geranium viscosissimum</i>

Group H: Trichomes absent, stomata and epidermal cells randomly arranged.

a. calcium oxalate present	
b. silica present	<i>Ledum groenlandicum</i>
b. silica absent	
d. epidermal morphology irregular	<i>Spiraea betulifolia,</i> <i>Stellaria media</i>
d. epidermal morphology rectangular	<i>Prunus virginiana</i>
d. epidermal morphology polygonal	
f. polar stem narrow	<i>Acer glabrum</i>
f. polar stem wide	<i>Chamerion angustifolium,</i> <i>Ribes aureum, Rumex</i> <i>stenophyllus</i>
a. calcium oxalate absent	
b. calcium carbonate present	<i>Arctostaphylos uva-ursi,</i> <i>Crataegus douglasii,</i> <i>Pedicularis groenlandica</i>
b. calcium carbonate absent	
c. silica present	<i>Mertensia ciliate</i>
c. silica absent	
d. scales present	<i>Opuntia macrorhiza</i>
d. scales absent	
e. polar stem narrow	<i>Agoseris aurantiaca,</i>

e. polar stem wide

Castilleja miniata,
Chrysothamnus nauseosus,
Cirsium foliosum, *Comandra*
Umbellata, *Dodecatheon*
conjugens, *Rhus aromatic*,
Tragopogon dubius
Chimaphila umbellata,
Cirsium scariosum, *Linnaea*
Borealis, *Pedicularis*
racemosa, *Penstemon*
procerus, *Sonchus arvensis*

Plant characteristics have been summarized in a spreadsheet (Table 3.1). The characteristics are divided into eight categories; epidermal morphology, epidermal pattern, anticlinal walls, stomata morphology, stomata pattern, trichomes and inclusions. Epidermal morphology is the shape of the epidermal cell borders; they are characterized as square or rectangular, parallelogram, irregular and polygonal. Epidermal pattern refers to the arrangement of epidermal cells; stacked is ordered patterning with cells end-to-end and one-atop-another whereas random is similar to the “jigsaw puzzle” or flagstone type arrangement. Anticlinal walls are classified as wavy or verrucate, sinuous, straight and straight-curved.

Stomata morphology characterizes stomata based on the separation of the lower woody lamella and the upper woody lamella (LWL-UWL). A separation of less than 5 microns is a narrow LWL-UWL, greater than 5 microns is a wide LWL-UWL whereas moderate is between 4-6 microns. In addition, the polar region LWL-UWL separation is classified as narrow or wide (less than or greater than 5 microns). The polar stem is also classified as narrow or wide (less than or greater than 5 microns).

Stomata pattern refers to the arrangement of stomata in the cellular matrix (ordered into parallel rows or random) whereas stomata subsidiary cells refers to the subsidiary epidermal cell arrangement around stomata (anomocytic, brachyparacytic and tetracytic). Trichomes are prickles, hairs and scales on the surface of leaves; they are classified as unbranched, double-ended, segmented, multi (multiple fibers joined at a common base) or stellate.

Inclusions are typically plant defense mechanisms against herbivory. Inclusions include calcium carbonate rhombohedral crystals, calcium oxalate globular and raphide druses, isotropic or anisotropic (non-crystalline or crystalline) silica and starch. A more complete description of these plant characteristics is presented in Henderson and Vucetich (2014) (chapter 5).

The following abbreviations have been used in the spreadsheet to conserve space:

Cellular structures

s/r: square or rectangular

par: parallelogram

irr: irregular

pol: polygonal

Stomata morphology

LWL-UWL: lower woody lamella-upper woody lamella spacing

pol: polar region spacing

stm: stem width

Stomata Subsidiary Cells

ano: anomocytic

bra: brachyparacytic

tet: tetracytic

Epidermal Pattern

stk: stacked brick-like

ran: random

Trichomes

unb: unbranched

d-e: double-ended

seg: segmented

mlt: multiple fibers per base

stl: stellate

Anticlinal walls

wav: wavy/verrucate

sin: sinuous

str: straight

s-c: straight-curved

Stomata pattern

par: parallel

ran: random

Inclusions

crb: calcium carbonates

oxl: calcium oxalate

sil: silicate

sth: starch

Table 3.1 Plant characteristics of GYE Elk Forage (see text for abbreviations)

Plate #	Group	Plant Scientific Name	Common Name	Family	Epidermal Morphology				Epidermal Pattern	
					s/r	par	irr	pol	stk	ran
1	B	<i>Abies lasiocarpa</i>	Fir, Subalpine	Pinaceae		x			x	
2	B	<i>Juniperus communis</i>	Juniper, Common	Cupressaceae	x	x			x	
3	B	<i>Juniperus scopulorum</i>	Juniper, Rocky Mountain	Cupressaceae	x				x	
4	B	<i>Picea engelmannii</i>	Spruce, Engelmann	Pinaceae	x	x			x	
5	B	<i>Picea pungens</i>	Spruce, Blue	Pinaceae	x	x			x	
6	B	<i>Pinus albicaulis</i>	Pine, Whitebark	Pinaceae	x	x			x	
7	B	<i>Pinus contorta</i>	Pine, Lodgepole	Pinaceae	x				x	
8	B	<i>Pinus flexilis</i>	Pine, Limber	Pinaceae	x	x			x	
9	B	<i>Pseudotsuga menziesii</i> var. <i>glauca</i>	Douglas-Fir	Pinaceae	x				x	
10	A	<i>Agropyron cristatum</i>	Wheatgrass, Crested	Poaceae	x	x			x	
11	A	<i>Aristida basiramea</i>	Threeawn, Forked	Poaceae	x				x	
12	A	<i>Bouteloua gracilis</i>	Blue Grama	Poaceae	x				x	
13	A	<i>Bromus inermis</i>	Brome, Smooth	Poaceae	x				x	
14	A	<i>Bromus tectorum</i>	Brome, Cheatgrass	Poaceae	x				x	
15	A	<i>Calamagrostis canadensis</i>	Bluejoint, Marsh Reedgrass	Poaceae	x				x	
16	A	<i>Carex haydeniana</i>	Sedge, Cloud	Cyperaceae	x				x	
17	A	<i>Carex raynoldsii</i>	Sedge, Raynold's	Cyperaceae	x				x	
18	A	<i>Dactylis glomerata</i>	Orchardgrass	Poaceae	x				x	
19	A	<i>Deschampsia cespitosa</i>	Hairgrass, Tufted	Poaceae	x				x	
20	A	<i>Elymus canadensis</i>	Wildrye, Canada	Poaceae	x				x	
21	A	<i>Elymus trachycaulus</i>	Wheatgrass, Slender	Poaceae	x				x	
22	A	<i>Festuca ovina</i>	Fescue, Sheep	Poaceae	x				x	
23	A	<i>Juncus arcticus</i>	Rush, Mountain	Juncaceae	x				x	
24	A	<i>Koeleria macrantha</i>	Junegrass, Prairie	Poaceae	x				x	
25	A	<i>Muhlenbergia frondosa</i>	Muhly, Wirestem	Poaceae	x				x	
26	A	<i>Phleum alpinum</i>	Timothy, Alpine	Poaceae	x				x	
27	A	<i>Phleum pratense</i>	Timothy	Poaceae	x				x	
28	A	<i>Poa alpina</i>	Bluegrass, Alpine	Poaceae	x				x	
29	A	<i>Poa bulbosa</i>	Bluegrass, Bulbous	Poaceae	x				x	
30	A	<i>Poa compressa</i>	Bluegrass, Canada	Poaceae	x				x	
31	A	<i>Poa pratensis</i>	Bluegrass, Kentucky	Poaceae	x				x	
32	A	<i>Poa secunda</i>	Bluegrass, Sandberg	Poaceae	x				x	
33	A	<i>Trisetum spicatum</i>	Trisetum, Spike	Poaceae	x				x	
34	H	<i>Acer glabrum</i>	Maple, Mountain or Douglas	Sapindaceae				x		x
35	G	<i>Acer negundo</i>	Boxelder	Sapindaceae				x		x
36	F	<i>Achillea millefolium</i>	Yarrow, Common	Asteraceae	x				x	
37	G	<i>Actaea rubra</i>	Baneberry, Red	Ranunculaceae			x			x
38	H	<i>Agoseris aurantiaca</i>	Agoseris, Orange	Asteraceae				x		x
39	F	<i>Agoseris glauca</i>	Agoseris, Pale	Asteraceae		x		x		x
40	C	<i>Allium textile</i>	Onion, Textile	Liliaceae	x				x	
41	G	<i>Amelanchier alnifolia</i>	Serviceberry, Saskatoon	Rosaceae			x			x
42	F	<i>Antennaria parvifolia</i>	Pussytoes, Small-leaf	Asteraceae				x		x
43	F	<i>Antennaria rosea</i>	Pussytoes, Rosy	Asteraceae				x		x
44	G	<i>Aquilegia flavescens</i>	Columbine, Yellow	Ranunculaceae				x		x
45	H	<i>Arctostaphylos uva-ursi</i>	Kinnikinnick	Ericaceae				x		x
46	G	<i>Arenaria serpyllifolia</i>	Sandwort, Thymelcaf	Caryophyllaceae			x			x
47	F	<i>Arnica cordifolia</i>	Arnica, Heartleaf	Asteraceae				x		x
48	G	<i>Artemisia cana</i>	Sagebrush, Silver	Asteraceae				x		x
49	G	<i>Artemisia frigida</i>	Sagewort, Prairie	Asteraceae				x		x
50	F	<i>Artemisia ludoviciana</i>	Sagebrush, White	Asteraceae				x		x
51	F	<i>Artemisia tridentata</i>	Sagebrush, Big	Asteraceae				x		x
52	G	<i>Artemisia tripartita</i>	Sagebrush, Threetip	Asteraceae				x		x
53	G	<i>Astragalus crassicaupus</i>	Milkvetch, Timber	Fabaceae	x			x		x
54	G	<i>Balsamorhiza sagittata</i>	Arrowleaf Balsamroot	Asteraceae	x			x		x
55	G	<i>Betula occidentalis</i>	Birch, Water	Betulaceae	x			x		x
56	C	<i>Camassia quamash</i>	Camas, Small	Liliaceae				x	x	
57	H	<i>Castilleja miniata</i>	Paintbrush, Giant Red Indian	Scrophulariaceae				x		x
58	G	<i>Ceanothus velutinus</i>	Snowbrush	Rhamnaceae	x			x		x
59	G	<i>Cercocarpus ledifolius</i>	Mountain Mahogany, Curl-leaf	Rosaceae				x		x
60	H	<i>Chamerion angustifolium</i>	Fireweed	Onagraceae				x		x
61	H	<i>Chimaphila umbellata</i>	Pipsissewa	Pyrolaceae			x			x
62	H	<i>Chrysothamnus nauseosus</i>	Rabbitbrush, Rubber	Asteraceae				x		x
63	H	<i>Cirsium foliosum</i>	Thistle, Elk	Asteraceae				x		x
64	H	<i>Cirsium scariosum</i>	Thistle, Meadow	Asteraceae				x		x
65	G	<i>Cirsium vulgare</i>	Thistle, Bull	Asteraceae				x		x
66	H	<i>Comandra umbellata</i>	Toadflax, Pale Bastard	Santalaceae				x		x
67	E	<i>Cornus canadensis</i>	Bunchberry	Cornaceae			x			x

Plate #	Group	Plant Scientific Name	Anticlinal Walls				Stomata Morphology			Stomata Pattern		Stomata Subsidiary Cells				Tr	
			wav	sin	str	s-c	LWL-UWL	pol	stm	par	ran	ano	bra	tet	unb	d-e	
1	B	<i>Abies lasiocarpa</i>	x				w	w	n	x				x			
2	B	<i>Juniperus communis</i>				x	n	n	n	x				x			
3	B	<i>Juniperus scopulorum</i>				x	n	n	n	x				x			
4	B	<i>Picea engelmannii</i>	x				n	n	w	x				x			
5	B	<i>Picea pungens</i>	x			x	w	n	w	x				x			
6	B	<i>Pinus albicaulis</i>		x			w	w	w	x				x			
7	B	<i>Pinus contorta</i>	x	x			w	w	w	x				x			
8	B	<i>Pinus flexilis</i>			x		w	w	w	x				x			
9	B	<i>Pseudotsuga menziesii</i> var. <i>glauca</i>			x	x	m	w	w	x				x			
10	A	<i>Agropyron cristatum</i>			x	x				x						x	
11	A	<i>Aristida basiramea</i>	x							x							
12	A	<i>Bouteloua gracilis</i>	x							x							
13	A	<i>Bromus inermis</i>			x					x							
14	A	<i>Bromus tectorum</i>			x					x						x	
15	A	<i>Calamagrostis canadensis</i>	x							x							
16	A	<i>Carex haydeniana</i>	x							x							
17	A	<i>Carex raynoldsii</i>	x	x						x							
18	A	<i>Dactylis glomerata</i>			x					x						x	
19	A	<i>Deschampsia cespitosa</i>	x							x							
20	A	<i>Elymus canadensis</i>	x							x						x	
21	A	<i>Elymus trachycaulus</i>			x	x				x						x	
22	A	<i>Festuca ovina</i>	x		x					x							
23	A	<i>Juncus arcticus</i>			x					x							
24	A	<i>Koeleria macrantha</i>			x					x							
25	A	<i>Muhlenbergia frondosa</i>			x					x							
26	A	<i>Phleum alpinum</i>		x						x							
27	A	<i>Phleum pratense</i>	x			x				x							
28	A	<i>Poa alpina</i>				x				x						x	
29	A	<i>Poa bulbosa</i>				x				x							
30	A	<i>Poa compressa</i>	x							x							
31	A	<i>Poa pratensis</i>	x							x							
32	A	<i>Poa secunda</i>	x							x						x	
33	A	<i>Trisetum spicatum</i>			x	x				x						x	
34	H	<i>Acer glabrum</i>			x	x	n	w	n		x	x					
35	G	<i>Acer negundo</i>			x		n	w	n		x	x				x	
36	F	<i>Achillea millefolium</i>			x	x						x				x	
37	G	<i>Actaea rubra</i>			x	x	w	n	n			x				x	
38	H	<i>Agoseris aurantiaca</i>			x	x	w	w	n		x	x					
39	F	<i>Agoseris glauca</i>	x				w	w	n		x	x					
40	C	<i>Allium textile</i>				x	m	m	m	x		x				x	
41	G	<i>Amelanchier alnifolia</i>	x				n	w	n		x					x	
42	F	<i>Antennaria parvifolia</i>			x		n	w	w		x					x	
43	F	<i>Antennaria rosea</i>			x		n	w	w		x					x	
44	G	<i>Aquilegia flavescens</i>			x		n	w	w		x	x				x	
45	H	<i>Arctostaphylos uva-ursi</i>				x	n	n	w		x						
46	G	<i>Arenaria serpyllifolia</i>	x				w	w	w		x					x	
47	F	<i>Arnica cordifolia</i>			x	x	n	n	w		x						
48	G	<i>Artemisia cana</i>			x	x	n	n	n		x					x	
49	G	<i>Artemisia frigida</i>			x	x	n	n	n		x					x	
50	F	<i>Artemisia ludoviciana</i>			x	x	n	n	n		x					x	
51	F	<i>Artemisia tridentata</i>			x	x	n	n	n		x					x	
52	G	<i>Artemisia tripartita</i>			x	x	n	n	n		x					x	
53	G	<i>Astragalus crassicaarpus</i>			x	x	n	n	n		x					x	
54	G	<i>Balsamorhiza sagittata</i>			x	x	n	w	w		x					x	
55	G	<i>Betula occidentalis</i>			x	x	n	n	n		x					x	
56	C	<i>Camassia quamash</i>			x	x	n	w	n	x							
57	H	<i>Castilleja miniata</i>			x	x	n	n	n		x						
58	G	<i>Ceanothus velutinus</i>			x	x					x					x	
59	G	<i>Cercocarpus ledifolius</i>			x	x					x					x	
60	H	<i>Chamerion angustifolium</i>			x	x	n	w	n		x						
61	H	<i>Chimaphila umbellata</i>				x	n	w	w		x						
62	H	<i>Chrysothamnus nauseosus</i>				x	n	n	n		x						
63	H	<i>Cirsium foliosum</i>				x	m	m	n		x						
64	H	<i>Cirsium scariosum</i>				x	m	w	w		x						
65	G	<i>Cirsium vulgare</i>				x	w	w	w		x	x				x	
66	H	<i>Comandra umbellata</i>				x	w	n	n		x						
67	E	<i>Cornus canadensis</i>				x	n	w	w		x	x				x	

Plate #	Group	Plant Scientific Name	ichomes			Inclusions			
			seg	mlt	stl	crb	oxl	sil	sth
1	B	<i>Abies lasiocarpa</i>							
2	B	<i>Juniperus communis</i>							
3	B	<i>Juniperus scopulorum</i>							
4	B	<i>Picea engelmannii</i>							
5	B	<i>Picea pungens</i>							
6	B	<i>Pinus albicaulis</i>				x			
7	B	<i>Pinus contorta</i>							
8	B	<i>Pinus flexilis</i>							
9	B	<i>Pseudotsuga menziesii</i> var. <i>glauca</i>							
10	A	<i>Agropyron cristatum</i>						x	
11	A	<i>Aristida basiramea</i>						x	
12	A	<i>Bouteloua gracilis</i>						x	
13	A	<i>Bromus inermis</i>						x	
14	A	<i>Bromus tectorum</i>						x	
15	A	<i>Calamagrostis canadensis</i>						x	
16	A	<i>Carex haydeniana</i>							
17	A	<i>Carex raynoldsii</i>							
18	A	<i>Dactylis glomerata</i>						x	
19	A	<i>Deschampsia cespitosa</i>						x	
20	A	<i>Elymus canadensis</i>						x	
21	A	<i>Elymus trachycaulus</i>						x	
22	A	<i>Festuca ovina</i>						x	
23	A	<i>Juncus arcticus</i>							
24	A	<i>Koeleria macrantha</i>						x	
25	A	<i>Muhlenbergia frondosa</i>						x	
26	A	<i>Phleum alpinum</i>						x	
27	A	<i>Phleum pratense</i>						x	
28	A	<i>Poa alpina</i>						x	
29	A	<i>Poa bulbosa</i>						x	
30	A	<i>Poa compressa</i>						x	
31	A	<i>Poa pratensis</i>						x	
32	A	<i>Poa secunda</i>						x	
33	A	<i>Trisetum spicatum</i>						x	
34	H	<i>Acer glabrum</i>					x		
35	G	<i>Acer negundo</i>				x	x		
36	F	<i>Achillea millefolium</i>	x						
37	G	<i>Actaea rubra</i>							
38	H	<i>Agoseris aurantiaca</i>							
39	F	<i>Agoseris glauca</i>	x						
40	C	<i>Allium textile</i>				x	x	x	
41	G	<i>Amelanchier alnifolia</i>				x	x		
42	F	<i>Antennaria parvifolia</i>	x						
43	F	<i>Antennaria rosea</i>	x						
44	G	<i>Aquilegia flavescens</i>						x	
45	H	<i>Arctostaphylos uva-ursi</i>				x			
46	G	<i>Arenaria serpyllifolia</i>					x		
47	F	<i>Arnica cordifolia</i>	x					x	
48	G	<i>Artemisia cana</i>						x	
49	G	<i>Artemisia frigida</i>						x	
50	F	<i>Artemisia ludoviciana</i>	x					x	
51	F	<i>Artemisia tridentata</i>	x					x	
52	G	<i>Artemisia tripartita</i>						x	
53	G	<i>Astragalus crassicaupus</i>							
54	G	<i>Balsamorhiza sagittata</i>						x	
55	G	<i>Betula occidentalis</i>					x		
56	C	<i>Camassia quamash</i>							
57	H	<i>Castilleja miniata</i>							
58	G	<i>Ceanothus velutinus</i>					x		
59	G	<i>Cercocarpus ledifolius</i>				x	x		
60	H	<i>Chamerion angustifolium</i>					x		
61	H	<i>Chimaphila umbellata</i>							
62	H	<i>Chrysanthamnus nauseosus</i>							
63	H	<i>Cirsium foliosum</i>							
64	H	<i>Cirsium scariosum</i>							
65	G	<i>Cirsium vulgare</i>						x	
66	H	<i>Comandra umbellata</i>							
67	E	<i>Cornus canadensis</i>					x		

Plate #	Group	Plant Scientific Name	Common Name	Family	Epidermal Morphology				Epidermal Pattern	
					s/r	par	irr	pol	stk	ran
68	E	<i>Cornus sericea</i>	Dogwood, Red Osier	Cornaceae			x			x
69	H	<i>Crataegus douglasii</i>	Hawthorns, Black	Rosaceae			x			x
70	G	<i>Crepis runcinata</i>	Hawksbeard, Fiddleleaf	Asteraceae				x		x
71	G	<i>Dasiphora fruticosa</i>	Cinquefoil, Shrubby	Rosaceae				x		x
72	G	<i>Delphinium bicolor</i>	Larkspur, Little	Ranunculaceae				x		x
73	H	<i>Dodecatheon conjugens</i>	Shootingstar, Bonneville	Primulaceae				x		x
74	E	<i>Elaeagnus commutata</i>	Silverberry	Elaeagnaceae			x			x
75	C	<i>Equisetum arvense</i>	Horsetail, Field	Equisetaceae	x				x	
76	C	<i>Equisetum fluviatile</i>	Horsetail, Water	Equisetaceae	x	x			x	
77	C	<i>Equisetum hyemale</i>	Horsetail, Rough	Equisetaceae	x				x	
78	F	<i>Erigeron sp.</i>	Fleabane	Asteraceae			x			x
79	G	<i>Eriogonum heracleoides</i>	Buckwheat, Parsnipflower	Polygonaceae				x		x
80	G	<i>Eriogonum ovalifolium</i>	Buckwheat, Cushion	Polygonaceae				x		x
81	G	<i>Eriogonum umbellatum</i>	Buckwheat, Sulfur-flower	Polygonaceae				x		x
82	G	<i>Fragaria virginiana</i>	Strawberry, Virginia	Rosaceae				x		x
83	D	<i>Galium boreale</i>	Bedstraw, Northern	Rubiaceae			x			x
84	G	<i>Geranium viscosissimum</i>	Geranium, Sticky	Geraniaceae			x			x
85	G	<i>Geum canadense</i>	Aven, White	Rosaceae			x	x		x
86	G	<i>Glycyrrhiza lepidota</i>	Licorice, American	Fabaceae			x	x		x
87	G	<i>Hedysarum boreale</i>	Sweetvetch, Northern	Fabaceae			x	x		x
88	G	<i>Heracleum maximum</i>	Cowparsnip, Common	Apiaceae			x	x		x
89	C	<i>Iris missouriensis</i>	Iris, Rocky Mountain	Iridaceae	x			x	x	
90	H	<i>Ledum groenlandicum</i>	Labrador tea, Bog	Ericaceae				x		x
91	H	<i>Linnaea borealis</i>	Twinflower	Caprifoliaceae			x	x		x
92	D	<i>Liquidambar styraciflua</i>	Sweetgum	Altingiaceae	x			x		x
93	G	<i>Lithospermum incisum</i>	Stoneseed, Narrowseed	Boraginaceae				x		x
94	G	<i>Lonicera involucrata</i>	Honeysuckle, Twinberry	Caprifoliaceae				x		x
95	G	<i>Lonicera utahensis</i>	Honeysuckle, Utah	Caprifoliaceae				x		x
96	G	<i>Lupinus sericeus</i>	Lupine, Silky	Fabaceae				x		x
97	C	<i>Lycopodium annotinum</i>	Clubmoss	Lycopodiaceae	x				x	
98	E	<i>Mahonia repens</i>	Barberry, Creeping	Berberidaceae	x			x	x	
99	C	<i>Maianthemum racemosum</i>	False Solomon's Seal,	Liliaceae				x	x	
100	C	<i>Maianthemum stellatum</i>	False Solomon's Seal, Starflowered	Liliaceae				x	x	
101	G	<i>Malus pumila</i>	Apple, Common	Rosaceae				x		x
102	G	<i>Medicago sativa</i>	Alfalfa	Fabaceae				x		x
103	H	<i>Mertensia ciliata</i>	Bluebells, Tall Fringed	Boraginaceae				x		x
104	F	<i>Mitella diphylla</i>	Miterwort	Saxifragaceae				x		x
105	G	<i>Myosotis alpestris</i>	Forget-Me-Not, Alpine	Boraginaceae				x		x
106	G	<i>Myriophyllum spp.</i>	Watermilfoil	Haloragaceae				x		x
107	D	<i>Nymphaea advena</i>	Waterlily, Yellow	Nymphaeaceae				x		x
108	D	<i>Oenothera macrocarpa</i>	Primrose, Bigfruit Evening	Onagraceae				x		x
109	H	<i>Opuntia macrorhiza</i>	Pricklypear, Twistspine	Cactaceae				x		x
110	G	<i>Oxytropis lambertii</i>	Locoweed, Purple	Fabaceae				x		x
111	H	<i>Pedicularis groenlandica</i>	Lousewort, Elephanthead	Scrophulariaceae				x		x
112	H	<i>Pedicularis racemosa</i>	Lousewort, Sickletop	Scrophulariaceae				x		x
113	H	<i>Penstemon procerus</i>	Penstemon, Littleflower	Scrophulariaceae				x		x
114	G	<i>Phacelia heterophylla</i>	Phacelia, Varileaf	Hydrophyllaceae				x		x
115	D	<i>Populus angustifolia</i>	Cottonwood, Narrowleaf	Salicaceae				x		x
116	D	<i>Populus balsamifera</i>	Poplar, Balsam	Salicaceae				x		x
117	H	<i>Populus tremuloides</i>	Aspen, Quaking	Salicaceae	x			x		x
118	G	<i>Potamogeton gramineus</i>	Pondweed	Potamogetonaceae	x			x		x
119	G	<i>Potentilla gracilis</i>	Cinquefoil, Slender	Rosaceae				x		x
120	H	<i>Prunus virginiana</i>	Chokecherry	Rosaceae	x					x
121	G	<i>Pteridium aquilinum</i>	Bracken, Western	Dennstaedtiaceae			x		x	
122	G	<i>Purshia tridentata</i>	Bitterbrush, Antelope	Rosaceae				x		x
123	H	<i>Rhamnus cathartica</i>	Buckthorn, European	Rhamnaceae				x		x
124	H	<i>Rhus aromatica</i>	Sumac, Fragrant	Anacardiaceae				x		x
125	H	<i>Ribes aureum</i>	Currant, Golden	Grossulariaceae				x		x
126	G	<i>Ribes inerme</i>	Gooseberry, White-stemmed	Grossulariaceae				x		x
127	G	<i>Ribes lacustre</i>	Currant, Prickly	Grossulariaceae				x		x
128	G	<i>Ribes oxycanthoides spp. cognatum</i>	Currant, Stream	Grossulariaceae				x		x
129	G	<i>Ribes viscosissimum</i>	Currant, Sticky	Grossulariaceae				x		x
130	G	<i>Rosa woodsii</i>	Rose, Woods (Prairie)	Rosaceae	x			x		x
131	G	<i>Rubus idaeus ssp. strigosus</i>	Raspberry, Grayleaf Red	Rosaceae	x			x		x
132	F	<i>Rubus parviflorus</i>	Thimbleberry, Western	Rosaceae	x			x		x
133	F	<i>Rudbeckia occidentalis</i>	Coneflower, Western	Asteraceae	x			x		x
134	H	<i>Rumex stenophyllus</i>	Sorrel, Alpine Sheep	Polygonaceae	x			x		x
135	D	<i>Salix fragilis</i>	Willow, Crack	Salicaceae	x			x		x

Plate #	Group	Plant Scientific Name	Anticlinal Walls				Stomata Morphology			Stomata Pattern		Stomata Subsidiary Cells					Tr	
			wav	sin	str	s-c	LWL-UWL	pol	stm	par	ran	ano	bra	tet	unb	d-e		
68	E	<i>Cornus sericea</i>				x	n	w	w		x	x				x		
69	H	<i>Crataegus douglasii</i>		x		x	w	n	n		x	x						
70	G	<i>Crepis runcinata</i>			x	x	n	n	w		x					x		
71	G	<i>Dasiphora fruticosa</i>				x					x					x		
72	G	<i>Delphinium bicolor</i>				x	n	n	n		x					x		
73	H	<i>Dodecatheon conjugens</i>				x	n	n	n		x							
74	E	<i>Elaeagnus commutata</i>		x			w	w	n		x	x						
75	C	<i>Equisetum arvense</i>	x	x			w	w		x								
76	C	<i>Equisetum fluviatile</i>	x	x			w	w		x								
77	C	<i>Equisetum hyemale</i>	x				n	n		x								
78	F	<i>Erigeron sp.</i>				x					x							
79	G	<i>Eriogonum heracleoides</i>				x	n	n	n		x					x		
80	G	<i>Eriogonum ovalifolium</i>				x	n	n	w		x					x		
81	G	<i>Eriogonum umbellatum</i>				x	n	n	n		x					x		
82	G	<i>Fragaria virginiana</i>				x	n	n	n		x					x		
83	D	<i>Galium boreale</i>				x	n	w	w		x		x			x		
84	G	<i>Geranium viscosissimum</i>				x					x					x		
85	G	<i>Geum canadense</i>				x	n	w	w		x					x		
86	G	<i>Glycyrrhiza lepidota</i>				x	w	w	w		x					x		
87	G	<i>Hedysarum boreale</i>				x					x					x		
88	G	<i>Heracleum maximum</i>				x					x					x		
89	C	<i>Iris missouriensis</i>			x	x	n	n	n	x								
90	H	<i>Ledum groenlandicum</i>				x	n	n	n		x							
91	H	<i>Linnaea borealis</i>	x				w	w	w		x							
92	D	<i>Liquidambar styraciflua</i>				x	n	n	w		x		x					
93	G	<i>Lithospermum incisum</i>				x	n	w	w		x					x		
94	G	<i>Lonicera involucrata</i>				x	n	w	w		x					x		
95	G	<i>Lonicera utahensis</i>				x	n	w	w		x					x		
96	G	<i>Lupinus sericeus</i>				x					x					x		
97	C	<i>Lycopodium annotinum</i>	x	x			n	w	w	x						x		
98	E	<i>Mahonia repens</i>			x	x	n	w	w	x			x					
99	C	<i>Maianthemum racemosum</i>				x	n	w	w	x			x			x		
100	C	<i>Maianthemum stellatum</i>				x	n	w	w	x			x			x		
101	G	<i>Malus pumila</i>				x	w	w	w		x					x		
102	G	<i>Medicago sativa</i>				x	w	w	w		x					x		
103	H	<i>Mertensia ciliata</i>				x	m	w	w		x							
104	F	<i>Mitella diphylla</i>				x	n	n	w		x							
105	G	<i>Myosotis alpestris</i>				x	n	w	w		x					x		
106	G	<i>Myriophyllum spp.</i>				x	n	n	n		x					x		
107	D	<i>Nymphaea advena</i>				x	n	n	w		x							
108	D	<i>Oenothera macrocarpa</i>				x	n	n	w		x		x			x		
109	H	<i>Opuntia macrorhiza</i>				x	w	w	w		x							
110	G	<i>Oxytropis lambertii</i>				x	n	w	n		x					x		
111	H	<i>Pedicularis groenlandica</i>				x	w	w	w		x							
112	H	<i>Pedicularis racemosa</i>				x	w	w	w		x							
113	H	<i>Penstemon procerus</i>				x	n	w	w		x							
114	G	<i>Phacelia heterophylla</i>				x	n	n	n		x					x		
115	D	<i>Populus angustifolia</i>				x	w	w	n		x		x					
116	D	<i>Populus balsamifera</i>				x	w	w	n		x		x			x		
117	H	<i>Populus tremuloides</i>			x	x	w	w	n		x		x					
118	G	<i>Potamogeton gramineus</i>				x	n	w	n		x					x		
119	G	<i>Potentilla gracilis</i>				x	n	w	n		x					x		
120	H	<i>Prunus virginiana</i>			x	x	n	w	w		x							
121	G	<i>Pteridium aquilinum</i>	x			x	w	w	w	x						x		
122	G	<i>Purshia tridentata</i>				x	n	n	w		x					x		
123	H	<i>Rhamnus cathartica</i>		x		x	w	n	w		x							
124	H	<i>Rhus aromatica</i>				x	n	w	n		x							
125	H	<i>Ribes aureum</i>				x	w	w	w		x							
126	G	<i>Ribes inerme</i>				x	n	w	w		x						x	
127	G	<i>Ribes lacustre</i>			x	x	n	w	w		x					x		
128	G	<i>Ribes oxycanthoides</i> spp. cognatum			x	x	n	w	w		x					x		
129	G	<i>Ribes viscosissimum</i>				x	n	w	n		x					x		
130	G	<i>Rosa woodsii</i>			x	x	n	w	m		x					x		
131	G	<i>Rubus idaeus</i> ssp. strigosus			x	x	n	w	w		x					x		
132	F	<i>Rubus parviflorus</i>			x	x	n	w	w		x							
133	F	<i>Rudbeckia occidentalis</i>			x	x	w	w	w		x							
134	H	<i>Rumex stenophyllus</i>				x	w	w	w		x							
135	D	<i>Salix fragilis</i>			x	x	w	w	w		x		x			x		

Plate #	Group	Plant Scientific Name	ichomes			Inclusions			
			seg	mlt	stl	crb	oxl	sil	sth
68	E	<i>Cornus sericea</i>					x		x
69	H	<i>Crataegus douglasii</i>				x			
70	G	<i>Crepis runcinata</i>							
71	G	<i>Dasiphora fruticosa</i>							
72	G	<i>Delphinium bicolor</i>							
73	H	<i>Dodecatheon conjugens</i>							
74	E	<i>Elaeagnus commutata</i>			x				
75	C	<i>Equisetum arvense</i>						x	
76	C	<i>Equisetum fluviatile</i>				x			
77	C	<i>Equisetum hyemale</i>						x	
78	F	<i>Erigeron sp.</i>	x				x		
79	G	<i>Eriogonum heracleoides</i>					x		
80	G	<i>Eriogonum ovalifolium</i>						x	
81	G	<i>Eriogonum umbellatum</i>						x	
82	G	<i>Fragaria virginiana</i>				x	x		
83	D	<i>Galium boreale</i>							
84	G	<i>Geranium viscosissimum</i>							
85	G	<i>Geum canadense</i>							
86	G	<i>Glycyrrhiza lepidota</i>							
87	G	<i>Hedysarum boreale</i>				x			
88	G	<i>Heracleum maximum</i>						x	
89	C	<i>Iris missouriensis</i>						x	
90	H	<i>Ledum groenlandicum</i>					x	x	
91	H	<i>Linnaea borealis</i>							
92	D	<i>Liquidambar styraciflua</i>					x		
93	G	<i>Lithospermum incisum</i>							
94	G	<i>Lonicera involucrata</i>					x		
95	G	<i>Lonicera utahensis</i>				x		x	
96	G	<i>Lupinus sericeus</i>						x	
97	C	<i>Lycopodium annotinum</i>							
98	E	<i>Mahonia repens</i>			x				
99	C	<i>Maianthemum racemosum</i>							
100	C	<i>Maianthemum stellatum</i>						x	
101	G	<i>Malus pumila</i>				x	x	x	
102	G	<i>Medicago sativa</i>						x	
103	H	<i>Mertensia ciliata</i>						x	
104	F	<i>Mitella diphylla</i>	x				x		
105	G	<i>Myosotis alpestris</i>						x	
106	G	<i>Myriophyllum spp.</i>					x		
107	D	<i>Nymphaea advena</i>							
108	D	<i>Oenothera macrocarpa</i>						x	
109	H	<i>Opuntia macrorrhiza</i>							
110	G	<i>Oxytropis lambertii</i>						x	
111	H	<i>Pedicularis groenlandica</i>				x			
112	H	<i>Pedicularis racemosa</i>							
113	H	<i>Penstemon procerus</i>							
114	G	<i>Phacelia heterophylla</i>							
115	D	<i>Populus angustifolia</i>				x	x		
116	D	<i>Populus balsamifera</i>					x		
117	H	<i>Populus tremuloides</i>				x			
118	G	<i>Potamogeton gramineus</i>					x		
119	G	<i>Potentilla gracilis</i>					x		
120	H	<i>Prunus virginiana</i>					x		
121	G	<i>Pteridium aquilinum</i>					x		
122	G	<i>Purshia tridentata</i>					x		
123	H	<i>Rhamnus cathartica</i>							
124	H	<i>Rhus aromatica</i>							
125	H	<i>Ribes aureum</i>					x		
126	G	<i>Ribes inerme</i>					x		
127	G	<i>Ribes lacustre</i>					x		
128	G	<i>Ribes oxycanthoides spp. cognatum</i>					x		
129	G	<i>Ribes viscosissimum</i>					x		
130	G	<i>Rosa woodsii</i>					x		
131	G	<i>Rubus idaeus ssp. strigosus</i>					x		
132	F	<i>Rubus parviflorus</i>	x				x		
133	F	<i>Rudbeckia occidentalis</i>	x						
134	H	<i>Rumex stenophyllus</i>					x		
135	D	<i>Salix fragilis</i>				x	x		

Plate #	Group	Plant Scientific Name	Common Name	Family	Epidermal Morphology				Epidermal Pattern	
					s/r	par	irr	pol	stk	ran
136	G	<i>Sambucus racemosa</i>	Elderberry	Caprifoliaceae			x			x
137	G	<i>Senecio plattensis</i>	Ragwort, Arrowleaf	Asteraceae			x	x		x
138	F	<i>Shepherdia canadensis</i>	Buffaloberry	Elaeagnaceae			x	x		x
139	F	<i>Solidago canadensis</i>	Goldenrod, Canada	Asteraceae	x			x		x
140	H	<i>Sonchus arvensis</i>	Sowthistle, Field	Asteraceae	x			x		x
141	H	<i>Spiraea betulifolia</i>	Spirea, White	Rosaceae			x			x
142	H	<i>Stellaria media</i>	Starwort	Caryophyllaceae			x	x		x
143	G	<i>Symphoricarpos albus</i>	Snowberry, Common	Caprifoliaceae	x			x		x
144	F	<i>Symphoricarpos occidentalis</i>	Snowberry, Western	Caprifoliaceae	x			x		x
145	F	<i>Taraxacum officinale</i>	Dandelion, Common	Asteraceae	x			x		x
146	H	<i>Tragopogon dubius</i>	Salsify, Yellow	Asteraceae	x			x		x
147	G	<i>Trifolium pratense</i>	Clover, Red	Fabaceae			x	x		x
148	G	<i>Trifolium repens</i>	Clover, White	Fabaceae	x			x		x
149	C	<i>Typha latifolia</i>	Cattail, Broadleaf	Typhaceae	x				x	
150	D	<i>Vaccinium angustifolium</i>	Blueberry, Lowbush	Ericaceae	x			x		x
151	G	<i>Vaccinium membranaceum</i>	Huckleberry, Thinleaf	Ericaceae	x			x		x
152	G	<i>Viola nuttallii</i>	Violet, Nuttall's	Violaceae	x			x		x
153	G	<i>Wyethia amplexicaulis</i>	Mule-Ears	Asteraceae			x	x		x
154	F	<i>Xanthium strumarium</i>	Cocklebur, Rough	Asteraceae			x	x		x
155	G	<i>Zizia aptera</i>	Zizia, Meadow	Apiaceae				x		x

Plate #	Group	Plant Scientific Name	Anticlinal Walls				Stomata Morphology			Stomata Pattern		Stomata Subsidiary Cells					Trichomes	
			wav	sin	str	s-c	LWL-UWL	pol	stm	par	ran	ano	bra	tet	unb	d-e		
136	G	<i>Sambucus racemosa</i>			x	x	w	w	w		x				x			
137	G	<i>Senecio plattensis</i>			x	x	m	m	w		x				x			
138	F	<i>Shepherdia canadensis</i>			x	x	m	w	w		x				x			
139	F	<i>Solidago canadensis</i>			x	x	w	w	w		x							
140	H	<i>Sonchus arvensis</i>			x	x	n	m	w		x							
141	H	<i>Spiraea betulifolia</i>			x	x	n	m	w		x							
142	H	<i>Stellaria media</i>			x	x	n	m	w		x							
143	G	<i>Symphoricarpos albus</i>			x	x	n	w	w		x						x	
144	F	<i>Symphoricarpos occidentalis</i>			x	x	n	w	n		x						x	
145	F	<i>Taraxacum officinale</i>			x	x	n	n	n		x							
146	H	<i>Tragopogon dubius</i>			x	x	n	n	n		x							
147	G	<i>Trifolium pratense</i>			x	x	n	n	n		x						x	
148	G	<i>Trifolium repens</i>			x	x	n	n	n		x						x	
149	C	<i>Typha latifolia</i>			x		n	n	w	x								
150	D	<i>Vaccinium angustifolium</i>			x	x	w	w	w		x		x					
151	G	<i>Vaccinium membranaceum</i>			x	x	w	w	w		x						x	
152	G	<i>Viola nuttallii</i>			x	x	n	n	w		x						x	
153	G	<i>Wyethia amplexicaulis</i>			x	x	n	n	w		x						x	
154	F	<i>Xanthium strumarium</i>			x	x					x							
155	G	<i>Zizia aptera</i>			x	x	w	m	m		x						x	

Plate #	Group	Plant Scientific Name	ichomes			Inclusions			
			seg	mlt	stl	crb	oxl	sil	sth
136	G	<i>Sambucus racemosa</i>					x		
137	G	<i>Senecio plattensis</i>							
138	F	<i>Shepherdia canadensis</i>					x		
139	F	<i>Solidago canadensis</i>	x						
140	H	<i>Sonchus arvensis</i>							
141	H	<i>Spiraea betulifolia</i>					x		
142	H	<i>Stellaria media</i>					x		
143	G	<i>Symphoricarpos albus</i>					x		
144	F	<i>Symphoricarpos occidentalis</i>					x		
145	F	<i>Taraxacum officinale</i>	x						
146	H	<i>Tragopogon dubius</i>							
147	G	<i>Trifolium pratense</i>						x	
148	G	<i>Trifolium repens</i>						x	
149	C	<i>Typha latifolia</i>							
150	D	<i>Vaccinium angustifolium</i>							
151	G	<i>Vaccinium membranaceum</i>				x	x		
152	G	<i>Viola nuttallii</i>					x		
153	G	<i>Wyethia amplexicaulis</i>							
154	F	<i>Xanthium strumarium</i>	x						
155	G	<i>Zizia aptera</i>							

3.4 GYE elk forage: Gymnosperms

Gymnosperms are seldom a preferred elk forage but are consumed in late autumn and winter. Nine conifers were sampled and are presented with descriptions and photographic plates. These include one fir (*Abies lasiocarpa*), one false fir (*Pseudotsuga menziesii* var. *glauca*), two spruces (*Picea engelmannii* and *P. pungens*) and three pines (*Pinus albicaulis*, *P. contorta*, and *P. flexilis*). Gymnosperms have square to rectangular epidermal cells that are stacked brick-like and stomata are in parallel rows and border by four subsidiary cells (tetracytic). The primary method to differentiate genera is by stomatal morphology. True firs have a wide separation between the lower woody lamella and the upper woody lamella (LWL_UWL) and have moderately wide polar stems. The spacing between the LWL-UWL is moderate for false firs however the polar stems are wider. Junipers have a narrow LWL-UWL spacing and narrow polar stems. LWL-UWL spacing is similar for spruces however polar stems are wide. Pines have a wide LWL-UWL spacing and wide polar stems. Descriptions and photographic plates of each species are presented in this section.

***Abies lasiocarpa*, subalpine fir;**

Family: Pinaceae (Plate 1)

Macroscopic Characteristics: Needles are flattened and linear, approximately 1.9-3.8 cm in length and 0.2 cm thick with parallel sides and rounded apex (Kershner, Nelson and Spellenberg 2008). A pair of stomatal lines occur on each side of the central rib of the abaxial surface. A central stomatal line occurs on the adaxial surface along the central groove.

Microscopic Characteristics: Epidermal cells are elongated parallelogram shaped structures with a length/width ratio of 1:1 to greater than 5:1. Anticlinal walls are wavy to verrucate; the long axis of epidermal cells are stacked in parallel brick-like rows. No phytoliths or trichomes were observed.

Stomata patterning is ordered into parallel rows; stoma pores are aligned axially to the long axis of epidermal cells. A pair of reniform shaped guard cells surround a cigar shaped stoma pore. Spacing between the lower woody lamellae and upper woody lamella is greater than 5 microns. The stoma is roughly rectangular in outline. The lower woody lamella is 5-10 microns longer than the upper woody lamella. The polar stems are relatively narrow.

Abies lasiocarpa
subalpine fir

Plate
1

Legend

Top Image: Epidermal cells are rectangular to parallelogram shaped with square ends. Anticlinal walls are wavy to verrucate. Stomata are aligned into parallel rows.
(PLM, single polar)

Bottom Image: Stomata with a pair of crescent shaped guard cells surrounding a fusiform shaped pore. The LWL-UWL spacing is wide. The polar stems are relatively narrow
(PLM, single polar)

***Juniperus communis*, common juniper;**

Family: Cupressaceae (Plate 2)

Macroscopic Characteristics: Needles are awl-shaped with a glaucous concave abaxial surface. Needles are approximately 1.3 cm in length with a pointed apex length (Kershner, Nelson and Spellenberg 2008). The adaxial surface is convex and glossy; the abaxial surface is concave with numerous stomatal lines.

Microscopic Characteristics: Epidermal cells are rectangular with some parallelogram shaped cells. Ends are square to angular with rounded corners. Cells are oriented in a brick-like arrangement with the long axis of cells parallel to each other. Cell length to width ratio ranges from approximately 1.5:1 to 5:1. Anticlinal walls are straight-curved.

The abaxial surface consists of a high density of stomata with pores aligned axially to the epidermal cell long axis. Stomata patterning is ordered into parallel rows with a pair of crescent guard cells surrounding a fusiform shaped stoma pore. The stoma is roughly rectangular with rounded polar ends. The stoma is slightly elongated with an approximate length to width aspect ratio of 1.3:1. The separation between the lower and upper woody lamellae is approximately 2 microns. The polar stem is narrow, approximately 2 microns, with a bifurcated extension at each end.

Juniperus communis
common juniper

Plate
2

Legend

Top Image: Abundant stomata in parallel rows are located in a field of parallelogram to rectangular shaped epidermal cells with straight anticlinal walls. (PLM, single polar)

Bottom Image: Detail image of stomata in parallel rows, crescent shaped guard cells surround a fusiform shaped stoma pore. Polar stems are narrow and extend beyond the rounded polar ends; stems are bowtie shaped. (PLM, single polar)

***Juniperus scopulorum*, Rocky Mountain juniper;**

Family: Cupressaceae (Plate 3)

Macroscopic Characteristics: Needles are scale-like with a length of approximately 0.16-0.9 cm (Kershner, Nelson and Spellenberg 2008). Resin glands are conspicuous; stomatal lines are evident in the hidden areas where scale-like needles overlap.

Microscopic Characteristics: Epidermal cells are rectangular shaped cells oriented in a brick-like arrangement with the long axis of cells parallel to each other. Ends are square to angular with rounded corners. Cell length to width ratio ranges from approximately 3:1 to 10:1. Anticlinal walls are straight-curved.

The abaxial surface consists of a high density of stomata with pores axially aligned to epidermal cell long axis. Stomata patterning is ordered into parallel rows; a pair of crescent guard cells surround a stoma pore. The stoma is roughly rectangular with rounded polar ends. The stoma is slightly elongated with an approximate length to width aspect ratio of 1.7:1. The separation between the lower and upper woody lamellae is approximately 2 microns. The polar stem is narrow, approximately 2 microns, with a bifurcated extension at each end.

Juniperus scopulorum
Rocky Mountain juniper

Plate
3

***Picea engelmannii*, Engelmann's spruce;**

Family: Pinaceae (Plate 4)

Macroscopic Characteristics: Needles are four-sided, approximately 2-3 cm long, with sharp tips (Kershaw, MacKinnon and Pojar 1998). Stomatal lines were observed on all four surfaces but more prominent on the abaxial surfaces.

Microscopic Characteristics: Epidermal cells are rectangular to parallelogram shaped with a length to width ratio from 1:1 to greater than 3:1. Cells are oriented in a brick-like arrangement with the long axis of cells parallel to each other. Anticlinal walls are sinuous to verrucate. No phytoliths or trichomes were observed.

Stomata patterning is ordered into parallel rows. A pair of crescent shaped guard cells surround a circular to rectangular pore. Guard cells have rounded sides and ends. The lower woody lamella is narrowly separated from the upper woody lamella however the polar stems are wide. The angle of attachment between polar stem and guard cell is narrow.

Picea engelmannii
Engelmann spruce

Plate
4

Legend

Top Image: Oval stomata are axially aligned to epidermal cells in parallel rows; stoma pores are rectangular with wide polar stems. Separation of lower and upper woody lamellae is narrow. Four subsidiary cells surround the stoma.
(PLM, single polar)

Bottom Image: Rectangular epidermal cells have sinuous to verrucate anticlinal walls.
(PLM, single polar)

***Picea pungens*, blue spruce;**

Family: Pinaceae (Plate 5)

Macroscopic Characteristics: Needles are four-sided, rigid, with sharp pointed tips; length is 2.1-3.2 cm (Kershner, Nelson and Spellenberg 2008). Stomatal lines were observed prominently on all four surfaces.

Microscopic Characteristics: Epidermal cells are rectangular to parallelogram shaped with a length to width ratios of 1:1 to greater than 5:1. Anticlinal walls are straight-curved to wavy. Cells are stacked end-to-end and in a brick-like patterns. No phytoliths or trichomes were observed.

Stomata patterning is ordered into parallel rows. Fusiform shaped stomata pores are parallel to the linear axis of the epidermal cells and occasionally lignified. Guard cells are crescent shaped with rounded sides and ends, the shape of the stoma is oval. Occasional chloroplast cells are within the guard cells. The lower woody lamella is narrowly separated from the upper woody lamella however the polar stems are wide. The angle of attachment between polar stem and guard cell is narrow.

Picea pungens
blue spruce

Plate
5

Legend

Top Image: Stomata are in parallel rows that are axially aligned with rectangular to parallelogram shaped epidermal cells. Stoma pores are fusiform shaped; some pores are lignified. Four subsidiary cells surround the stoma, two at the polar ends and one on each side of the guard cells.
(PLM, single polar)

Bottom Image: The anticlinal walls are wavy.
(PLM, single polar)

***Pinus albicaulis*, whitebark pine**

Family: Pinaceae (Plate 6)

Macroscopic Characteristics: Five stiff triangle shaped needles, approximately 2.5-7.5 cm in length, are enclosed with a fascicle (Kershner, Nelson and Spellenberg 2008). The adaxial surface is smooth and glossy; faint stomatal lines are arranged in linear rows on the two abaxial surfaces.

Microscopic Characteristics: Epidermal cells are rectangular to parallelogram shaped with a length to width ratio greater than 5:1. Anticlinal walls are sinuous; epidermal cells are stacked end-to-end and arranged in a brick-like pattern. Occasional carbonates druses were observed. No trichomes were observed.

Stomata patterning is ordered into parallel rows. Stomata, rectangular in outline, have fusiform shaped pores that are occasionally lignified. Guard cells are crescent shaped and stomata pores are aligned parallel to the linear axis of the epidermal cells and stomata rows. Spacing between the lower woody lamellae and upper woody lamella is greater than 5 microns. The polar stem width is approximately 5 microns.

Pinus albicaulis
whitebark pine

Plate
6

Legend

Top Image: Epidermal cells are rectangular to parallelogram shaped with sinuous to verrucate anticlinal walls. Stomata are axially aligned in parallel rows.
(PLM, single polar)

Bottom Image: Stoma consists of a pair of crescent shaped guard cells surrounding an oblong fusiform shaped pore. Spacing between lower and upper woody lamellae is greater than 5 microns. Polar stems are also relatively wide.
(PLM, single polar)

***Pinus contorta*, lodgepole pine**

Family: Pinaceae (Plate 7)

Macroscopic Characteristics: Two stiff, twisted, triangle shaped needles, approximately 2.5-7.5 cm in length, are enclosed with a fascicle. (Kershner, Nelson and Spellenberg 2008). Needles are more curved than triangular; stomatal lines are prominent on the concave abaxial surface and near the margins of the convex adaxial surface.

Microscopic Characteristics: Epidermal cells are rectangular and oriented in a brick-like arrangement with the long axis of cells parallel to each other. Cell length to width ratio ranges from approximately 1:1 to greater than 5:1. Anticlinal walls are sinuous to wavy. No trichomes were observed.

The abaxial surface consists parallel rows of stomata. Stomata are axially aligned with epidermal cell long axis. A pair of crescent guard cells surround an oblong stoma pore; some pores are lignified. The polar ends of guard cells, adjacent to the polar stems, are thickened. Stomata are slightly elongated with an approximate length to width aspect ratio of 2.5:1. The polar stem width is wide and the spacing between the lower and upper woody lamellae is greater than 5 microns.

Pinus contorta
lodgepole pine

Plate
7

***Pinus flexilis*, limber pine**

Family: Pinaceae (Plate 8)

Macroscopic Characteristics: Five rigid curved triangle shaped needles, approximately 3.8-10.2 cm in length, are enclosed with a fascicle (Kershner, Nelson and Spellenberg 2008). The adaxial surface is slightly convex and glossy. The concave abaxial surfaces are slightly concave with faint stomatal lines.

Microscopic Characteristics: Rectangular to parallelogram shaped epidermal cells have straight anticlinal walls. Cells have square ends. Cell length to width ratio ranges from approximately 3:1 to greater than 5:1. Cells are aligned end-to-end and stacked in a brick-like pattern. No trichomes were observed.

The abaxial surfaces consist of an ordered patterning of stomata in linear rows with pores axially aligned to the epidermal cell long axis. A pair of crescent guard cells surround a cigar-shaped stoma pore, some pores are lignified. Stomata are slightly elongated with a length to width aspect ratio of approximately 1.9:1. The polar stem width and the spacing between the lower and upper woody lamellae is greater than 5 microns.

Pinus flexilis
limber pine

Plate
8

Legend

Top Image: Rectangular to parallelogram shaped epidermal cells have straight anticlinal walls. Cells have square ends. Stomata are arranged in a linear row; the stomata are axially oriented with epidermal cells.

(PLM, single polar)

Bottom Image: A pair of crescent shaped guard cells surround a cigar-shaped stoma pore, some pores are lignified.

(PLM, single polar)

***Pseudotsuga menziesii* var. *glauca*, Douglas-fir**

Family: Pinaceae (Plate 9)

Macroscopic Characteristics: Needles are flattened and linear, approximately 1.9-3.2 cm in length (Kershner, Nelson and Spellenberg 2008). A pair of stomatal lines occur on each side of the central rib of the abaxial surface.

Microscopic Characteristics: Epidermal cells are long rectangular cellular structures with rounded ends. Cells are aligned end-to-end in a brick-like pattern; length to width ratio ranges from 3:1 to greater than 5:1. Anticlinal walls are straight to straight-curved. No phytoliths or trichomes were observed.

The abaxial surface consists of an ordered patterning of parallel rows of stomata with pores aligned axially to epidermal cell long axis. A pair of crescent guard cells surround an oval to short fusiform shaped pore. Stomata are nearly circular with an approximate length to width aspect ratio of 1.3:1. The width of the polar stem is approximately 5 microns however the spacing between the lower and upper woody lamellae is approximately 4 microns.

Pseudotsuga menziesii var. *glauca*
Douglas-fir

Plate
9

Legend

Epidermal cells are long rectangular cellular structures with rounded ends. Cells are aligned end-to-end in a brick-like pattern; length to width ratio ranges from 3:1 to greater than 5:1. Anticlinal walls are straight to straight-curved. The abaxial surface consists of an ordered patterning of parallel rows of stomata with pores aligned axially to epidermal cell long axis. A pair of crescent guard cells surround an oval to short fusiform shaped pore.
(PLM, single polar)

3.5 GYE elk forage: Graminoids

Graminoids are preferred forage (form a significant portion of elk diet) in the winter and spring and form less of a dietary component in the summer and early autumn. Twenty-four grass species are presented with descriptions and photographic plates. Graminoid stomata consist of guard cells with bulbous ends and parallel sides along the stoma. Stomata are in parallel rows with the stoma axially aligned to the long axis of the epidermal cells. Stomata bordered by a pair of subsidiary cells that are parallel to the stomata opening, and epidermal cells that are square to rectangular and stacked in a brick-like pattern.

Graminoids that are members of the Poaceae family have phytoliths whereas the families Juncaceae (*Juncus arcticus*) and Cyperaceae (*Carex haydeniana* and *C. raynoldsii*) do not have silica inclusions. Six of the graminoids have prickly trichomes (*Dactylis glomerata*, *Elymus canadensis*, *E. trachycaulus*, *Poa alpine*, *P. secunda* and *Trisetum spicatum*). Because of the square to rectangular epidermal cells that are stacked brick-like, the parallel rows of stomata, and the bulbous ends of stomata guard cells, graminoids are readily differentiated from other plant groups. Most individual species of grasses can be determined using phytolith and trichome morphology. Descriptions and photographic plates of each graminoid species are presented in this section.

***Agropyron cristatum*, crested wheatgrass;**

Family: Poaceae (Plate 10)

Macroscopic Characteristics: Flat leaf blades are approximately 0.2 cm in width with hairs on the margins and abaxial surface.

Microscopic Characteristics: Epidermal cells are rectangular to parallelogram in shape with rounded corners. Cells are aligned end-to-end and stacked in a brick-like pattern; length to width ratio ranges from 1.5:1 to 4:1. Anticlinal walls are straight to straight-curved. Trichomes consist of hollow fibers. Trichomes are attached with a bulbous end and range from short and stubby to long with pointed ends. Phytoliths are orbicular to slightly ovate in shape along leaf veins.

Stomata have an ordered pattern of parallel rows with pores nearly aligned axially to the epidermal cell long axis. A pair of bilobed guard cells surround an elongated thin pore. Guard cells are surrounded by a pair of low dome-shaped subsidiary cells; the length to width aspect ratio of stomatal complex is approximately 2.7:1.

Agropyron cristatum
crested wheatgrass

Plate
22

Legend

Top Image: Parallel rows of stomata, trichome bases, phytoliths and epidermal cells with crenate anticlinal walls. Leaf vein shown in upper third of image include trichome bases and phytoliths. (brightfield, single polar)

Bottom Image: Detail image of trichome bases with hollow pointed short trichomes. Trichome bases are located in field of epidermal cells with irregular anticlinal walls. (brightfield, single polar)

***Aristida basiramea*, forked threeawn;**

Family: Poaceae (Plate 11)

Macroscopic Characteristics: The adaxial surface is mostly flat with prominent striations; the abaxial surface is bisected by a central vein with parallel striations on each side of the vein. The approximate leaf width is 0.1-0.15 cm.

Microscopic Characteristics: Epidermal cells are rectangular with squared ends that are aligned end-to-end in a brick-like pattern; length to width ratio ranges from 2:1 to greater than 5:1. Anticlinal walls are verrucate. Elongated bilobate phytoliths, with a length to width ratio of approximately 4:1, occur axially among epidermal cells. Bilobate phytoliths have straight anticlinal walls. No trichomes were observed.

Stomata have an ordered patterning of parallel rows of stomata with pores aligned parallel to epidermal cell long axis. Guard cells are bilobal; guard cells surround an elongated thin pore. Subsidiary cells are low-dome shaped. Stoma complex are slightly diamond shaped with a length to width aspect ratio of 1.2:1.

Aristida basiramea
forked threeawn

Plate
11

***Bouteloua gracilis*, blue grama;**

Family: Poaceae (Plate 12)

Macroscopic Characteristics: Leaf blades are twisted with a slight roll toward the abaxial surface and a width of approximately 0.1-0.2 cm. Blade margins are slightly serrated.

Microscopic Characteristics: Epidermal cells are rectangular with squared ends that are aligned end-to-end in a brick-like pattern; length to width ratio ranges from 2:1 to greater than 5:1. Anticlinal walls are verrucate. Phytoliths are barrel shaped and located transaxially to the long axis of the epidermal cells. Phytolith length to width aspect ratio ranges from 1:1-2:1.

Stomata occur in parallel rows with pores aligned axially with the epidermal cell long axis. Guard cells are bilobal and surround an elongated thin pore. Guard cells are bordered by a pair of low-domed to triangular subsidiary cells. The stomatal complex has a length to width aspect ratio of approximately 1.8:1.

Bouteloua gracilis
blue grama

Plate
12

***Bromus inermis*, smooth brome;**

Family: Poaceae (Plate 13)

Macroscopic Characteristics: Flat leaf blades with prominent veins are approximately 0.5-1.0 cm wide.

Microscopic Characteristics: Epidermal cells are rectangular with squared ends. Cells are aligned end-to-end and stacked in a brick-like pattern; length to width ratio ranges from 2:1 to greater than 5:1. Anticlinal walls are straight. Rectangular phytoliths with an approximate length to width ratio of 2:1 are aligned axially along leaf veins. Some phytoliths are in chains and others are randomly located along veins.

Stomata occur in parallel rows with guard cells and pores aligned axially with epidermal cell long axis. Guard cells are bilobal and surround an elongated thin pore. Guard cells are surrounded by a pair of subsidiary cells with parallel sides; the length to width aspect ratio of stomatal complex is 2.1:1.

Bromus inermis
smooth brome

Plate
13

***Bromus tectorum*, cheatgrass;**

Family: Poaceae (Plate 14)

Macroscopic Characteristics: Flat leaf blades are approximately 0.15-0.4 cm wide with abundant surface hairs.

Microscopic Characteristics: Epidermal cells are rectangular with squared ends. Cells are aligned end-to-end and stacked in a brick-like pattern; the length to width ratio of most cells are greater than 5:1. Anticlinal walls are straight. Rectangular phytoliths, with an approximate length to width ratio of 4:1, are aligned axially along leaf veins. Some phytoliths are in chains and others are randomly located along veins. Abundant trichomes consist of hollow fibers attach to the epidermal cells with a bulbous end and pointed terminal end. Epidermal attachment bases are circular to slightly elongated.

Stomata occur in parallel rows with guard cells and pores aligned axially with the epidermal cell long axis. Guard cells are bilobal and surround an elongated thin pore. Guard cells are surrounded by a pair of subsidiary cells that are parallel sided; the length to width aspect ratio of stomatal complex is approximately 2.7:1.

Bromus tectorum
cheatgrass

Plate
14

***Calamagrostis canadensis*, bluejoint;**

Family: Poaceae (Plate 15)

Macroscopic Characteristics: Flat leaf blades are approximately 0.4-1.0 cm wide with prominent veins. The margins are serrated.

Microscopic Characteristics: Epidermal cells are rectangular with squared to angled ends. Cells are aligned end-to-end in a brick-like pattern with length to width ratio greater than 5:1. Occasional square epidermal short cells are interspersed between the long cells. Anticlinal walls are verrucate. Oval and egg-shaped inclusions are aligned axially with epidermal cells and veins. The oval inclusions are located over epidermal cells with a length to width ratio of 1:1 to 1.5:1. Egg-shaped inclusions are located over veins have a length to width ratio of approximately 2:1. Phytoliths are elongated rectangular shapes with sinuous outlines.

Stomata occur in parallel rows with pores aligned axially with epidermal cell long axis. Guard cells are bilobal and surround an elongated thin pore. Guard cells are surrounded by a pair of rectangular subsidiary cells; the length to width aspect ratio of stomatal complex is approximately 3.6:1. Subsidiary cells are parallel-sided.

Calamagrostis canadensis
bluejoint

Plate
15

***Carex haydeniana*, cloud sedge;**

Family: Cyperaceae (Plate 16)

Macroscopic Characteristics: Flat leaf blades are approximately 0.1-0.3 cm wide with prominent veins. The margins are serrated.

Microscopic Characteristics: Epidermal cells are rectangular with squared ends that are aligned end-to-end in a brick-like pattern. Cell length to width ratio ranges from 2:1 to 4:1. Anticlinal walls are crenate to verrucate.

Stomata occur in parallel rows with pores aligned axially with the epidermal cell long axis. Guard cells are bilobal with flat lateral sides and rounded ends. Guard cells surround an elongated thin pore. Subsidiary cells surround the guard cells. Subsidiary cells are dome-like with flattened outer lateral surfaces. The stomatal complex has an approximately length to width ratio of 1.4:1.

Carex haydeniana
cloud sedge

Plate
16

Legend

Top Image: Stomata are axially aligned in parallel rows with the long axis of epidermal cells. Stomata consists of bilobal guard cells surrounding a thin long pore. A pair of subsidiary cells surround the guard cells.
(PLM, single polar)

Bottom Image: Epidermal cells are rectangular to parallelogram shaped with crenate to verrucate anticlinal walls.
(PLM, single polar)

***Carex raynoldsii*, Raynold's sedge;**

Family: Cyperaceae (Plate 17)

Macroscopic Characteristics: Flat leaf blades are approximately 0.3-0.7 cm wide. Veins are prominent on the abaxial surface.

Microscopic Characteristics: Epidermal cells are rectangular with angled to square ends that are aligned end-to-end in a brick-like pattern. Cells have a length to width ratio that ranges from 2:1 to greater than 5:1. Anticlinal walls are sinuous to verrucate.

Stomata occur in parallel rows with pores aligned axially with the epidermal cell long axis. Guard cells are bilobal with flat lateral sides and rounded ends. Guard cells surround an elongated thin pore. Domed subsidiary cells with parallel lateral sides surround the guard cells. The stomatal complex has an approximately length to width ratio of 3.4:1.

Carex raynoldsii
Raynold's sedge

Plate
17

Legend

Top Image: Epidermal cells are rectangular to parallelogram shaped with crenate to verrucate anticlinal walls. Stomata are axially aligned in parallel rows with the long axis of epidermal cells. (PLM, single polar)

Bottom Image: Stomata consists of bilobal guard cells surrounding a thin long pore. A pair of domed subsidiary cells with flat lateral sides surround the guard cells. (PLM, single polar)

***Dactylis glomerata*, orchardgrass;**

Family: Poaceae (Plate 18)

Macroscopic Characteristics: Glabrous flat leaf blades are approximately 0.2-0.4 cm wide. Leaf margins are serrate.

Microscopic Characteristics: Epidermal cells are rectangular with square ends that are aligned end-to-end in a brick-like pattern. Cell length to width ratio ranges from 2:1 to greater than 5:1. Anticlinal walls are straight. Polylobate with occasional bilobate phytoliths with an approximate length to width ratio of 2:1 to 4:1 are aligned axially along leaf veins. Prickles, with a length to width ratio that ranges from 2:1-3:1 are located axially along veins.

Stomata occur in parallel rows with pores aligned axially with epidermal cell long axis. Guard cells are bilobal with flat lateral sides and rounded ends that surround an elongated pore. Domed subsidiary cells with flat parallel lateral sides surround the guard cells. The stomatal complex has an approximately length to width ratio of 2.3:1.

Dactylis glomerata
Orchardgrass

Plate
18

Legend

Top Image: Epidermal cells are rectangular to parallelogram shaped with crenate anticlinal walls. Stomata are axially aligned in parallel rows with the long axis of epidermal cells. Stomata consists of bi-lobal guard cells surrounding a thin long pore. A pair of subsidiary cells surround the guard cells.
(PLM, single polar)

Bottom Image: Phytoliths are elongated with sinuous margins.
(PLM, single polar)

***Deschampsia cespitosa*, tufted hairgrass;**

Family: Poaceae (Plate 19)

Macroscopic Characteristics: Stiff flat leaf blades with prominent veins are approximately 0.2-0.5 cm wide. Veins are edged with recurved prickles.

Microscopic Characteristics: Epidermal cells are rectangular with ends that vary from flat to rounded. Cells are aligned end-to-end in a brick-like pattern with a length to width ratio that ranges from 3:1 to greater than 5:1. Anticlinal walls are crenate. Ovate to oblong phytoliths with an approximate length to width ratio of 1.5:1 to 2:1 are located along leaf veins and epidermal cells.

Stomata occur in parallel rows with pores aligned axially with epidermal cell long axis. Bilobal guard cells surround an elongated pore. Subsidiary cells with parallel lateral sides and rounded ends surround the guard cells. The stomatal complex has an approximately length to width ratio of 4:1.

Deschampsia cespitosa
tufted hairgrass

Plate
19

***Elymus canadensis*, Canada wildrye;**

Family: Poaceae (Plate 20)

Macroscopic Characteristics: Stiff flat leaf blades with prominent veins are approximately 0.2-0.5 cm wide. Veins are edged with recurved prickles.

Microscopic Characteristics: Epidermal cells are rectangular with flat ends. Cells are aligned end-to-end and stacked in a brick-like pattern. Cell length to width ratio is greater than 5:1. Occasional short square epidermal cells were observed. Anticlinal walls are crenate. Ovate to oblong phytoliths with an approximate length to width ratio of 1.5:1 to 2:1 are located along leaf veins and epidermal cells. Oblong trichome (prickle) bases are located axially on veins.

Stomata occur in parallel rows with pores aligned axially with the epidermal cell long axis. Guard cells are bilobal surrounding an elongated pore. Subsidiary cells with parallel lateral sides and rounded ends surround the guard cells. The stomatal complex has an approximately length to width ratio of 2.2:1.

Elymus canadensis
Canada wildrye

Plate
20

***Elymus trachycaulus*, slender wheatgrass;**

Family: Poaceae (Plate 21)

Macroscopic Characteristics: Stiff flat leaf blades with prominent veins are approximately 0.25-0.5 cm wide. Veins are edged with recurved prickles.

Microscopic Characteristics: Epidermal cells are rectangular with square to rounded ends. Cells are aligned end-to-end and stacked in a brick-like pattern. Cells with a length to width ratio ranges from 2:1 to greater than 5:1. Anticlinal walls are straight to straight-curved. Ovate to oblong phytoliths with an approximate length to width ratio of 1.5:1 to 3:1 are located along leaf veins and epidermal cells. Oblong trichome (prickle) bases are located axially on veins.

Stomata occur in parallel rows with pores aligned axially with epidermal cell long axis. Guard cells are bilobal and surround an elongated pore. Subsidiary cells with parallel lateral sides and rounded ends surround the guard cells. The stomatal complex has an approximately length to width ratio of 2.7:1.

Elymus trachycaulus
slender wheatgrass

Plate
21

***Festuca ovina*, sheep fescue;**

Family: Poaceae (Plate 22)

Macroscopic Characteristics: Stiff curled leaf blades with prominent veins are approximately 0.3-0.6 cm wide. Leaf margins are finely serrate.

Microscopic Characteristics: Epidermal cells are rectangular with square ends. Cells are aligned end-to-end and stacked in a brick-like pattern. Cell length to width ratio ranges from 3:1 and to greater than 5:1. Anticlinal walls are straight to verrucate. Ovate to oblong phytoliths with an approximate length to width ratio of 1:1 to 3:1 are aligned along leaf veins and epidermal cells.

Stomata occur in parallel rows with pores aligned axially with the epidermal cell long axis. Guard cells are bilobal and surround an elongated pore. Subsidiary cells are dome-shaped with rounded lateral sides and rounded ends. The stomatal complex has an approximately length to width ratio of 2:1.

Festuca ovina
sheep fescue

Plate
22

***Juncus arcticus*, mountain rush;**

Family: Juncaceae (Plate 23)

Macroscopic Characteristics: Leaf blades of *Juncus arcticus* are typically absent, stems are round and solid.

Microscopic Characteristics: Epidermal surface of stem was mounted. Epidermal cells are rectangular with slightly rounded flat ends. Cells are aligned end-to-end in a brick-like pattern with length to width ratio that is greater than 5:1. Anticlinal walls are straight to irregular.

Stomata occur in parallel rows with pores aligned axially with the epidermal cell long axis. Guard cells are fat crescents surrounding an elongated pore. When pore is open, it forms a fusiform-shape. Thin subsidiary cells with rounded lateral sides and ends surround the guard cells. The stomatal complex has an approximately length to width ratio of 2.3:1.

Juncus arcticus
mountain rush

Plate
23

***Koeleria macrantha*, prairie junegrass;**

Family: Poaceae (Plate 24)

Macroscopic Characteristics: Stiff flat leaf blades with prominent veins have an approximate width of 0.1-0.25 cm. The abaxial surface is pubescent.

Microscopic Characteristics: Epidermal cells are rectangular with slightly rounded flat ends. Cells are aligned end-to-end and stacked in a brick-like pattern. Cell length to width ratio is greater than 5:1. Anticlinal walls are straight to irregular. Ovate to oblong phytoliths, with an approximate length to width ratio of 1:1 to 3:1, are located along leaf veins and epidermal cells.

Stomata occur in parallel rows with pores aligned axially with the epidermal cell long axis. Guard cells are bilobal and surround an elongated pore. When pore is open, it forms a fusiform shape. Subsidiary cells with flat lateral sides and rounded polar ends surround the guard cells. The stomatal complex has an approximately length to width ratio of 1.7:1.

Koeleria macrantha
prairie junegrass

Plate
24

Legend

Top Image: Stomata, tri-chome bases and epidermal cells occur in parallel rows. Phytoliths are square to rectangular. Tri-chome bases are oval to oblong.
(PLM, single polar)

Bottom Image: Trichome bases connect with hollow short pointed trichomes. Tri-chome bases are located in field of epidermal cells. Epidermal cells have irregular anticlinal walls.
(PLM, single polar)

***Muhlenbergia frondosa*, wirestem muhly;**

Family: Poaceae (Plate 25)

Macroscopic Characteristics: Flat leaf blades with prominent veins have an approximate width of 0.7 cm. Leaf blades are glabrous.

Microscopic Characteristics: Epidermal cells are square to rectangular with flat ends. Cells are aligned end-to-end and stacked in a brick-like pattern. Cell length to width ratio ranges from 1:1 to greater than 5:1. Anticlinal walls are straight to irregular. Barrel-shaped phytoliths with an approximate length to width ratio of 1.5:1 are located along leaf veins.

Stomata are small and occur in parallel rows with pores aligned axially to the epidermal cell long axis. Guard cells are bilobal and surround an elongated pore. Subsidiary cells are high dome-shaped and surround the guard cells. The stomatal complex has an approximately length to width ratio of 1.2:1.

Muhlenbergia frondosa
wirestem muhly

Plate
25

Legend

Top image: Bilobal guard cells surround a thin pore. The subsidiary cells are rounded on the polar ends and lateral sides. Stomata are in parallel rows that are axially aligned with epidermal cells. (PLM, single polar)

Bottom image: Barrel-shaped phytoliths are axially aligned with leaf veins. Epidermal cell anticlinal walls are irregular to wavy. (PLM, single polar)

***Phleum alpinum*, alpine timothy;**

Family: Poaceae (Plate 26)

Macroscopic Characteristics: Flat leaf blades have an approximate width of 0.5-1.2 cm. Leaf blades are glabrous and margins are finely serrate.

Microscopic Characteristics: Epidermal cells are rectangular with flat to angled ends. Cells are aligned end-to-end and stacked in a brick-like pattern with a length to width ratio greater than 5:1. Anticlinal walls are irregular. Polylobal phytoliths with an approximate length to width ratio of 2.7:1 are located along leaf veins.

Stomata occur in parallel rows with pores aligned axially to the epidermal cell long axis. Guard cells are bilobal surrounding an elongated pore. Subsidiary cells surround the guard cells; lateral sides are flattened and the polar ends are rounded. The stomatal complex has an approximately length to width ratio of 1.7:1.

Phleum alpinum
alpine timothy

Plate
26

Legend

Rectangular epidermal cells with flat to angled ends are aligned end-to-end; cells are stacked brick-like. Anticlinal walls are irregular. Polylobal phytoliths are axially aligned with leaf veins. Stomata are arranged in parallel rows. Bilobal guard cells surround a thin pore. A pair of subsidiary cells surround the guard cells. Subsidiary cells have flat lateral sides and rounded ends. (PLM, single polar)

***Phleum pratense*, timothy**

Family: Poaceae (Plate 27)

Macroscopic Characteristics: Flat leaf blades have an approximate width of 0.3-0.9 cm. The leaf veins are prominent on the adaxial surface.

Microscopic Characteristics: Epidermal cells are rectangular with flat to angled ends. Cells are aligned end-to-end and stacked in a brick-like pattern. Cell length to width ratios range from 3:1 to greater than 5:1. Anticlinal walls are straight-curved to wavy. Scutiform shaped phytoliths with an approximate length to width ratio of 2:1 are located along leaf veins.

Stomata occur in parallel rows with pores aligned axially to the epidermal cell long axis. Guard cells are bilobal surrounding an elongated pore. Subsidiary cells surround the guard cells; polar ends rounded. The lateral sides of subsidiary cells range from low-domed to flat. The stomatal complex has an approximately length to width ratio of 1.8:1.

Phleum pratense
timothy

Plate
27

Legend

Rectangular epidermal cells with flat to angled ends are aligned end-to-end; cells are stacked brick-like. Anticlinal walls are straight-curved to wavy. Scutiform shaped phytoliths are axially aligned with leaf veins. Stomata are arranged in parallel rows. Bilobal guard cells surround a thin pore. A pair of subsidiary cells surround the guard cells. Subsidiary cells are low-domes to flat with rounded ends.
(PLM, single polar)

***Poa alpina*, alpine bluegrass**

Family: Poaceae (Plate 28)

Macroscopic Characteristics: Flat leaf blades have an approximate width of 0.2-0.5 cm. Short abaxial hairs are present.

Microscopic Characteristics: Epidermal cells are rectangular with flat to angled ends. Cells are aligned end-to-end in a brick-like pattern with a length to width ratio greater than 5:1. Anticlinal walls are straight-curved. Rectangular and oblong shaped phytoliths with an approximate length to width ratio of 3:1 are located along leaf veins and epidermal cells. Trichome bases, roughly scutiform shaped, are scattered among the epidermal cells.

Stomata occur in parallel rows with pores aligned axially to the epidermal cell long axis. Guard cells are bilobal surrounding an elongated pore. Subsidiary cells surround the guard cells. Subsidiary cell polar ends are rounded; lateral sides range from parallel to low-domed. The stomatal complex has an approximately length to width ratio of 1.5:1.

Poa alpina
alpine bluegrass

Plate
28

***Poa bulbosa*, bulbous bluegrass**

Family: Poaceae (Plate 29)

Macroscopic Characteristics: Flat leaf blades have an approximate width of 0.1-0.2 cm. Blades are glabrous.

Microscopic Characteristics: Epidermal cells are rectangular with flat to angled ends. Cells are aligned end-to-end and stacked in a brick-like pattern. Cell length to width ratios range from 2:1 to greater than 5:1. Anticlinal walls are straight-curved. Polylobal shaped phytoliths with a length to width ratio greater than 5:1 are located along leaf veins.

Stomata occur in parallel rows with pores aligned axially to the epidermal cell long axis. Guard cells are bilobal surrounding an elongated pore. Subsidiary cells surround the guard cells. Subsidiary lateral sides are parallel however polar ends are rounded. The stomatal complex has an approximately length to width ratio of 4:1.

Poa bulbosa
bulbous bluegrass

Plate
29

***Poa compressa*, Canada bluegrass**

Family: Poaceae (Plate 30)

Macroscopic Characteristics: Flat leaf blades have an approximate width of 0.1-0.4 cm. Blades are stiff and glabrous, veins are prominent and margins are serrate.

Microscopic Characteristics: Epidermal cells are rectangular with flat to angled ends. Cells are aligned end-to-end and stacked in a brick-like pattern. Cell length to width ratio ranges from 3:1 to greater than 5:1. Anticlinal walls are wavy to verrucate. Trapeziform phytoliths are located transaxially to the epidermal cell long axis.

Stomata occur in parallel rows with pores aligned axially to the epidermal cell long axis. Guard cells are bilobal with a large circular bulbous end. Guard cells surround an elongated pore. Subsidiary cells surround the guard cells with lateral sides that are parallel however polar ends are rounded. The stomatal complex has an approximately length to width ratio of 1.3:1.

Poa compressa
Canada bluegrass

Plate
30

Legend

Top image: Epidermal cells are rectangular with wavy to verrucate anticlinal walls. Cells are end-to-end and stacked brick-like. Phytoliths are trapeziform and are transaxially aligned with the epidermal cell long axis. Stomata are aligned with the epidermal cells in parallel rows. (PLM, single polar)

Bottom image: Phytoliths are trapeziform with parallel lateral sides and angular ends. (PLM, single polar)

***Poa pratensis*, Kentucky bluegrass**

Family: Poaceae (Plate 31)

Macroscopic Characteristics: Flat leaf blades have an approximate width of 0.2-0.4 cm.

Microscopic Characteristics: Epidermal cells are rectangular with flat ends. Cells are aligned end-to-end and stacked in a brick-like pattern. The cell length to width ratio is greater than 5:1. Anticlinal walls are wavy to verrucate. Trapeziform phytoliths are located transaxially to the leaf veins.

Stomata occur in parallel rows with pores aligned axially to the epidermal cell long axis. Guard cells are bilobal and surround an elongated pore. Subsidiary cells surround the guard cells with rounded polar ends and domed lateral sides. The guard cell polar ends extend beyond the subsidiary cells. The stomatal complex has an approximately length to width ratio of 1.3:1.

Poa pratensis
Kentucky bluegrass

Plate
31

***Poa secunda*, Sandberg bluegrass**

Family: Poaceae (Plate 32)

Macroscopic Characteristics: Leaf blades have an approximate width of 0.1-0.3 cm. Leaf veins are scabrous; veins are prominent on abaxial surface.

Microscopic Characteristics: Epidermal cells are rectangular with flat ends. Cells are aligned end-to-end and stacked in a brick-like pattern. The cell length to width ratio ranges from 3:1 to greater than 5:1. Anticlinal walls are verrucate. Polylobal phytoliths are located axial to the leaf veins. Prickle trichome bases are located on borders of leaf veins.

Stomata occur in parallel rows with pores aligned axially to the epidermal cell long axis. Guard cells are bilobal and surround an elongated pore. Subsidiary cells surround the guard cells with flattened to slightly concave lateral sides and rounded polar ends. The stomatal complex has an approximately length to width ratio of 3.3:1.

Poa secunda
Sandberg bluegrass

Plate
32

***Trisetum spicatum*, spike trisetum**

Family: Poaceae (Plate 33)

Macroscopic Characteristics: Flat leaf blades have an approximate width of 0.1-0.4 cm. Veins are prominent on abaxial surface and margins are finely serrate.

Microscopic Characteristics: Epidermal cells are rectangular with flat ends. Cells are aligned end-to-end and stacked in a brick-like pattern. The cell length to width ratio is greater than 5:1. Anticlinal walls are straight to straight-curved. Trichomes are short prickles that are stubby and hollow with a pointed apex. Trichome bases are rectangular. Rectangular phytoliths are located axially to the epidermal cell long axis.

Stomata occur in parallel rows with pores aligned axially to the epidermal cell long axis. Guard cells are bilobal and surround an elongated pore. Subsidiary cells surround the guard cells with flattened lateral sides and rounded polar ends. The stomatal complex has an approximately length to width ratio of 3.7:1.

Trisetum spicatum
spike trisetum

Plate
33

3.6 GYE elk forage: forbs, non-graminoid monocots and woody dicots

Forbs, ferns, mosses, non-graminoid monocots and dicots represents preferred forage during the late spring, summer and autumn. Because of the elevation of the Greater Yellowstone Ecosystem, the growing season is relatively short. Winter snow pack begins to dissipate in the lower elevations of the Tetons toward the end of April and in Lamar Valley of Yellowstone. Graminoids and the Salicaceae family (genera *Populus* and *Salix*) are among the first to leaf-out but these are quickly followed by the understory forbs, monocots and other dicots. The non-graminoid monocots have parallel veins and the epidermal cells and stomata are generally axially aligned with the veins.

In contrast, the forbs, ferns, mosses and woody dicots are characterized by a random arrangement of irregular-shaped epidermal cells and stomata. Many have trichomes that range from simple unbranched fibers to multi-segmented or multi-branched bundles. Occasionally, stellate trichomes are encountered. Calcium carbonate rhombohedral crystals and calcium oxalate druses are also distinctive in some genera or species. Descriptions and photographic plates are presented in this section.

***Acer glabrum*, mountain maple;**

Family: Sapindaceae (Plate 34)

Macroscopic Characteristics: Leaves are three to five lobed with double serrated margins. Leaves are approximately 7.5-12.5 cm in length and width (Kershner, Nelson and Spellenberg 2008). The adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are polygonal shaped with an approximately length to width ratio that ranges from 1:1 to 2:1. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Globular shaped calcium oxalate druses are randomly arranged in the epidermal cell matrix. No trichomes were observed.

Anomocytic stomata occur randomly among the epidermal cells. The stoma consists of a pair of crescent shaped guard cells surrounding an oval pore. The stoma is slightly oblong with a length to width ratio of 1.3:1. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides but wide at polar ends. Polar stems are narrow.

Acer glabrum
mountain maple

Plate
34

Legend

Top image: Polygonal shaped epidermal cells with straight anticlinal walls are arranged in a flagstone pattern. Anomocytic stomata are randomly arranged in the epidermal cell matrix. The stoma consists of two crescent shaped guard cells surrounding an oval pore.
(PLM, single polar)

Bottom image: Globular shaped calcium oxalate crystals are randomly arranged in the epidermal cell matrix.
(PLM, single polar)

***Acer negundo*, boxelder;**

Family: Sapindaceae (Plate 35)

Macroscopic Characteristics: Leaves are pinnately compound with three to five leaflets per stem. Each leaflet is three-lobed with the central lobe longer than the two side lobes. Leaflet length is approximately 5-10 cm (Kershner, Nelson and Spellenberg 2008). Hairs are abundant along leaf veins of the abaxial surface.

Microscopic Characteristics: Epidermal cells are polygonal shaped with an approximately length to width ratio of 1:1. Cells are arranged in a flagstone pattern. Anticlinal walls are straight. Abundant globular calcium oxalate druses and occasional calcium carbonate rhombohedrals are located along leaf veins. Hollow curved trichomes with a pointed apex are attached to epidermal cells. Trichomes have a bulbous end with a hexangle base; a rosette of epidermal cells surrounds the base attachment.

Anomocytic stomata are randomly located in the epidermal cell matrix. Stomata consist of two crescent guard cells surrounding an oval pore. The stoma is nearly circular with a length to width ratio of 1.3:1. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides but wide at polar ends. Polar stems are narrow.

Acer negundo
boxelder

Plate
35

Legend

Top image: Epidermal cells are polygonal shaped and arranged in a flagstone pattern. Anticlinal walls are straight. Anomocytic stomata are randomly located in the epidermal cell matrix. Stomata consist of two crescent shaped guard cells that surround an oval pore.
(PLM, single polar)

Bottom image: Trichomes are hollow with wavy to straight sides; they are attached to a hexangle epidermal base.
(PLM, single polar)

***Achillea millefolium*, common yarrow;**

Family: Asteraceae (Plate 36)

Macroscopic Characteristics: Yarrow leaves are feathery, fern-like and pubescent. The leaf length is approximately 3-10 cm and width is 0.1-0.2 cm (Kershaw, MacKinnon, and Pojar 1998).

Microscopic Characteristics: Epidermal cells are rectangular with a length to width ratio that varies from 3:1 to greater than 5:1. Cells are arranged end-to-end and stacked in a brick-like pattern. Anticlinal walls are straight to straight-curved. Two varieties of trichomes were observed. Multi-segmented trichomes are randomly distributed in the epidermal cell matrix. Segmented trichomes have rectangular bases that are rounded at one end. The second variety of trichome is long round fibers with parallel sides and a pointed apex. No phytoliths were observed.

Anomocytic stomata occur randomly among the epidermal cells. Stoma consist of two guard cells surrounding an oval to fusiform pore. The polar ends of the guard cells are elongated. The stoma lateral sides are rounded. The length to width ratio is approximately 1.8:1. No pattern of subsidiary cells was observed.

Achillea millefolium
common yarrow

Plate
36

Legend

Top image: Rectangular epidermal cells are arranged end-to-end and stacked like bricks. Anticlinal walls are straight to straight-curved. Multi-segmented trichomes with rectangular bases are randomly distributed in the epidermal cell matrix. (brightfield, single polar)

Bottom image: Stomata with two elongated guard cells surround an oval to fusiform pore. (brightfield, single polar)

***Actaea rubra*, red baneberry;**

Family: Ranunculaceae (Plate 37)

Macroscopic Characteristics: Leaves are divided into three lobes with coarse sharp teeth. The leaf length is approximately 2-10 cm (Kershaw, MacKinnon, and Pojar 1998). The adaxial surface is glabrous whereas the abaxial surface has scattered hairs.

Microscopic Characteristics: Epidermal cells are irregular in shape with straight to straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Straight hollow trichomes with smooth sides are randomly located in the epidermal cell matrix. Trichome bases have reinforced striations that appear like fine roots.

Anomocytic stomata occur randomly among the epidermal cells. Stomata are circular and consist of two crescent shaped guard cells surrounding a fusiform shaped pore. The pore is large with the appearance of an almond. The stoma length to width ratio is approximately 1.2:1. The separation between the upper woody lamella and lower woody lamella is wide on the lateral sides but narrow at polar ends. Polar stems are narrow. No pattern of subsidiary cells was observed.

Actaea rubra
red baneberry

Plate
37

***Agoseris aurantiaca*, orange Agoseris;**

Family: Asteraceae (Plate 38)

Macroscopic Characteristics: Leaves are lance-shaped and arranged in a basal rosette with smooth margins. Leaves are 5-35 cm long and 0.1-3 cm in width cm (Kershaw, MacKinnon, and Pojar 1998). A few hairs were observed on the adaxial surface; the abaxial surface is pubescent and hairs on the veins.

Microscopic Characteristics: Epidermal cells are polygonal shaped with a length to width ratio that ranges from 1:1 to 3:1. The anticlinal walls are straight to straight-curved. Cells are arranged in a jigsaw puzzle pattern. No trichomes or phytolith inclusions were observed.

Anomocytic stomata occur randomly among the epidermal cells. Stoma consist of two crescent shaped guard cells surrounding a fusiform shaped pore. The length to width ratio is approximately 1.3:1. The separation between the upper woody lamella and lower woody lamella is wide on the lateral sides and at polar ends. Polar stems are distinct and relatively narrow. No pattern of subsidiary cells was observed.

Agoseris aurantiaca
orange agoseris

Plate
38

Legend

Epidermal cells are polygonal shaped with straight to straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Stomata consist of a pair of crescent shaped guard cells surrounding a fusiform shaped pore. Polar ends are relatively narrow and distinct. Stomata are slightly oblong and randomly arranged in the epidermal cell matrix. The separation between the upper and lower woody lamella is wide on the lateral sides and at polar ends. (PLM, single polar)

***Agoseris glauca*, pale Agoseris;**

Family: Asteraceae (Plate 39)

Macroscopic Characteristics: Leaf blades are lanceolate to oblanceolate, approximately 2-50 cm in length and the margins are entire to dentate. The adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are parallelogram to polygonal shaped with thick verrucate anticlinal walls. Cells ends vary from square to angled with occasional pointed ends. Cells are arranged end-to-end and somewhat stacked like bricks. Trichomes are short stalks with globular ends; the trichome complex has the appearance of a “water tower”. No phytolith inclusions were observed.

Anomocytic stomata occur randomly among the epidermal cells. Stoma consist of two crescent shaped guard cells surrounding a fusiform shaped pore. The length to width ratio is approximately 1.9:1. The separation between the upper woody lamella and lower woody lamella is wide on the lateral sides and at polar ends. Polar ends are distinct and narrow. No pattern of subsidiary cells was observed.

Agoseris glauca
pale Agoseris

Plate
39

Legend

Top Image: Trichomes are short stalked with globular heads.
(PLM, single polar)

Bottom Image: Polygonal to parallelogram shaped epidermal cells are arranged end-to-end. Some cells are stacked in brick-like pattern. Stomata are randomly arranged and consist of a pair of crescent shaped guard cells surrounding a fusiform shaped pore. Polar ends are narrow and distinct.
(PLM, single polar)

Allium textile, textile onion;

Family: Liliaceae (Plate 40)

Macroscopic Characteristics: Grass-like leaves have prominent veins and a width of approximately 0.15 cm. No hairs were observed on the adaxial or abaxial surfaces.

Microscopic Characteristics: Epidermal cells are rectangular shaped and oriented end-to-end; cells are stacked in a brick-like pattern. Cell ends are flat to angled with slight side curvatures. Anticlinal walls are thin and straight-curved. Phytoliths are scattered randomly among the epidermal cells. Phytoliths consist of acicular and bilobate cells, rectangular carbonate inclusions and calcium oxalate globular crystals. Trichomes are long hair-like structures with straight-curved margins and mostly hollow interiors.

Numerous anomocytic stomata are axially aligned with epidermal cells. Stomata consist of a pair of elongated guard cells surrounding a long fusiform pore. The length to width ratio of the stoma is approximately 1.8:1. Stoma are long and oval with rounded lateral sides and polar ends. The separation between the upper woody lamella and lower woody lamella is relatively narrow on the lateral sides and at polar ends. Polar ends are relatively narrow. No pattern of subsidiary cells was observed.

Allium textile
textile onion

Plate
40

Legend

Top image: Epidermal cells are rectangular in shape and arranged end-to-end in a brick-like pattern. Anticlinal walls are straight-curved. Phytolith inclusions include rectangular carbonates and globular calcium oxalate crystals.
(PLM, single polar)

Bottom image: Stomata with elongated guard cells are parallel to epidermal cells. Phytoliths are rectangular.
(PLM, single polar)

***Amelanchier alnifolia*, Saskatoon;**

Family: Rosaceae (Plate 41)

Macroscopic Characteristics: Leaves are round to oval with a rounded tip. The length is approximately 2-5 cm; the upper half of the leaves are coarsely serrate (Kershaw, MacKinnon, and Pojar 1998).

Microscopic Characteristics: Epidermal cells are irregular shaped with wavy anticlinal walls. Cells are arranged in a flagstone or jigsaw puzzle type pattern. Phytoliths include globular calcium oxalate druses and calcium carbonates rhombohedral crystals. The rhombohedral crystals are aligned with the leaf veins; calcium oxalate druses are aligned with veins and in the epidermal cell field. Trichome bases consist of 5-7 cells arranged in a rosette pattern around a central attachment point.

Numerous stomata are randomly arranged in the epidermal cell matrix. Stomata consists of a pair of crescent guard cells surrounding an oval pore. The length to width ratio of the stomatal complex is approximately 1.6:1. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides but wide at polar ends. Polar stems are moderately narrow. No pattern of subsidiary cells was observed.

Amelanchier alnifolia
saskatoon

Plate
41

Legend

Top image: Epidermal cells are irregular in shape with wavy anticlinal walls. Stomata are randomly arranged in the epidermal cell matrix. Guard cells have a crescent shape surrounding a narrow pore. (PLM, single polar)

Bottom image: Rhombohedral calcium carbonates are aligned with leaf veins; calcium oxalate globular crystals are aligned with veins and in the epidermal cell matrix. (PLM, single polar)

***Antennaria parvifolia*, small-leaf pussytoes;**

Family: Asteraceae (Plate 42)

Macroscopic Characteristics: Leaves are spatulate shaped with abundant hairs on the adaxial and abaxial surfaces. Length is approximately 3.5 cm long.

Microscopic Characteristics: Epidermal cells are polygonal shaped with straight anticlinal walls. Cells are arranged in a flagstone type pattern. Two trichome types were observed. Long flat fiber ribbons attach to epidermal cell matrix with trapeziform bases. The second type of trichome are short stalks with globular ends that has the appearance of “water towers”. No phytolith inclusions were observed.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consists of a pair of crescent guard cells surrounding a fusiform shaped pore. The overall shape of the stoma is nearly circular with curved lateral sides and polar ends. The length to width ratio of the stomatal complex is approximately 1.3:1. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides and wide at the polar ends. Polar stems are relatively wide.

Antennaria parvifolia
small-leaf pussytoes

Plate
42

Legend

Top image: Epidermal cells are polygonal shaped with straight anticlinal walls. Stomata have a pair of crescent shaped guard cells surrounding a fusiform shaped pore.
(PLM, single polar)

Bottom image: Two trichome types were observed. Long flat ribbons are attach to trapeziform bases. The second type have the appearance of "watertowers" with a stalked base and a globular top.
(PLM, single polar)

***Antennaria rosea*, rosy pussytoes;**

Family: Asteraceae (Plate 43)

Macroscopic Characteristics: Leaves are basal, spatulate shaped with abundant hairs on both the adaxial and abaxial surfaces. Leaf length is approximately 1-4 cm.

Microscopic Characteristics: Epidermal cells are polygonal shaped with straight anticlinal walls. Cells are arranged in a flagstone type pattern. Two trichome types were observed. Long flat fiber ribbons attach to epidermal cell matrix with trapeziform bases. The second type of trichome are short stalks with globular ends that has the appearance of “water towers”. No phytolith inclusions were observed.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consists of a pair of crescent guard cells surrounding a fusiform shaped pore. The overall shape of the stoma is nearly circular with curved lateral sides and polar ends. The length to width ratio of the stomatal complex is approximately 1.4:1. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides and wide at the polar ends. Polar stems are relatively wide.

Antennaria rosea
rosy pussytoes

Plate
43

***Aquilegia flavescens*, yellow columbine;**

Family: Asteraceae (Plate 44)

Macroscopic Characteristics: Leaves are compound with three leaflets per leaf. Leaflets are lobed with rounded apices and entire margins. Leaflets are 2-6 cm with abundant hairs on the adaxial surface.

Microscopic Characteristics: Epidermal cells are polygonal shaped with straight anticlinal walls. Cells are arranged in a flagstone type pattern. Trichomes are straight sided and hollow with trapeziform bases. Anisotropic unconsolidated phytolith crystals are scattered among the epidermal cells.

Anomocytic stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent guard cells surrounding an oblong to fat fusiform shaped pore. The length to width ratio of the stomatal complex is approximately 1.5:1. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides and wide at the polar ends. Polar stems are relatively wide.

Aquilegia flavescens
yellow columbine

Plate
44

Legend

Top image: Polygonal epidermal cells with straight anticlinal walls are arranged in a flagstone pattern. Stomata are randomly arranged and consist of a pair of crescent shaped guard cells surrounding a fat fusiform shaped pore. (PLM, single polar)

Bottom image: Trichomes are hollow fibers with straight sides and trapeziform bases. (PLM, single polar)

Arctostaphylos uva-ursi, kinnikinnick;

Family: Ericaceae (Plate 45)

Macroscopic Characteristics: Leaves are evergreen, thick, paddle-shaped and stiff with a length of approximately 1-3 cm (Kershaw, MacKinnon and Pojar 1998). Margins are entire with glabrous adaxial and abaxial surfaces.

Microscopic Characteristics: Epidermal cells are polygonal shaped with at length to width ratio that ranges from 1:1 to 2:1. Cells are arranged in a flagstone type pattern. Anticlinal walls are straight-curved. Calcium carbonate rhombohedral druses are aligned with veins and some in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consists of a pair of crescent guard cells surrounding an oblong to fusiform shaped pore. The overall shape of the stoma is nearly circular with curved lateral sides and polar ends. The length to width ratio of the stomatal complex is approximately 1.2:1. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides and polar ends. Polar stems are wide.

Arctostaphylos uva-ursi
kinnikinnick

Plate
45

Legend

Polygonal epidermal cells are arranged in a flagstone pattern. Anticlinal walls are straight-curved. Calcium carbonate rhombohedral druses are aligned with veins and some in the epidermal cell matrix. Stomata consist of a pair of fat guard cells surrounding an oblong to fusiform shaped pore. . The separation between the upper and lower woody lamella is narrow on the lateral sides and polar ends. Polar stems are wide.
(PLM, single polar)

***Arenaria serpyllifolia*, thymeleaf sandwort;**

Family: Ericaceae (Plate 46)

Macroscopic Characteristics: Leaves are smooth and ovate with hairs on margin; leaves are approximately 0.6 cm long.

Microscopic Characteristics: Epidermal cells are irregular shaped with wavy anticlinal walls. Cells are arranged in a jigsaw puzzle type pattern. Trichomes are long flat ribbon-like fibers. Calcium oxalate crystal were globular shaped and randomly arranged in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consists of a pair of crescent guard cells surrounding an oblong to oval shaped pore. The overall shape of the stoma is nearly circular with curved lateral sides and polar ends. The length to width ratio of the stomatal complex is approximately 1.1:1. The separation between the upper woody lamella and lower woody lamella is wide on the lateral sides and polar ends. Polar stems are wide.

Arenaria serpyllifolia
thymeleaf sandwort

Plate
46

Legend

Top image: Epidermal cells are irregular shaped with wavy anticlinal walls. Trichomes are flat ribbons. Calcium oxalate crystal were globular shaped and randomly arranged in the epidermal cell matrix. (PLM, single polar)

Bottom image: Stomata consist of two crescent guard cells surrounding an oblong to oval pore. Stomata are randomly arranged in a field of irregular epidermal cells. (PLM, single polar)

***Arnica cordifolia*, heartleaf Arnica;**

Family: Asteraceae (Plate 47)

Macroscopic Characteristics: Leaves are lance-shaped with a length of approximately 4-10 cm and a width of 3-9 cm (Kershaw, MacKinnon and Pojar 1998). Margins are coarsely serrate. Hairs were observed on the adaxial and abaxial surfaces.

Microscopic Characteristics: Epidermal cells are polygonal shaped with straight to straight-curved anticlinal walls. Trichomes are short and segmented into a few polygonal segments with a pointed apex. The base is circular. Fine grained anisotropic phytoliths are scattered in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consists of a pair of crescent guard cells surrounding an oblong to oval shaped pore. The overall shape of the stoma is nearly circular with curved lateral sides and polar ends. The length to width ratio of the stomatal complex is approximately 1.9:1. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides and polar ends. Polar stems are relatively wide.

Arnica cordifolia
heartleaf Arnica

Plate
47

***Artemisia cana*, silver sagebrush;**

Family: Asteraceae (Plate 48)

Macroscopic Characteristics: Leaves are linear, approximately 2-9 cm long and 0.2-0.7 cm wide. Margins are entire; the adaxial and abaxial surfaces have a grayish-white pubescence.

Microscopic Characteristics: Epidermal cells are polygonal shaped with straight to straight-curved anticlinal walls. Abundant trichomes are long fibers with straight sides. Occasional anisotropic phytoliths are square to rectangular.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consists of a pair of crescent guard cells surrounding a fusiform pore. The length to width ratio of the stomatal complex is approximately 1.2:1. The overall shape of the stoma is nearly circular with curved lateral sides and polar ends. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides and polar ends. Polar stems are narrow.

Artemisia cana
silver sagebrush

Plate
48

***Artemisia frigida*, prairie sagewort;**

Family: Asteraceae (Plate 49)

Macroscopic Characteristics: Leaves pinnately divided with 2-3 lobes, lancet shaped, and with a length of approximately 1.2 cm. Margins are entire; the adaxial and abaxial surfaces have a grayish-white pubescence.

Microscopic Characteristics: Epidermal cells are polygonal shaped with straight to straight-curved anticlinal walls. Trichomes are long fibers with straight sides. Occasional phytoliths are fusiform to oblong.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consists of a pair of crescent guard cells surrounding a fusiform pore. The length to width ratio of the stomatal complex is approximately 1.3:1. The overall shape of the stoma is nearly circular with curved lateral sides and polar ends. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides and polar ends. Polar stems are narrow.

Artemisia frigida
prairie sagewort

Plate
49

***Artemisia ludoviciana*, white sagebrush;**

Family: Asteraceae (Plate 50)

Macroscopic Characteristics: Leaves are lancet shaped with a length of approximately 3-11 cm. Margins are entire; the adaxial and abaxial surfaces have a grayish-white pubescence.

Microscopic Characteristics: Epidermal cells are polygonal shaped with straight to straight-curved anticlinal walls. Two types of trichomes are present. Long fibers with straight sides and short stalk-like fibers with globular ends. Occasional phytoliths are fusiform to oblong.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consists of a pair of crescent guard cells surrounding a fusiform to oblong pore. The length to width ratio of the stomatal complex is approximately 1.4:1. The overall shape of the stoma is oval with curved lateral sides and polar ends. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides and polar ends. Polar stems are narrow.

Artemisia ludoviciana
white sagebrush

Plate
50

***Artemisia tridentata*, big sagebrush;**

Family: Asteraceae (Plate 51)

Macroscopic Characteristics: Leaves are wedge shaped with three teeth and have a length of approximately 1-2 cm (Kershaw, MacKinnon and Pojar 1998). Margins are entire; the adaxial and abaxial surfaces have a grayish-white pubescence.

Microscopic Characteristics: Epidermal cells are polygonal shaped with straight to straight-curved anticlinal walls. Two types of trichomes are present. Long fibers with straight sides and short stalk-like fibers with globular ends. Occasional phytoliths are fusiform to oblong.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consists of a pair of crescent guard cells surrounding a fusiform to oblong pore. The length to width ratio of the stomatal complex is approximately 1.2:1. The overall shape of the stoma is round with curved lateral sides and polar ends. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides and polar ends. Polar stems are narrow.

Artemisia tridentata
big sagebrush

Plate
51

***Artemisia tripartita*, threetip sagebrush;**

Family: Asteraceae (Plate 52)

Macroscopic Characteristics: Leaves are wedge shaped and have a length of 0.5-0.4 cm. Margins are entire; the adaxial and abaxial surfaces have a grayish-white pubescence.

Microscopic Characteristics: Epidermal cells are polygonal shaped with straight to straight-curved anticlinal walls. Trichomes are long fibers with straight sides. Occasional phytoliths are fusiform to oblong.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform to oblong pore. The length to width ratio of the stoma is approximately 1.3:1. The overall shape of the stoma is round to oval with curved lateral sides and polar ends. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides and polar ends. Polar stems are narrow.

Artemisia tripartita
threetip sagebrush

Plate
52

***Astragalus crassicaarpus*, groundplum milkvetch;**

Family: Asteraceae (Plate 53)

Macroscopic Characteristics: Hairy leaflets are oval to elliptical with a width of 0.6 cm and a length of 0.8-1.3 cm. Margins are entire; the adaxial and abaxial surfaces have a grayish-white pubescence.

Microscopic Characteristics: Epidermal cells are rectangular to polygonal shaped with straight to straight-curved anticlinal walls. Trichomes are wide long fibers with straight sides and round base. The base is surrounded with a rosette of epidermal cells.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an oblong to fusiform to oblong pore. The length to width ratio of the stoma is approximately 1.3:1. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides and polar ends. Polar stems are narrow.

Astragalus crassicarpus
groundplum milkvetch

Plate
53

Legend

Epidermal cells include polygonal and rectangular cells arranged in a flagstone pattern. Trichomes are wide long fibers with an oval base. The base is surrounded by a rosette of epidermal cells. Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent guard cells surrounding an oblong to fusiform shaped pore.
(PLM, single polar)

***Balsamorhiza sagittata*, arrowleaf balsamroot;**

Family: Asteraceae (Plate 54)

Macroscopic Characteristics: Leaves are triangle in shape (arrowhead shaped) with an approximately length of 20-30 cm and a width of 5-15 cm (Kershaw, MacKinnon and Pojar 1998). Hairs are abundant on the adaxial and abaxial surfaces.

Microscopic Characteristics: Epidermal cells are rectangular to polygonal shaped with straight to straight-curved anticlinal walls. Numerous rectangular rough-sided phytoliths are axially aligned with veins. Numerous trichomes with non-parallel sides have circular bases with a pointed apex.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an oblong to fusiform pore. The length to width ratio of the stoma is approximately 1.6:1. The overall shape of the stoma is oval with curved lateral sides and polar ends. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides and wide at the polar ends.

Balsamorhiza sagittata
arrowleaf balsamroot

Plate
54

***Betula occidentalis*, water birch;**

Family: Betulaceae (Plate 55)

Macroscopic Characteristics: Leaves are ovate with an approximately length of 2-5 cm (Kershner, Nelson and Spellenberg 2008). Margins are single to doubly serrate. Fine hairs cover the abaxial surface and overlie abaxial and abaxial veins.

Microscopic Characteristics: Epidermal cells are rectangular to polygonal shaped with straight to straight-curved anticlinal walls. Short trichomes have straight sides with a pointed apex; epidermal cells at base are arranged in a rosette. Numerous calcium oxalate druses are randomly scattered in the epidermal matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an oblong to fusiform-shaped pore. The length to width ratio of the stoma is approximately 1.6:1. The overall shape of the stoma is oval with curved lateral sides and polar ends. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides and polar ends. Polar stems are narrow.

Betula occidentalis
water birch

Plate
55

Legend

Top Image: Epidermal cells are rectangular to polygonal shaped with straight-angled to straight anticlinal walls. Calcium oxalate druses are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of oblong guard cells and a rectangular pore. (PLM, single polar)

Bottom Image: Trichomes consist of straight sided fibers with a pointed apex; epidermal cells surrounding the base are in rosette pattern. (PLM, single polar)

***Camassia quamash*, small camas;**

Family: Liliaceae (Plate 56)

Macroscopic Characteristics: Leaves are long grass-like structure with a length exceeding 20 cm. Leaf surfaces are glabrous and abaxial veins are prominent.

Microscopic Characteristics: Epidermal cells are polygonal shaped; cells are nearly octagonal. Anticlinal walls are straight to straight-curved. No trichomes or phytoliths were observed.

Stomata are arranged in parallel rows. Stomata consist of a pair of crescent-shaped guard cells surrounding an elongated pore. The length to width ratio of the stoma is approximately 1.6:1. The overall shape of the stoma is oval with nearly flat lateral sides and curved polar ends. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides and wide at the polar ends. Polar stems are narrow.

Camassia quamash
small camas

Plate
56

Legend

Epidermal cells are polygonal with straight to straight-curved anticlinal walls. Oblong stomata are arranged in parallel rows. Stomata consist of a pair of crescent guard cells surrounding an elongated pore slit. The separation between the upper and lower woody lamella is narrow on the lateral sides and relatively wide at the polar ends. Polar stems are narrow.

(PLM, single polar)

***Castilleja miniata*, giant red Indian paintbrush;**

Family: Scrophulariaceae (Plate 57)

Macroscopic Characteristics: Leaves are linear to lancet shaped with a length of approximately 5-7 cm (Kershaw, MacKinnon and Pojar 2016). Leaves are three veined and margins are entire.

Microscopic Characteristics: Epidermal cells are polygonal shaped with straight to straight-curved anticlinal walls. The length to width ratio ranges from 1:1 to 2:1.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an elongated pore. The length to width ratio of the stoma is approximately 1.4:1. Stomata are elevated above the epidermal cell matrix; each stoma appears similar to a mini-volcano. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides and polar ends. Polar stems are narrow.

Castilleja miniata
giant red Indian paintbrush

Plate
57

Legend

Epidermal cells are polygonal with straight to straight-curved anticlinal walls. Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent guard cells surrounding an fusiform pore. Stomata are elevated above the epidermal cell matrix; each stoma appears similar to a mini-volcano. The separation between the upper and lower woody lamella is narrow on the lateral sides and polar ends. Polar stems are narrow. (PLM, single polar)

***Ceanothus velutinus*, snowbush;**

Family: Rhamnaceae (Plate 58)

Macroscopic Characteristics: Leaves are oval and glaucous with an approximate length of 4-8 cm.

Microscopic Characteristics: Epidermal cells are square to polygonal shaped with straight to straight-curved anticlinal walls. The length to width ratio ranges from 2:1 to 4:1. Trichomes are curved, unbranched fibers with straight-walls and a pointed apex. Globular calcium oxalate druses are aligned with leave veins with some scattered in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an elongated pore. The length to width ratio of the stoma is approximately 1.4:1.

Ceanothus velutinus
snowbush

Plate
58

***Cercocarpus ledifolius*, curl-leaf mountain mahogany;**

Family: Rosaceae (Plate 59)

Macroscopic Characteristics: Leaves are narrowly elliptic with a length of 1.3-4 cm wide (Kershner, Nelson and Spellenberg 2008). Margins are entire and strongly rolled toward abaxial surface. The adaxial surface is glabrous whereas the abaxial surface is hairy.

Microscopic Characteristics: Epidermal cells are polygonal shaped with straight to straight-curved anticlinal walls. Trichomes are curved unbranched straight wall fibers with a pointed apex. Globular calcium oxalate and calcium carbonates rhombohedrals are aligned with leave veins.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an elongated pore. The length to width ratio of the stoma is approximately 1.4:1.

Cercocarpus ledifolius
curl-leaf mountain mahogany

Plate
59

***Chamerion angustifolium*, fireweed;**

Family: Rhamnaceae (Plate 60)

Macroscopic Characteristics: Leaves are lancet shaped with a length of 2-20cm and width of 0.5-3.5 cm tips (Kershaw, MacKinnon and Pojar 1998). The margins are entire and short hairs border the central vein on the abaxial surface.

Microscopic Characteristics: Epidermal cells are polygonal with straight to straight-curved anticlinal walls. Globular calcium oxalate druses are scattered randomly in epidermal cell matrix.

Stomata consist of a pair of guard cells surrounding an elongated fusiform-shaped pore. Stomata are elevated above the cell matrix with reinforced striations. The length to width ratio of the stoma is approximately 2.4:1. The separation between the lower and upper woody lamella is narrow on the lateral sides and wider at the polar ends. The polar ends are narrow.

Chamerion angustifolium
fireweed

Plate
60

***Chimaphila umbellate*, pipsissewa;**

Family: Rhamnaceae (Plate 61)

Macroscopic Characteristics: Leaves are evergreen and spoon-shaped with a length of 2-8 cm (Kershaw, MacKinnon and Pojar 1998). Margins are sharply serrate with a dark green adaxial surface and near glaucous abaxial surface. The adaxial and abaxial surfaces and veins are glabrous.

Microscopic Characteristics: Epidermal cells are irregular shaped with straight-curved anticlinal walls. Cells are interconnected in a jigsaw puzzle-like pattern. No trichomes or phytoliths were observed.

Stomata are near-circular with two crescent-shaped guard cells surrounding an oval pore. Polar ends appear triangular because of the angle formed between the guard cells and polar end. The length to width ratio of the stoma is approximately 1.1:1. The separation between the lower and upper lamella is narrow at the lateral sides but wide at the polar ends. The polar stems are relatively wide.

Chimaphila umbellate
pipsissewa

Plate
61

***Chrysothamnus nauseosus*, rubber rabbitbush;**

Family: Asteraceae (Plate 62)

Macroscopic Characteristics: Rabbitbush leaves are oblong to lancet shaped with a length of 3-6 cm and width of 1 cm (Kershaw, MacKinnon and Pojar 1998). Adaxial and abaxial leaf surfaces are hairy.

Microscopic Characteristics: Epidermal cells are polygonal shaped with straight-curved anticlinal walls. Leaves are arranged in a flagstone pattern. No trichomes or phytoliths were observed.

Stomata are randomly arranged in the epidermal cell matrix with crescent-shaped guard cells surrounding a fusiform-shaped pore. The length to width ratio of the stoma ranges from 1.2:1 to 1.5:1. The overall shape of the stoma is circular to oval with curved lateral sides and polar ends. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides and at the polar ends. Polar stems are narrow.

Chrysothamnus nauseosus
rubber rabbitbush

Plate
62

***Cirsium foliosum*, elk thistle;**

Family: Asteraceae (Plate 63)

Macroscopic Characteristics: Leaves are oblong to lancet shaped with a length of approximately 10-15 cm. Margins are bordered with stout spines. The adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are rounded polygons arranged in a flagstone pattern. Anticlinal walls are thick and straight-curved. The length to width ratio ranges from 1:1 to 2:1. No phytoliths or trichomes were observed.

Stomata are randomly arranged in the epidermal cell matrix with crescent-shaped guard cells surrounding an oval to fusiform-shaped pore. The length to width ratio of the stoma is approximately 1.5:1. The overall shape of the stoma is oval with curved lateral sides and polar ends. The separation between the upper woody lamella and lower woody lamella is nearly wide on the lateral sides and at the polar ends. Polar stems are narrow.

Cirsium foliosum
elk thistle

Plate
63

***Cirsium scariosum*, meadow thistle;**

Family: Asteraceae (Plate 64)

Macroscopic Characteristics: Leaves are lobed, hairless and oblong with an approximately length of 10-30 cm and width of 1.25-5 cm. Stout spines are located at tips of each lobe.

Microscopic Characteristics: Epidermal cells are rounded polygons arranged in a flagstone pattern with thick straight-curved anticlinal walls. The length to width ratio ranges from 1:1 to 3:1. Cells are arranged in a flagstone pattern.

Stomata are randomly arranged in the epidermal cell matrix with crescent-shaped guard cells surrounding an oval to fusiform-shaped pore. The length to width ratio of the stoma is approximately 1.5:1. The separation between the upper woody lamella and the lower woody lamella is moderately wide on the lateral sides and wider at the polar ends. The polar stems are relatively wide.

Cirsium scariosum
meadow thistle

Plate
64

***Cirsium vulgare*, bull thistle;**

Family: Asteraceae (Plate 65)

Macroscopic Characteristics: Leaves are lancet-shaped with an approximately length of 7-30 cm. Margins are rimmed with stout spines.

Microscopic Characteristics: Epidermal cells are polygonal shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Trichomes are long flat fibers. A few phytoliths are scattered among the epidermal cells.

Stomata are randomly arranged in the epidermal cell matrix with a pair of crescent-shaped guard cells surrounding an oval to fusiform-shaped pore. The length to width ratio of the stoma is approximately 1.4:1. The separation between the upper woody lamella and the lower woody lamella is wide at the lateral sides and polar ends. The polar stems are wide.

Cirsium vulgare
bull thistle

Plate
65

Legend

Top Image: Epidermal cells are polygonal with straight-curved anticlinal walls. Stomata are circular to slightly oblong with a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The separation between the upper and lower woody lamella is wide at the lateral sides and the polar ends.
(PLM, single polar)

Bottom Image: Trichomes are long flat fibers that form a thick mat.
(PLM, single polar)

***Comandra umbellata*, pale bastard toadflax;**

Family: Santalaceae (Plate 66)

Macroscopic Characteristics: Leaves are lancet-shaped with an approximately length of 1-4 cm and width of 2 cm (Kershaw, MacKinnon and Pojar 1998). Three veins radiate from a common apex at the petiole. The adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are polygonal and arranged in a flagstone pattern. Anticlinal walls are straight-curved. No trichomes or phytoliths were observed.

Stomata are roughly aligned with the leaf veins. Stomata consist of a pair of elongated bilobal guard cells surrounding a thin pore. A pair of subsidiary cells surround the guard cells. The length to width ratio of the stoma is approximately 2.4:1. The separation between the upper woody lamella and the lower woody lamella is wide at the lateral sides and narrow at the polar ends. The polar stems are narrow.

Comandra umbellata
pale bastard toadflax

Plate
66

Legend

Epidermal cells are polygonal with straight-curved anticlinal walls. Cells are arranged in flagstone pattern. Stomata are roughly aligned with veins and consist of a pair of bilobate guard cells surrounding a thin pore. A pair of subsidiary cells surround the guard cells. The separation between the upper and the lower woody lamella is wide at the lateral sides and narrow at the polar ends. The polar stems are narrow.
(PLM, single polar)

***Cornus canadensis*, bunchberry;**

Family: Cornaceae (Plate 67)

Macroscopic Characteristics: Four obovate leaves are arranged around a central stem. Leaf margins are entire with a length of approximately 2-8 cm and width of 5 cm (Kershaw, MacKinnon and Pojar 1998).

Microscopic Characteristics: Epidermal cells are irregular shaped and arranged in a flagstone or jigsaw puzzle pattern. Anticlinal walls are straight-curved. Trichomes are double-ended and straight-sided with pointed apex. The bases are oval to hexangle, each base is surrounded by a rosette of epidermal cells. Cells surround the bases are polygonal with straight anticlinal walls. Calcium oxalate druses are scattered randomly in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix; crescent-shaped guard cells surround a fusiform-shaped pore. The length to width ratio of the stoma is approximately 1.3:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are wide.

Cornus canadensis
bunchberry

Plate
67

Legend

Top Image: Epidermal cells are irregular-shaped with straight-curved anticlinal walls. Cells are arranged in flagstone pattern. Trichomes have straight margins with pointed apices.
(PLM, single polar)

Bottom Image: Trichome bases are oval to hexangle with a rosette of epidermal cells. The cells surround the base are polygonal.
(PLM, single polar)

***Cornus sericea*, red-osier dogwood;**

Family: Cornaceae (Plate 68)

Macroscopic Characteristics: Red-osier dogwood leaves are ovate to oblong with an approximate length of 2-10 cm (Kershaw, MacKinnon and Pojar 1998). Five to seven prominent veins converge toward the pointed tip.

Microscopic Characteristics: Epidermal cells are irregular shaped and arranged in a flagstone pattern. Anticlinal walls are straight-curved. Trichomes are double-ended and straight-sided with pointed apexes and a central core that is oval to hexangle. Calcium oxalate druses and starch grains are scattered randomly in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix; crescent-shaped guard cells surround a fusiform-shaped pore. The length to width ratio of the stoma is approximately 1.2:1.

Cornus sericea
red-osier dogwood

Plate
68

***Crataegus douglasii*, hawthorn;**

Family: Rosaceae (Plate 69)

Macroscopic Characteristics: Hawthorne leaves are obovate to round with an approximately length of 2.5-10 cm. Hairs are present on the adaxial and abaxial surfaces and veins.

Microscopic Characteristics: Epidermal cells are irregular shaped and arranged in a flagstone pattern. Anticlinal walls are straight-curved to sinuous. Calcium carbonate rhombohedral druses are aligned with the leaf veins.

Anomocytic stomata are randomly arranged in the epidermal cell matrix. Stomata consist of crescent-shaped guard cells surrounding a fusiform-shaped pore. The length to width ratio of the stoma is approximately 1.6:1. The separation between the upper woody lamella and the lower woody lamella is wide at the lateral sides and narrower at the polar ends. The polar stems are narrow.

Crataegus douglasii
black hawthorn

Plate
69

Legend

Top Image: Epidermal cells are irregular-shaped with straight-curved to sinuous anticlinal walls. Multiple randomly arranged stomata consist of a pair of crescent-shaped guard cells surround a fusiform-shaped pore. (PLM, single polar)

Bottom Image: Calcium carbonate rhombohedral druses are aligned with leaf veins.. (PLM, single polar)

***Crepis runcinate*, fiddleleaf hawksbeard;**

Family: Asteraceae (Plate 70)

Macroscopic Characteristics: Leaves are lanceolate to elliptic with an approximately length of 4-30 cm and width of 0.5-8 cm. Hairs are scattered on the abaxial surface however the adaxial surface is glabrous.

Microscopic Characteristics: Epidermal cells are polygonal-shaped and arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Abundant long trichomes are wide, flat and ribbon-like. No phytoliths were observed.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of crescent-shaped guard cells surround a fusiform-shaped pore. The length to width ratio of the stoma is approximately 1.2:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and the polar ends. The polar stems are wide.

Crepis runcinata
fiddleleaf hawksbeard

Plate
70

Legend

Top Image: Epidermal cells are polygonal-shaped with straight to straight-curved anticlinal walls. Multiple randomly arranged stomata consist of a pair of crescent-shaped cells surrounding a fusiform-shaped pore. The separation between the upper and lower woody lamella is narrow at the lateral sides and polar ends.
(PLM, single polar)

Bottom Image: Trichome fibers are long and flat.
(PLM, single polar)

***Dasiphora fruticosa*, shrubby cinquefoil;**

Family: Rosaceae (Plate 71)

Macroscopic Characteristics: Leaves have smooth margins that are revolute. The leaf length and width is approximately 1.2-2.5 cm. Abundant hairs coat the adaxial and abaxial surfaces.

Microscopic Characteristics: Epidermal cells are polygonal shaped and arranged in a flagstone pattern. Anticlinal walls are straight-curved. Abundant long trichomes are flat; bases are oval to hexangle with a rosette of epidermal cells surrounding the base.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surround a fusiform-shaped pore. The length to width ratio of the stoma is approximately 1.4:1.

Dasiphora fruticosa
shrubby cinquefoil

Plate
71

Legend

Epidermal cells are polygonal-shaped and arranged in a flagstone pattern. Anticlinal walls are straight-curved. Trichomes are long and flat; bases are oval to hexangle. Trichome bases are surrounded by a rosette of epidermal cells. Globular calcium oxalate druses are randomly arranged in the epidermal cell matrix. (PLM, single polar)

***Delphinium bicolor*, little larkspur;**

Family: Ranunculaceae (Plate 72)

Macroscopic Characteristics: Leaves have wide rounded lobes with an approximately length of 1-4 cm. Leaf surfaces are lightly pubescence.

Microscopic Characteristics: Epidermal cells are polygonal-shaped and arranged in a flagstone pattern. Anticlinal walls are straight-curved. Trichomes have straight sides and pointed apex. Trichomes are hollow with a rounded to bulbous end. No phytoliths were observed.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surround a fusiform-shaped pore. The length to width ratio of the stoma is approximately 1:1. The stomata walls are thin. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and the polar ends. The polar stems are narrow.

Delphinium bicolor
little larkspur

Plate
72

***Dodecatheon conjugens*, Bonneville shootingstar;**

Family: Ranunculaceae (Plate 73)

Macroscopic Characteristics: Leaves are spatulate to oblanceolate with a length of 1-10 cm. The adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are polygonal shaped and arranged in a flagstone pattern. Anticlinal walls are straight-curved. No trichomes or phytoliths were observed.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surround a fusiform-shaped pore. The length to width ratio of the stoma is approximately 1.3:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and the polar ends. The polar stems are narrow.

Dodecatheon conjugens
Bonneville shootingstar

Plate
73

***Elaeagnus commutata*, silverberry;**

Family: Elaeagnaceae (Plate 74)

Macroscopic Characteristics: Leaves are egg to lancet-shaped with an approximately length of 2-6 cm. The adaxial and abaxial surfaces are punctuated with numerous scales and stellate hairs.

Microscopic Characteristics: Epidermal cells are irregular shaped and arranged in a flagstone pattern. Anticlinal walls are sinuous. Stellate trichomes and stellate scales are scattered randomly.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surround a fusiform-shaped pore. The length to width ratio of the stoma is approximately 1.3:1. The separation between the upper woody lamella and the lower woody lamella is wide at the lateral sides and the polar ends. The polar stems are narrow.

Elaeagnus commutata
silverberry

Plate
74

Legend

Top Image: Epidermal cells are irregular shaped and arranged in a flagstone pattern with sinuous anticlinal walls. Stellate trichomes are scattered randomly. Stellate scales are also observed. (PLM, single polar)

Bottom Image: Stomata are randomly arranged in the epidermal cell matrix; crescent-shaped guard cells surround a fusiform-shaped pore. (PLM, single polar)

***Equisetum arvense*, field horsetail;**

Family: Equisetaceae (Plate 75)

Macroscopic Characteristics: Field horsetail consist of two varieties. One variety is a fertile plant that is 10-25 cm in height and 0.3-0.5 cm in width with brown scale-like leaves and an apical spore cone. The second variety is sterile and grows after the fertile stems die off in late spring. The sterile variety consists of succulent stems that are 10-90 cm in height and 0.3-0.5 cm in width. Leaf sheaths consist of 4-15 teeth that encircle the stems.

Microscopic Characteristics: Epidermal cells are rectangular with irregular margins. Cells are stacked end-to-end and arranged in a brick-like pattern. Circular structures are centered within the epidermal cells. Phytoliths are randomly arranged in the epidermal cell matrix.

Stomata are arranged in near-parallel rows. Stomata consist of a narrow pore surrounded by guard cells and a pair of subsidiary cells with radiating ribs. A pair of phytoliths are positioned at polar ends of the stoma pore. The length to width ratio of the stoma is approximately 1:1. The separation between the upper woody lamella and the lower woody lamella is wide at the lateral sides and the polar ends.

Equisetum arvense
field horsetail

Plate
75

***Equisetum fluviatile*, water horsetail;**

Family: Equisetaceae (Plate 76)

Macroscopic Characteristics: Water horsetail consists of bamboo-like hollow stems approximately 1-2 cm in diameter. Each stem is topped with an apical spore cone

Microscopic Characteristics: Epidermal cells are rectangular to parallelogram shaped with straight to irregular anticlinal walls. Cells are stacked end-to-end and arranged in a brick-like pattern. Calcium druses were observed in the epidermal matrix. No trichomes were observed.

Stomata are arranged in parallel rows. Stomata consist of a narrow pore surrounded by guard cells and a pair of subsidiary cells with radiating ribs. The length to width ratio of the stoma is approximately 1:1. The separation between the upper woody lamella and the lower woody lamella is wide at the lateral sides and the polar ends.

Equisetum fluviatile
water horsetail

Plate
76

Legend

Epidermal cells are rectangular to parallelogram-shaped with straight to irregular margins. Cells are stacked end-to-end and arranged in a brick-like pattern. Stomata consist of an long pore surrounded by radiating ribs. Stomata are arranged in parallel rows. Calcium phytoliths are randomly arranged in the epidermal cell matrix.
(PLM, single polar)

***Equisetum hyemale*, rough horsetail;**

Family: Equisetaceae (Plate 77)

Macroscopic Characteristics: Rough horsetail consists of bamboo-like hollow stems approximately 1-2 cm in diameter. Tiny leaves encircle the stem forming a sheath at each joint.

Microscopic Characteristics: Epidermal cells are rectangular with wavy to irregular anticlinal walls. Cells are stacked end-to-end and arranged in a brick-like pattern. Phytoliths were observed in the epidermal matrix.

Stomata are arranged in parallel rows. Stomata consist of a narrow pore surrounded by guard cells and a pair of subsidiary cells with radiating ribs. The length to width ratio of the stoma is approximately 1:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and the polar ends.

Equisetum hyemale
rough horsetail

Plate
77

***Erigeron sp.*, fleabane;**

Family: Asteraceae (Plate 78)

Macroscopic Characteristics: Leaves are lancet-shaped with coarsely toothed margins. The leaf length is approximately 2-10 cm and the width is 1 cm. The adaxial and abaxial surfaces are hairy.

Microscopic Characteristics: Epidermal cells are irregular shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Globular calcium oxalate druses are aligned with leaf veins. Trichomes are multi-segmented with straight-sides and pointed apexes.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surround a fusiform-shaped pore. The length to width ratio of the stoma is approximately 1.3:1.

Erigeron sp.
fleabane

Plate
78

Legend

Top Image: Epidermal cells are irregular-shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Globular calcium oxalate druses are aligned with leaf veins.
(PLM, single polar)

Bottom Image: Trichomes are multi-segmented with straight sides and pointed apices.
(PLM, single polar)

***Eriogonum heracleoides*, parsnipflower buckwheat;**

Family: Polygonaceae (Plate 79)

Macroscopic Characteristics: Leaves are in rosettes; individual leaves are spatula-shaped with a length of approximately 0.5-3 cm. The abaxial surface is covered with dense hairs.

Microscopic Characteristics: Epidermal cells are polygonal shaped and arranged in a flagstone pattern. Anticlinal walls are straight-curved. Globular calcium oxalate druses are randomly located in the epidermal cell matrix. Trichomes are long flat fibers with non-parallel sides.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a fusiform-shaped pore surrounded by guard cells. The length to width ratio of the stoma is approximately 1.1:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and the polar ends. The polar stems are narrow.

Eriogonum heracleoides
parsnipflower buckwheat

Plate
79

Legend

Epidermal cells are polygonal shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Globular calcium oxalate phytoliths are randomly larranged in the epidermal cell matrix. Trichomes are long flat fibers with non-parallel sides. Stomata consist of a pair of crescent-shaped guard cells surrounding a narrow pore. (PLM, single polar)

***Erigonum ovalifolium.*, cushion buckwheat;**

Family: Polygonaceae (Plate 80)

Macroscopic Characteristics: Leaves are basal and egg-shaped with a length of approximately 1 cm. The abaxial surface is glaucous and densely hairy.

Microscopic Characteristics: Epidermal cells are polygonal shaped with straight-curved anticlinal walls. Cells are arranged in flagstone pattern. Phytoliths are randomly located in the epidermal cell matrix. Trichomes are hooked-shaped with straight sides.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a narrow pore surrounded by guard cells. The length to width ratio of the stoma is approximately 1.4:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and the polar ends. The polar stems are relatively wide.

Eriogonum ovalifolium
cushion buckwheat

Plate
80

***Eriogonum umbellatum*, sulfur-flower buckwheat;**

Family: Polygonaceae (Plate 81)

Macroscopic Characteristics: Leaves are basal in whorls, hairy and spatula-shaped with a length of approximately 1-3 cm. Abundant hairs are located on the adaxial surface; the abaxial surface is glaucous and densely hairy.

Microscopic Characteristics: Epidermal cells are polygonal shaped with straight-curved anticlinal walls. Cells are arranged in flagstone pattern. Phytoliths are randomly located in the epidermal cell matrix. Trichomes are long hollow fibers with near parallel sides.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a fusiform pore surrounded by guard cells. The length to width ratio of the stoma is approximately 1.3:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and the polar ends. The polar stems are narrow.

Eriogonum umbellatum
sulfur-flower buckwheat

Plate
81

Legend

Top Image: Epidermal cells are polygonal-shaped with straight-curved anticlinal walls. Phytoliths are randomly located in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore.
(PLM, single polar)

Bottom Image: Trichomes are long, hollow fibers with near parallel sides.
(PLM, single polar)

***Fragaria virginiana*, Virginia strawberry;**

Family: Rosaceae (Plate 82)

Macroscopic Characteristics: Leaves are basal and divided into three toothed leaflets with a width of approximately of 5-10 cm.

Microscopic Characteristics: Epidermal cells are polygonal-shaped with straight-curved anticlinal walls. Cells are arranged in flagstone pattern. Calcium oxalate druses and calcium carbonates crystals are aligned with the leaf veins and scattered in epidermal cell matrix. Trichomes are hook-shaped with straight-sides and pointed apexes.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a fusiform-shaped pore surrounded by a pair of guard cells. The length to width ratio of the stoma is approximately 1.4:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and the polar ends. The polar stems are narrow.

Fragaria virginiana
Virginia strawberry

Plate
82

Legend

Top Image: Epidermal cells are polygonal-shaped with straight-curved anticlinal walls. Calcium oxalate and calcium carbonates crystals are aligned with the leaf veins and scattered in the epidermal cell matrix. Trichomes are hook-shaped with straight sides and pointed apexes. (PLM, single polar)

Bottom Image: Stomata are randomly arranged and consist of a pair of guard cells with fusiform-shaped pore. (PLM, single polar)

***Galium boreale*, northern bedstraw;**

Family: Rubiaceae (Plate 83)

Macroscopic Characteristics: Leaves are lancet to linear-shaped. Leaves are arranged in whorls of four that are approximately 2-6 cm in length.

Microscopic Characteristics: Epidermal cells are irregular-shaped with straight-curved anticlinal walls. Cells are arranged in jigsaw puzzle pattern. Trichomes are hook shaped with straight-sides and pointed apices. Bases are surrounded by a rosette of epidermal cells. Epidermal cells surround the trichome bases are irregular-shaped.

Brachyparacytic stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a fusiform pore surrounded by guard cells. The length to width ratio of the stoma is approximately 1.7:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are wide.

Galium boreale
northern bedstraw

Plate
83

Legend

Epidermal cells are irregular shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Trichomes are hook-shaped with straight-sides and pointed apexes. Bases are surrounded by a rosette of epidermal cells. Brachyparacytic stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. (PLM, single polar)

***Geranium viscosissimum*, sticky geranium;**

Family: Geraniaceae (Plate 84)

Macroscopic Characteristics: Leaves have a long petiole with deeply palmately lobed toothed sections. Leaf length is approximate 3-12 cm.

Microscopic Characteristics: Epidermal cells are irregular-shaped with straight-curved anticlinal walls. Cells are arranged in flagstone pattern. Trichomes are straight spears with straight-sides and pointed apexes. Bases are surrounded by a rosette of epidermal cells.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a fusiform-shaped pore surrounded by crescent-shaped guard cells. The length to width ratio of the stoma is approximately 2:1.

Geranium viscosissimum
sticky geranium

Plate
84

***Geum canadense*, white aven;**

Family: Rosaceae (Plate 85)

Macroscopic Characteristics: Leaves are approximately 10 cm long and 8 cm wide. Leaves are lanceolate-shape and coarsely serrated.

Microscopic Characteristics: Epidermal cells are polygonal to irregular-shaped with straight-curved anticlinal walls. Cells are arranged in flagstone pattern. Trichomes are straight spears with straight sides and pointed apexes. Bases are circular to hexangle.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a fusiform-shaped pore surrounded by guard cells. The length to width ratio of the stoma ranges from 1.3:1 to 2.6:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are wide.

Geum canadense
white aven

Plate
85

Glycyrrhiza lepidota, American licorice;

Family: Fabaceae (Plate 86)

Macroscopic Characteristics: Leaves are pinnately compound with leaflets that are approximately 2-4 cm in length.

Microscopic Characteristics: Epidermal cells are polygonal to irregular-shaped with straight-curved anticlinal walls. Cells are arranged in flagstone pattern. Trichomes are long, segmented fibers with smooth sides and rounded bases

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a fusiform-shaped pore surrounded by crescent-shaped guard cells. The length to width ratio of the stoma ranges from 1.3:1 to 1.6:1. The separation between the upper woody lamella and the lower woody lamella is wide at the lateral sides and the polar ends. The polar stems are wide.

Glycyrrhiza lepidota
American licorice

Plate
86

***Hedysarum boreale*, Northern Sweetvetch;**

Family: Fabaceae (Plate 87)

Macroscopic Characteristics: Leaves are compound and consist of 7-15 leaflets per leaf. Leaflets are lancet to obovate with a length of approximately 1-2 cm.

Microscopic Characteristics: Epidermal cells are polygonal to irregular-shaped with straight-curved anticlinal walls. Cells are arranged in flagstone pattern. Trichomes are curved fibers with straight to slightly textured sides. Fibers have a pointed apex and round base. Calcium carbonate rhombohedral druses are aligned with leaf veins.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a fusiform-shaped pore surrounded by crescent-shaped guard cells. Guard cell side walls are flattened. The length to width ratio of the stoma is 1.6:1.

Hedysarum boreale
northern sweetvetch

Plate
87

Legend

Top Image: Epidermal cells are polygonal to irregular-shaped with straight-curved anticlinal walls. Trichomes are curved fibers with straight to slightly textured sides. Fibers have a pointed apex and round base.
(PLM, single polar)

Bottom Image: Calcium carbonate rhombohedral druses are aligned with leaf veins.
(PLM, single polar)

***Heracleum maximum*, common cowparsnip;**

Family: Apiaceae (Plate 88)

Macroscopic Characteristics: Cowparsnip leaves are very large with 3-5 lobes. Leaf width is approximately 40 cm.

Microscopic Characteristics: Epidermal cells are polygonal to irregular-shaped with straight-curved anticlinal walls. Cells are arranged in flagstone or jigsaw puzzle pattern. Trichomes are flat fibers with straight sides, a pointed apex and semicircle (half-moon) base. Phytoliths are randomly arranged in the epidermal cell matrix.

Stomata are randomly arranged, anomocytic and primarily located on abaxial epidermis. A pair of crescent-shaped guard cells surround an oval to fusiform-shaped pore.

Heracleum maximum
cowparsnip

Plate
88

Legend

Epidermal cells are polygonal to irregular-shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Trichomes are abundant and consist of slightly curved flat fibers with semi-circular (half-moon) shaped bases. Stomata consist of a pair of guard cells surrounding a fusiform-shaped pore.
(PLM, single polar)

***Iris missouriensis*, Rocky Mountain iris;**

Family: Iridaceae (Plate 89)

Macroscopic Characteristics: Leaves are long with parallel venation. Width of leaves are 0.3-0.9 cm.

Microscopic Characteristics: Epidermal cells are rectangular to polygonal shaped. Cells are aligned end-to-end and stacked brick-like. Anticlinal walls are straight to straight-curved. Cell end walls are squared to slightly rounded. Rectangular phytoliths are aligned with leaf veins.

Stomata are circular and aligned in parallel rows between the epidermal cells. Stomata consist of an oval to fusiform-shaped pore surrounded by fat guard cells. The length to width ratio of the stoma is 1.2:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and the polar ends. The polar stems are narrow.

Iris missouriensis
Rocky Mountain iris

Plate
89

***Ledum groenlandicum*, bog Labrador tea;**

Family: Ericaceae (Plate 90)

Macroscopic Characteristics: Linear, woolly, leathery leaves are alternate, simple and approximately 5 cm in length and 2 cm in width.

Microscopic Characteristics: Epidermal cells are polygonal with straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Phytoliths and calcium oxalate druses are randomly arranged in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata are nearly circular and consist of crescent-shaped guard cells surrounding an elongated pore. The stoma has an approximately length to width ratio of 1:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and the polar ends. The polar stems are narrow.

Ledum groenlandicum
bog Labrador tea

Plate
90

Legend

Epidermal cells are polygonal with straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Phytoliths and calcium oxalate druses are randomly located in the epidermal cell matrix. Stomata consist of crescent shaped guard cells with an elongated pore. The separation between the upper and lower woody lamella is narrow at the lateral sides and the polar ends. The polar stems are narrow. (PLM, single polar)

Linnaea borealis, twinflower;

Family: Caprifoliaceae (Plate 91)

Macroscopic Characteristics: Leaves are opposite, evergreen and oval with a length of 0.3-1 cm and width of 0.2-0.7 cm.

Microscopic Characteristics: Epidermal cells are polygonal to irregular-shaped with verrucate anticlinal walls. Cells are arranged in a flagstone or jigsaw puzzle pattern. No phytoliths were observed in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of crescent-shaped guard cells with a fusiform-shaped pore. The stoma has an approximate length to width ratio of 1:1. The separation between the upper woody lamella and the lower woody lamella is wide at the lateral sides and the polar ends. The polar stems are wide.

Linnaea borealis
twinflower

Plate
91

Liquidambar styraciflua, sweetgum;

Family: Altingiaceae (Plate 92)

Macroscopic Characteristics: Leaves are star-shaped with five pointed palmate lobes. Leaf length is approximately 7.5-12 cm.

Microscopic Characteristics: Epidermal cells are rectangular to polygonal with straight-curved anticlinal walls. Rectangular cells are aligned with leaf veins and polygonal cells are randomly arranged like flagstones in the epidermal cell matrix. Calcium oxalate druses are randomly arranged in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata are oblong and consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The stoma has an approximately length to width ratio of 2.1:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and the polar ends. The polar stems are wide.

Liquidambar styraciflua
sweetgum

Plate
92

***Lithospermum incisum*, narrowleaf stoneseed;**

Family: Boraginaceae (Plate 93)

Macroscopic Characteristics: Leaves are narrow with pointed apex; length is approximately 6 cm. Coarse hairs cover the adaxial and abaxial surfaces.

Microscopic Characteristics: Epidermal cells are polygonal-shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Trichomes are hollow spears with pointed apexes. Bases are hexangle with a rosette of epidermal cells surrounding the base.

Stomata are randomly arranged. Stomata are oblong and consist of a pair of crescent-shaped guard cells surrounding a fat fusiform pore. The stoma has an approximately length to width ratio of 1.2:1. Phytoliths fill some of the stomata pores. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are wide.

Lithospermum incisum
western stoneseed

Plate
93

Legend

Epidermal cells are polygonal-shaped with straight-angled anticlinal walls. Cells are arranged in a flagstone pattern. Trichomes are hollow spears with pointed apices. Bases are hexangle with a rosette of epidermal cells surrounding the base. Stomata are randomly arranged with a pair of crescent-shaped guard cells and surrounding an oval to fusiform pore. Phytoliths fill some of the stomata pores. (PLM, single polar)

***Lonicera involucrata*, twinberry honeysuckle;**

Family: Caprifoliaceae (Plate 94)

Macroscopic Characteristics: Leaves are elliptic with pointed apices. Leaf length is approximately 3–16 cm with a width of 2–8 cm. Margins and the abaxial surface are punctuated with hairs.

Microscopic Characteristics: Epidermal cells are polygonal-shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Trichomes are heavily textured spears with pointed apices. Bases are reinforced. Calcium oxalate druses are randomly arranged in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells and an elongated pore on an elevated reinforced base. The stoma has an approximately length to width ratio of 1.1:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are relatively wide.

Lonicera involucrata
twinberry honeysuckle

Plate
94

Legend

Top Image: Epidermal cells are polygonal-shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Calcium oxalate druses are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells and an elongated pore. (PLM, single polar)

Bottom Image: Trichomes are textured with reinforced bases. (PLM, single polar)

***Lonicera utahensis*, Utah honeysuckle;**

Family: Caprifoliaceae (Plate 95)

Macroscopic Characteristics: Leaves are oval to oblong with an approximately length of approximately 8 cm and a width of 4 cm. Occasional hairs cover the adaxial and abaxial surfaces.

Microscopic Characteristics: Epidermal cells are polygonal-shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Phytoliths are randomly arranged in the epidermal cell matrix. Abundant calcium carbonate rhombohedral druses are aligned with leaf veins. Trichomes are straight-sided with hemi-circular bases.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore on an elevated reinforced base. The stoma has an approximately length to width ratio of 1.3:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are relatively wide.

Lonicera utahensis
Utah honeysuckle

Plate
95

Legend

Epidermal cells are polygonal-shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Phytoliths are randomly arranged in the epidermal cell matrix. Abundant calcium carbonate rhombohedral druses are aligned with leaf veins. Trichomes are straight-sided with hemi-circular bases. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore.
(PLM, single polar)

***Lupinus sericeus*, silky lupine;**

Family: Fabaceae (Plate 96)

Macroscopic Characteristics: Leaves are palmately compound with 9 lancet-shaped leaflets that are approximately 6 cm long.

Microscopic Characteristics: Epidermal cells are polygonal-shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Phytoliths are randomly arranged in the epidermal cell matrix. Trichome edges vary from wavy to straight-sided with a circular base.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.4:1.

Lupinus sericeus
silky lupine

Plate
96

Legend

Epidermal cells are polygonal-shaped with straight-angled anticlinal walls. Cells are arranged in a flagstone pattern. Phytoliths are randomly arranged in the epidermal cell matrix. Trichomes edges vary from wavy to straight-sided with a circular base. Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. (PLM, single polar)

***Lycopodium annotinum*, clubmoss; Family:**

Lycopodiaceae (Plate 97)

Macroscopic Characteristics: Leaves are needle-like with a pointed apex; length is approximately 0.3-1 cm.

Microscopic Characteristics: Epidermal cells are rectangular with verrucate to sinuous anticlinal walls. Cells are arranged end-to-end and stacked in a brick-like pattern. Trichomes are long flat fibers.

Stomata are axially aligned with the long axis of the epidermal cells. Stomata consist of a pair of crescent shaped guard cells and a fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.2:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are relatively wide.

Lycopodium annotinum
clubmoss

Plate
97

Legend

Epidermal cells are rectangular with verrucate to sinuous anticlinal walls. Cells are arranged end-to-end and stacked in a brick-like pattern. Stomata are axially aligned with the long axis of the epidermal cells. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore.
(PLM, single polar)

***Mahonia repens*, creeping barberry;**

Family: Berberidaceae (Plate 98)

Macroscopic Characteristics: Holly-shaped leaves are glossy with 5-7 spines along the margins. The adaxial surface is glabrous however hairs randomly cover the abaxial surface.

Microscopic Characteristics: Epidermal cells are rectangular to polygonal-shaped with straight to straight-curved anticlinal walls. Trichomes are stellate-shaped with straight sides and an oval base.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a round to fusiform-shaped pore. The length to width ratio of the stoma is approximately 1:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are wide.

Mahonia repens
creeping barberry

Plate
98

Legend

Top Image: Epidermal cells include polygonal and rectangular cells arranged in a flagstone pattern. Anticlinal walls are straight-curved. Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of fat crescent-shaped guard cells surrounding a round to fusiform-shaped pore.
(PLM, single polar)

Bottom Image: Trichomes are stellate-shaped fibers with an oval base.
(PLM, single polar)

***Maianthemum racemosum*, false Solomon's seal;**

Family: Liliaceae (Plate 99)

Macroscopic Characteristics: Leaves are oblong to lanceolate with a length of 7-15 cm and a width 1.2-2.4 cm. The adaxial surface is glabrous. Tufts of hairs are on the margins and the abaxial surface.

Microscopic Characteristics: Epidermal cells are polygonal-shaped and arranged with the long axis of the cells parallel with leaf veins. Anticlinal walls are straight-curved. Phytoliths are randomly arranged in the epidermal cell matrix. Trichomes are long with straight, parallel sides.

Stomata are arranged mostly in parallel rows. Stomata consist of crescent-shaped guard cells surrounding a round to fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.5:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are wide.

Maianthemum racemosum
false Solomon's seal

Plate
99

***Maianthemum stellatum*, starflowered false Solomon's seal;**

Family: Liliaceae (Plate 100)

Macroscopic Characteristics: Leaves are narrow-elliptic to lanceolate with rounded bases and pointed apex. Leaf length is approximately 12.5-15 cm.

Microscopic Characteristics: Epidermal cells are polygonal-shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Phytoliths are randomly arranged in the epidermal cell matrix. Trichomes are hollow, hooked spears with straight to slightly textured margins.

Brachyparacytic stomata are randomly arranged in the epidermal cell matrix. Stomata are circular and consist of crescent-shaped guard cells surrounding an oval to fusiform-shaped pore. The stoma has an approximately length to width ratio of 1:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are wide.

Maianthemum stellatum
starflowered false Solomon's seal

Plate
100

***Malus pumila*, common apple;**

Family: Rosaceae (Plate 101)

Macroscopic Characteristics: Leaves are simple, oval and serrate with a length of 7.5-10 cm and a width of 4-5 cm.

Microscopic Characteristics: Epidermal cells are polygonal-shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone or jigsaw puzzle pattern. Calcium carbonate rhombohedral druses are aligned with leaf veins; calcium oxalate druses are randomly arranged. Trichomes have slightly textured margins and rounded apexes.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of crescent-shaped guard cells surrounding an oval to fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.3:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are wide.

Malus pumila
common apple

Plate
101

***Medicago sativa*, alfalfa;**

Family: Fabaceae (Plate 102)

Macroscopic Characteristics: Leaves are trifoliate and coarsely toothed. Leaf length is approximately 5-10 cm. The adaxial surface is glabrous however the abaxial surface is pubescence.

Microscopic Characteristics: Epidermal cells are polygonal-shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Phytoliths are randomly arranged in the epidermal cell matrix. Trichomes have slightly textured margins and pointed apexes.

Abundant stomata are randomly arranged in the epidermal cell matrix. Stomata consist of crescent-shaped guard cells surrounding a narrow pore. The stoma has an approximately length to width ratio of 1.8:1. The separation between the upper woody lamella and the lower woody lamella is wide at the lateral sides and the polar ends. The polar stems are wide.

Medicago sativa
alfalfa

Plate
102

***Mertensia ciliata*, tall fringed bluebells;**

Family: Boraginaceae (Plate 103)

Macroscopic Characteristics: Leaves are oval with prominent veins and pointed apices. Margins are serrated and the length is approximately 15 cm. The adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are polygonal-shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Phytoliths are randomly arranged in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The stoma has an approximately length to width ratio of 2.2:1. The separation between the upper woody lamella and the lower woody lamella is relatively wide at the lateral sides and wide the polar ends. The polar stems are wide.

Mertensia ciliata
tall fringed bluebells

Plate
103

Legend

Epidermal cells are polygonal-shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Phytoliths are randomly arranged in the epidermal cell matrix. Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The separation between the upper and lower woody lamella is relatively wide at the lateral sides and wide the polar ends. (PLM, single polar)

***Mitella diphylla*, miterwort;**

Family: Saxifragaceae (Plate 104)

Macroscopic Characteristics: Leaves are cordate, hairy and coarsely serrated with 3-5 shallow lobes.

Microscopic Characteristics: Epidermal cells are polygonal-shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Trichomes are segmented with ball-shaped segmented heads. Calcium oxalate druses are randomly arranged.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. Phytoliths are located at polar ends of guard cells. The stoma has an approximately length to width ratio of 1.8:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and wide the polar ends. The polar stems are wide.

Mitella diphylla
miterwort

Plate
104

Legend

Top Image: Epidermal cells are polygonal with straight-angled anticlinal walls. Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform pore. Phytoliths are located at polar ends of guard cells. (PLM, single polar)

Bottom Image: Trichomes are segmented with ball-shaped segmented heads. Calcium oxalate are randomly arranged. (PLM, single polar)

***Myosotis alpestris*, alpine forget-me-not;**

Family: Boraginaceae (Plate 105)

Macroscopic Characteristics: Leaves are oblong to ovate with long hairs and tufted tips. Hairs are observed on the adaxial and abaxial surfaces.

Microscopic Characteristics: Epidermal cells are polygonal-shaped with straight-curved anticlinal walls. Trichomes have slightly textured margins with a circular base. Epidermal cells surround the base in a rosette pattern. Phytoliths are randomly arranged in the epidermal cell matrix.

Stomata are randomly arranged; stomata consist of a pair of crescent-shaped guard cells with a small oval pore. The stoma has an approximately length to width ratio of 1.4:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are wide.

Myosotis alpestris
alpine forget-me-not

Plate
105

***Myriophyllum* spp., watermilfoil;**

Family: Haloragaceae (Plate 106)

Macroscopic Characteristics: Leaves are thread-like with a length of approximately 0.4-1.3 cm.

Microscopic Characteristics: Epidermal cells are square to polygonal-shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Calcium oxalate druses are randomly arranged. Trichomes are short, straight-sided spears with a slight hook.

Stomata are randomly arranged in the epidermal cell matrix. Stomata are circular to oval with a pair of crescent-shaped guard cells surrounding a thin pore. The stoma has an approximately length to width ratio of 1.3-1.7:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and the polar ends. The polar stems are narrow.

***Myriophyllum* spp.**
watermilfoil

**Plate
106**

Nymphaea advena, yellow waterlily;

Family: Nymphaeaceae (Plate 107)

Macroscopic Characteristics: Leaves are large and circular with notched centers.

Microscopic Characteristics: Epidermal cells are polygonal-shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone or jigsaw puzzle pattern.

Stomata are randomly arranged in the epidermal cell matrix. Stomata are circular-shaped and consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.1:1. The stoma is generally not bilaterally symmetric. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and the polar ends. The polar stems are narrow.

Nymphaea advena
yellow waterlily

Plate
107

***Oenothera macrocarpa*, bigfruit evening primrose;**

Family: Onagraceae (Plate 108)

Macroscopic Characteristics: Leaves are long, narrow, and lancet-shaped. Leaves are approximately 15 cm long and 2.5 cm wide. The margins are entire and both adaxial and abaxial surfaces are hairy.

Microscopic Characteristics: Epidermal cells are polygonal-shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Trichomes are straight-sided hooked fibers with a base of epidermal cells in a rosette pattern. Phytoliths are randomly arranged in the epidermal matrix.

Brachyparacytic stomata are randomly arranged in the epidermal cell matrix. Stomata are oblong and consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The stoma has an approximately length to width ratio of 2:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and the polar ends. The polar stems are wide.

Oenothera macrocarpa
black tupelo

Plate
108

***Opuntia macrorhiza*, twistspine pricklypear;**

Family: Cactaceae (Plate 109)

Macroscopic Characteristics: Thick pads are green and succulent with scattered downward spines; pad length is approximately 10-15 cm.

Microscopic Characteristics: Epidermal cells are polygonal-shaped with thick straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Scales are randomly located on the surface of the pads. Scales are abundant and non-overlapping. Stomata are randomly arranged in the epidermal cell matrix. Stomata are oblong and consist of a pair of thick hemi-circular shaped guard cells surrounding a fusiform-shaped pore. The stoma has an approximately length to width ratio of 2.3:1. The separation between the upper woody lamella and the lower woody lamella is wide at the lateral sides and the polar ends. The polar stems are wide.

Opuntia macrorhiza
twistspine pricklypear

Plate
109

Legend

Top Image: Scales are randomly located on the surface of the pads. Scales are abundant and non-overlapping.
(PLM, single polar)

Bottom Image: Stomata are randomly arranged in the epidermal cell matrix. Stomata are oblong and consist of a pair of thick hemi-circular shaped guard cells surrounding a fusiform-shaped pore.
(PLM, single polar)

***Oxytropis lambertii*, locoweed crazyweed;**

Family: Fabaceae (Plate 110)

Macroscopic Characteristics: Leaves are divided into 7-13 narrow divisions. The margins are entire and both adaxial and abaxial surfaces are hairy.

Microscopic Characteristics: Epidermal images are polygonal-shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Phyloliths are randomly arranged in the epidermal cell matrix. Trichomes have wrinkled margins and hollow interior. Bases are concentric and circular.

Stomata are randomly arranged in the epidermal cell matrix. Stomata are oblong and consist of a pair of crescent-shaped guard cells surrounding a circular pore. The stoma has an approximately length to width ratio of 2.3:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are narrow.

Oxytropis lambertii
purple locoweed

Plate
110

***Pedicularis groenlandica*, elephanthead lousewort;**

Family: Scrophulariaceae (Plate 111)

Macroscopic Characteristics: Leaves are sharply-serrate, fernlike and occur low on the stem. Leaf length is approximately 5-25 cm. The adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal images are polygonal-shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Calcium carbonate rhombohedral druses are randomly arranged in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata are oblong and consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.8:1. The separation between the upper woody lamella and the lower woody lamella is wide at the lateral sides and the polar ends. The polar stems are wide.

Pedicularis groenlandica
elephant lousewort

Plate
111

Legend

Epidermal images are polygonal shaped with straight-angled anticlinal walls. Cells are arranged in a flagstone pattern. Calcium carbonate rhombohedral druses are randomly arranged in the epidermal cell matrix. Stomata are randomly arranged in the epidermal cell matrix. Stomata are oblong and consist of a pair of crescent-shaped guard cells surrounding a fusiform pore. (PLM, single polar)

***Pedicularis racemosa*, sickletop lousewort;**

Family: Scrophulariaceae (Plate 112)

Macroscopic Characteristics: Leaves are linear and serrated; length is approximately 10 cm. The adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal images are polygonal-shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone pattern.

Stomata are randomly arranged in the epidermal cell matrix. Stomata are oblong and consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The stoma has an approximately length to width ratio of 2.2:1. The separation between the upper woody lamella and the lower woody lamella is wide at the lateral sides and the polar ends. The polar stems are wide.

Pedicularis racemosa
sickletop lousewort

Plate
112

***Penstemon procerus*, littleflower penstemon;**

Family: Scrophulariaceae (Plate 113)

Macroscopic Characteristics: Leaves are elliptic to oblanceolate with entire margins. Leaf length is approximately 10 cm and width is 1.5 cm. The adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are polygonal-shaped with straight-curved anticlinal walls. Cells are arranged in a jigsaw puzzle pattern. No trichomes or phytoliths were observed.

Stomata are randomly arranged in the epidermal cell matrix. Stomata are slightly oblong and consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.4:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are wide.

Penstemon procerus
littleflower penstemon

Plate
113

***Phacelia heterophylla*, varileaf Phacelia;**

Family: Hydrophyllaceae (Plate 114)

Macroscopic Characteristics: Leaves have divided leaf blades with 1-2 pairs per petiole; leaflets are oval to lance-shaped. Long hairs partially cover the adaxial and abaxial surfaces.

Microscopic Characteristics: Epidermal cells are polygonal-shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone or jigsaw puzzle pattern. Trichomes are slightly curved fibers with textured margins and pointed apexes.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform pore. The stoma has an approximately length to width ratio of 1.6:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and the polar ends. The polar stems are narrow.

Phacelia heterophylla
varileaf Phacelia

Plate
114

Legend

Top Image: Epidermal cells are polygonal shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Stomata are randomly arranged in the epidermal cell matrix. Stomata are slightly oblong and consist of a pair of crescent-shaped guard cells surrounding a fusiform pore. (PLM, single polar)

Bottom Image: Trichomes are slightly curved fibers with textured margins and pointed apices. (PLM, single polar)

***Populus angustifolia*, narrowleaf cottonwood**

Family: Salicaceae (Plate 115)

Macroscopic Characteristics: Leaves are lanceolate to ovate with an approximately length of 5-13 cm. Leaf margins are serrate

Microscopic Characteristics: Epidermal cells are polygonal-shaped with aspect ratio of approximately 1:1. Anticlinal walls are straight-curved. Calcium carbonate rhombohedral crystals are aligned with the leaf veins. Calcium oxalate druses are randomly scattered in the epidermal cell matrix.

Brachyparacytic stomata are randomly arranged in the epidermal cell matrix. A pair of oblong crescent-shaped guard cells surround a fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.8:1. The separation between the upper wood lamella and the lower woody lamella is wide at the lateral sides and relatively wide at the polar ends. The polar stems are narrow.

Populus angustifolia
narrowleaf poplar

Plate
115

***Populus balsamifera*, balsam poplar;**

Family: Salicaceae (Plate 116)

Macroscopic Characteristics: Leaves margins are notched with pointed apices, length is approximately 12 cm.

Microscopic Characteristics: Epidermal cells are polygonal-shaped and cells are arranged in a flagstone or jigsaw puzzle pattern. Anticlinal walls are straight-curved. Calcium oxalate druses are randomly scattered in the epidermal cell matrix. Trichomes are straight to slightly curved spears with pointed apices. Bases are reinforced.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells with fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.2:1. The separation between the upper wood lamella and the lower woody lamella is wide at the lateral sides and relatively wide at the polar ends. The polar stems are narrow.

Populus balsamifera
balsam poplar

Plate
116

Legend

Epidermal cells are polygonal-shaped. Cells are arranged in a flagstone pattern. Anticlinal walls are straight-curved. Calcium oxalate druses are randomly scattered in the epidermal cell matrix. Trichomes are straight to slightly curved spears with pointed apexes. Bases are reinforced. Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells with fusiform-shaped pore.
(PLM, single polar)

***Populus tremuloides*, quaking aspen;**

Family: Salicaceae (Plate 117)

Macroscopic Characteristics: Leaves are oval with a length of 3-7 cm. The margins are bluntly serrate; the adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are polygonal-shaped. Cells are arranged in a flagstone or jigsaw puzzle pattern. Anticlinal walls are straight to straight-curved. Calcium carbonate rhombohedral druses are aligned with the leaf veins.

Stomata are oblong and randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells with fusiform-shaped pore. The stoma has an approximately length to width ratio of 2.1:1. The separation between the upper wood lamella and the lower woody lamella is wide at the lateral sides and relatively wide at the polar ends. The polar stems are narrow.

Populus tremuloides
quaking aspen

Plate
117

***Potamogeton gramineus*, variable leaf pondweed;**

Family: Potamogetonaceae (Plate 118)

Macroscopic Characteristics: Leaves are ovate with wide serrations. The length is approximately 4-9 cm and the width of 0.5-1.2 cm. Hairs are scattered on the adaxial surface and more abundant on the abaxial surface.

Microscopic Characteristics: Epidermal cells are rectangular to polygonal-shaped. Cells near veins are rectangular and stacked brick-like. Cells in the open matrix are polygonal and arranged in flagstone pattern. Anticlinal walls are straight to straight-curved. Calcium oxalate druses are randomly arranged in the epidermal cell matrix. Trichomes are hollow with vertical striations and pointed apices.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells with fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.8:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are narrow.

Potamogeton gramineus
variable leaf pondweed

Plate
118

Legend

Epidermal cells are rectangular to polygonal-shaped. Cells near veins are rectangular and stacked brick-like. Cells in the open matrix are polygonal and arranged in flagstone pattern. Anticlinal walls are straight to straight-curved. Calcium oxalate druses are randomly arranged in the epidermal cell matrix. Trichomes are hollow with vertical striations and pointed apices. Stomata consist of a pair of crescent-shaped guard cells with fusiform-shaped pore. (PLM, single polar)

***Potentilla gracilis*, slender cinquefoil;**

Family: Rosaceae (Plate 119)

Macroscopic Characteristics: Leaves are relatively narrow with a length of 4-9 cm and a width of 0.5-1.2 cm.

Microscopic Characteristics: Epidermal cells are polygonal-shaped. Anticlinal walls are straight-curved. Trichomes consist of long parallel sides and shorter spear-like fibers. Spear-like trichomes are hollow with vertical striations and pointed apexes. Calcium oxalate druses are randomly arranged in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells with fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.4:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are narrow.

Potentilla gracilis
slender cinquefoil

Plate
119

Legend

Top Image: Epidermal cells are polygonal-shaped. Anticlinal walls are straight-curved. Trichomes have long parallel sides and shorter spear-like fibers. Stomata consist of a pair of crescent-shaped guard cells with fusi-form-shaped pore. (PLM, single polar)

Bottom Image: Calcium oxalate druses are randomly arranged in the epidermal cell matrix. Spear-like trichomes are hollow with vertical striations and pointed apices. (PLM, single polar)

***Prunus virginiana*, chokecherry;**

Family: Rosaceae (Plate 120)

Macroscopic Characteristics: Leaves are oval with a length of approximately 3-10 cm. Margins are serrate.

Microscopic Characteristics: Epidermal cells are polygonal-shaped. Cells are arranged in a jigsaw puzzle pattern. Anticlinal walls are straight to straight-curved. Calcium oxalate druses are mostly aligned with leaf veins.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an oblong to fusiform-shaped pore. Stomata are attached to epidermal cells with reinforced fibers. The stoma has an approximately length to width ratio of 1.2-1.4:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are wide.

Prunus virginiana
chokecherry

Plate
120

***Pteridium aquilinum*, western brackenfern;**

Family: Dennstaedtiaceae (Plate 121)

Macroscopic Characteristics: Fronds are triangular with a length of approximately 1 meter.

Microscopic Characteristics: Epidermal cells are irregular-shaped. Cells are arranged in a jigsaw puzzle pattern. Anticlinal walls are straight-curved to wavy. Veins are in parallel rows and vein epidermal cells are elongated with wavy margins.

Stomata are aligned with leaf veins; the long axis of the guard cells are aligned with the veins. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.7:1. The separation between the upper wood lamella and the lower woody lamella is wide at the lateral sides and the polar ends. The polar stems are wide.

Pteridium aquilinum
western brackenfield

Plate
121

***Purshia tridentata*, antelope bitterbrush;**

Family: Rosaceae (Plate 122)

Macroscopic Characteristics: Leaves are three to five lobes with a length of 0.5-2 cm. Both the adaxial and abaxial surfaces are hairy.

Microscopic Characteristics: Epidermal cells are polygonal-shaped. Cells are arranged in a flagstone pattern. Anticlinal walls are straight-curved. Cells over veins are rectangular with straight anticlinal walls. Two varieties of trichomes were observed, one is long fibers with smooth parallel walls. The second variety is short spears with pointed apexes. Calcium oxalate druses are scattered randomly in the epidermal cell matrix.

Stomata are randomly arranged and consist of a pair of crescent-shaped guard cells surrounding a narrow pore. The stoma has an approximately length to width ratio that ranges from 1:1 to 1.4:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and the polar ends. The polar stems are wide.

Purshia tridentata
antelope bitterbrush

Plate
122

***Rhamnus cathartica*, European buckthorn;**

Family: Rhamnaceae (Plate 123)

Macroscopic Characteristics: Leaves are oval to elliptic with a length of 2.5-9 cm and a width of 1-3.5 cm. Margins are coarsely serrate; the adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are polygonal-shaped and arranged in a flagstone or jigsaw puzzle pattern. Anticlinal walls are straight-curved to sinuous. No phytoliths or trichomes were observed.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an elongated fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.4:1. The separation between the upper wood lamella and the lower woody lamella is relatively wide at the lateral sides and narrow at the polar ends. The polar stems are wide.

Rhamnus cathartica
European buckthorn

Plate
123

Legend

Epidermal cells are polygonal-shaped. Anticlinal walls are straight-curved to sinuous. Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an elongated fusiform-shaped pore. The separation between the upper and lower woody lamella is relatively wide at the lateral sides and narrow at the polar ends. Polar stems are wide. (PLM, single polar)

***Rhus aromatica*, fragrant sumac;**

Family: Anacardiaceae (Plate 124)

Macroscopic Characteristics: Leaves are trifoliate and dentate to crenate. Leaf length is approximately 7.5 cm and width is approximately 2 cm. The adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are polygonal-shaped. Cells are arranged in a jigsaw puzzle pattern. Anticlinal walls are straight-curved. Trichomes are straight to slightly curved spears.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an oval to fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.9:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are relatively narrow.

Rhus aromatica
fragrant sumac

Plate
124

Legend

Top Image: Epidermal cells are polygonal-shaped. Cells are arranged in a flagstone pattern. Anticlinal walls are straight-curved. Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an oval to fusiform-shaped pore.
(PLMd, single polar)

Bottom Image: Trichomes are straight to slightly curved spears.
(PLM, single polar)

***Ribes aureum*, golden currant;**

Family: Grossulariaceae (Plate 125)

Macroscopic Characteristics: Leaves are circular with rounded lobes. Leaves are approximately 5 cm in diameter. The adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are polygonal-shaped. Cells are arranged in a flagstone or jigsaw puzzle pattern. Anticlinal walls are straight to straight-curved. Calcium oxalate druses are randomly arranged in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of elongated crescent-shaped guard cells surrounding a fusiform-shaped pore. The stoma has an approximately length to width ratio of 2:1. The separation between the upper wood lamella and the lower woody lamella is wide at the lateral sides and wide at the polar ends. The polar stems are relatively wide.

Ribes aureum
golden currant

Plate
125

***Ribes inerme*, whitestem gooseberry;**

Family: Grossulariaceae (Plate 126)

Macroscopic Characteristics: Leaves are small and deeply divided into 3-5 toothed lobes. The adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are polygonal-shaped. Cells are arranged in a flagstone or jigsaw puzzle pattern. Anticlinal walls are straight to straight-curved. Calcium oxalate druses are randomly arranged.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. Some pores are lignified. The stoma has an approximately length to width ratio of 1.1:1. The separation between the upper wood lamella and the lower woody lamella is wide at the lateral sides and wide at the polar ends. The polar stems are relatively wide.

Ribes inerme
whitestem gooseberry

Plate
126

***Ribes lacustre*, prickly currant;**

Family: Grossulariaceae (Plate 127)

Macroscopic Characteristics: Leaves are maple-like with 3-7 deep lobes. Width of the leaves is approximately 2-5 cm.

Microscopic Characteristics: Epidermal cells are polygonal-shaped. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Calcium oxalate druses are randomly arranged. Trichomes are straight to curved spears with smooth margins.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an oval to fusiform-shaped pore. Stomata are attached to epidermal cells with reinforced fibers. The stoma has an approximately length to width ratio of 1.2:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are relatively wide.

Ribes lacustre
prickly currant

Plate
127

***Ribes oxyacanthoides* spp. *cognatum*, stream currant;**

Family: Grossulariaceae (Plate 128)

Macroscopic Characteristics: Leaves are maple-like with 3-5 deeply cut lobes. Width of the leaves is approximately 3-4 cm.

Microscopic Characteristics: Epidermal cells are polygonal-shaped. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Calcium oxalate druses are randomly arranged. Trichomes are straight to curved with pointed apices.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. Some pores are lignified. The stoma has an approximately length to width ratio of 1.4:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are relatively wide.

Ribes oxycanthoides spp. *cognatum*
stream currant

Plate
128

***Ribes viscosissimum*, sticky currant;**

Family: Grossulariaceae (Plate 129)

Macroscopic Characteristics: Leaves are maple-like with 3-5 rounded, blunt-toothed lobes. The adaxial surface is glabrous whereas the abaxial veins are covered with coarse bristles.

Microscopic Characteristics: Epidermal cells are polygonal-shaped. Cells are arranged in a flagstone or jigsaw puzzle pattern. Cells under veins are rectangular to elongated polygons. Anticlinal walls are straight to straight-curved. Calcium oxalate druses are randomly arranged. Trichomes have straight sides and pointed apices.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.2:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are relatively wide.

Ribes viscosissimum
sticky currant

Plate
129

***Rosa woodsii*, Woods' rose;**

Family: Rosaceae (Plate 130)

Macroscopic Characteristics: Leaves are pinnately compound with 5-7 oval leaflets; leaflets are 3-4 cm long. The margins are coarsely serrate. The adaxial surface is glabrous whereas hairs are present on the margins and the abaxial surface.

Microscopic Characteristics Epidermal cells are polygonal-shaped. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Calcium oxalate druses are aligned with veins and randomly arranged. Trichomes are hollow and curved to wavy. Apexes are pointed, and margins are smooth. Trichomes bases are primarily attached to leaf veins.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.4:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are relatively narrow.

Rosa woodsii
Woods' rose

Plate
130

***Rubus idaeus ssp. strigosus*, grayleaf red raspberry;**

Family: Rosaceae (Plate 131)

Macroscopic Characteristics: Leaves are pinnately compound with three leaflets on petioles that are stiff bristled; leaflets are serrate with a length of 4-10 cm. The adaxial surface is glabrous whereas the abaxial surface is pubescent.

Microscopic Characteristics Epidermal cells are polygonal to rectangular shaped. Cells under veins are oblong to rectangular whereas cells in the epidermal cell matrix are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Calcium oxalate druses are randomly arranged. Trichomes include straight to curved spears and long sinuous fiber with smooth margins. Spears have bases that have rectangular to hexangle bases with a rosette of epidermal cells.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are wide.

Rubus idaeus ssp. strigosus
grayleaf red raspberry

Plate
131

***Rubus parviflorus*, thimbleberry;**

Family: Rosaceae (Plate 132)

Macroscopic Characteristics: Leaves are palmate (maple-like) with 3-7 lobes and a width of 5-20 cm. Margins are serrated; the adaxial and abaxial surfaces are pubescent.

Microscopic Characteristics Epidermal cells are polygonal to rectangular shaped. Cells under veins are oblong to rectangular whereas cells in the epidermal cell matrix are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Calcium oxalate druses are randomly arranged.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.3:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are wide.

Rubus parviflorus
thimbleberry

Plate
132

***Rudbeckia occidentalis*, western coneflower;**

Family: Asteraceae (Plate 133)

Macroscopic Characteristics: Leaves vary from ovate to rounded with a cordate base; leaf length is up to 15 cm long. Hairs are apparent on the adaxial and abaxial surfaces as well as the margins and veins.

Microscopic Characteristics Epidermal cells are polygonal to rectangular-shaped. Cells under veins are oblong to rectangular whereas cells in the epidermal cell matrix are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Trichomes are segmented fibers with smooth margins and pointed apexes.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.8:1. The separation between the upper wood lamella and the lower woody lamella is wide at the lateral sides and the polar ends. The polar stems are wide.

Rudbeckia occidentalis
western coneflower

Plate
133

Legend

Top Image: Epidermal cells are polygonal to rectangular-shaped. Anticlinal walls are straight to straight-curved. Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore.
(PLM, single polar)

Bottom Image: Trichomes are segmented fibers with smooth margins and pointed apices.
(PLM, single polar)

***Rumex stenophyllus*, narrowleaf dock;**

Family: Polygonaceae (Plate 134)

Macroscopic Characteristics: Leaves are oblong to lanceolate with a length of 15-25 cm and a width of 2-7 cm.

Microscopic Characteristics: Epidermal cells are rectangular to polygonal-shaped. Anticlinal walls are straight to straight-curved. Calcite oxalate druses are well developed and randomly arranged in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. Some stomata are deformed. The stoma has an approximately length to width ratio of 1.4:1. The separation between the upper wood lamella and the lower woody lamella is wide at the lateral sides and the polar ends. The polar stems are wide.

Rumex stenophyllus
narrowleaf dock

Plate
134

***Salix fragilis*, crack willow;**

Family: Salicaceae (Plate 135)

Macroscopic Characteristics: Leaves are lanceolate with finely serrated margins; length is approximately 9-15 cm and the width is 1.5-3 cm. The adaxial surface is glabrous whereas occasional hairs are observed on the abaxial veins.

Microscopic Characteristics: Epidermal cells are rectangular to polygonal shaped. Anticlinal walls are straight to straight-curved. Calcite carbonate rhombohedral druses are aligned with veins. Calcite oxalate druses are randomly arranged in the epidermal cell matrix. Trichomes have straight sides with hollow interiors and pointed apices.

Brachyparacytic stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform pore. The stoma has an approximately length to width ratio of 1.2:1. The separation between the upper wood lamella and the lower woody lamella is wide at the lateral sides and the polar ends. The polar stems are wide.

Salix fragilis
crack willow

Plate
135

***Sambucus racemosa*, red elderberry;**

Family: Caprifoliaceae (Plate 136)

Macroscopic Characteristics: Leaves are pinnately compound with 5-7 leaflets; leaflet length is 15-23 cm. Hairs are lightly scattered on the adaxial surface and margins whereas they are heavier on the abaxial surface.

Microscopic Characteristics: Epidermal cells are irregular shaped. Anticlinal walls are straight to straight-curved. Calcite oxalate druses are randomly arranged in the epidermal cell matrix. Trichomes are straight to curved fibers with pointed apexes and smooth margins.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.4:1. The separation between the upper wood lamella and the lower woody lamella is relatively wide at the lateral sides and the polar ends. The polar stems are wide.

Sambucus racemosa
red elderberry

Plate
136

***Senecio plattensis*, arrowleaf ragwort;**

Family: Asteraceae (Plate 137)

Macroscopic Characteristics: Leaves are serrate, elliptic to lanceolate with a length of approximately 6.5 cm and width of 2.5 cm. The adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are polygonal to irregular-shaped cells. Anticlinal walls are straight to straight-curved. Trichomes are flat with smooth margins and pointed apexes.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an oval to fusiform-shaped pore. At times, guard cells are deformed. The stoma has an approximately length to width ratio of 1.3:1. The separation between the upper wood lamella and the lower woody lamella is relatively narrow at the lateral sides and relatively wide the polar ends. The polar stems are wide.

Senecio plattensis
arrowleaf ragwort

Plate
137

***Shepherdia canadensis*, russet buffaloberry;**

Family: Elaeagnaceae (Plate 138)

Macroscopic Characteristics: Leaves are oval to ovate with entire margins; length is approximately 1-6 cm and width is 1.3 cm. The adaxial and abaxial surfaces are pubescent.

Microscopic Characteristics: Epidermal cells are polygonal to irregular-shaped cells. Anticlinal walls are straight to straight-curved. Trichomes have smooth margins and pointed apices. Trichome bases are round to oval with a rosette of epidermal cells surrounding the base. Calcium oxalate druses are randomly arranged.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform pore. The stoma has an approximately length to width ratio of 1.6:1. The separation between the upper wood lamella and the lower woody lamella is relatively narrow at the lateral sides and wide the polar ends. The polar stems are wide.

Shepherdia canadensis
russet buffaloberry

Plate
138

***Solidago canadensis*, Canada goldenrod;**

Family: Asteraceae (Plate 139)

Macroscopic Characteristics: Leaves are lance-shaped, serrated with tapers at both ends; length is approximately 15 cm and width of 2.5 cm.

Microscopic Characteristics: Epidermal cells are rectangular to polygonal shaped cells. Anticlinal walls are straight to straight-curved. Cells under veins are rectangular whereas other cells were polygonal. Trichomes are segmented and wide with blunt apexes.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform pore. Some guard cells are deformed. The stoma has an approximately length to width ratio of 1.4:1. The separation between the upper wood lamella and the lower woody lamella is wide at the lateral sides and the polar ends. The polar stems are wide.

Solidago canadensis
Canada goldenrod

Plate
139

***Sonchus arvensis*, field sowthistle;**

Family: Asteraceae (Plate 140)

Macroscopic Characteristics: Leaves are alternate, lancet-shaped with an approximate length of 5-40 cm. The adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are rectangular to polygonal-shaped cells. Anticlinal walls are straight to straight-curved. Cells under veins are rectangular whereas other cells are rectangular to polygonal.

Abundant stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an oval to fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.4:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and relatively wide at the polar ends. The polar stems are wide.

Sonchus arvensis
field sowthistle

Plate
140

Legend

Epidermal cells are rectangular to polygonal-shaped cells. Anticlinal walls are straight to straight-curved. Cells under veins are rectangular whereas other cells are rectangular to polygonal. Abundant stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an oval to fusiform-shaped pore.
(PLM, single polar)

***Spiraea betulifolia*, white spirea;**

Family: Rosaceae (Plate 141)

Macroscopic Characteristics: Leaves have round to ovate with serrate margins. The length is approximately 5 cm. The lower half of the leaf margin is entire; the upper half is coarsely serrate. The adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are irregular-shaped cells. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Calcium oxalate druses are randomly arranged.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a narrow pore. The stoma has an approximately length to width ratio of 1.5:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and relatively wide at the polar ends. The polar stems are wide.

Spiraea betulifolia
white spirea

Plate
141

***Stellaria media*, starwort;**

Family: Caryophyllaceae (Plate 142)

Macroscopic Characteristics: Leaves have oval to ovate with entire margins; length is approximately 2 cm and 1.2 cm wide. The adaxial and abaxial surfaces are glabrous; the margins are entire.

Microscopic Characteristics: Epidermal cells are polygonal to irregular shaped cells. Cells are arranged in a flagstone or jigsaw puzzle pattern. Anticlinal walls are straight to straight-curved. Calcium oxalate druses are randomly arranged.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an oval to fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.3:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and relatively wide at the polar ends. The polar stems are wide.

Stellaria media
starwort

Plate
142

***Symphoricarpos albus*, common snowberry;**

Family: Caprifoliaceae (Plate 143)

Macroscopic Characteristics: Leaves are elliptic to oval with smooth margins; approximate length is 2-5 cm. Hairs are on the margin and the adaxial and abaxial surfaces.

Microscopic Characteristics: Epidermal cells are rectangular to polygonal-shaped cells. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Calcium oxalate druses are mostly aligned with the veins. Trichomes are hooked shaped fibers with pointed apexes.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an oval to fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.1:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are wide.

Symphoricarpos albus
common snowberry

Plate
143

***Symphoricarpos occidentalis*, western snowberry;**

Family: Caprifoliaceae (Plate 144)

Macroscopic Characteristics: Leaves are leathery, elliptic to oval with rounded to blunt apexes. The approximate length is 2.5-8 cm and a width of 2-5 cm. The adaxial surface is glabrous whereas the hairs cover the abaxial veins.

Microscopic Characteristics: Epidermal cells are rectangular to polygonal shaped cells. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Calcium oxalate druses randomly arranged in the epidermal cell matrix. Trichomes are hooked shaped fibers with pointed apexes.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an oval to fusiform-shaped pore. The polar ends are wide. The stoma has an approximately length to width ratio of 1.1:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are relatively narrow.

Symphoricarpos occidentalis
western snowberry

Plate
144

***Taraxacum officinale*, common dandelion;**

Family: Asteraceae (Plate 145)

Macroscopic Characteristics: Leaves are oblanceolate to obovate with shallow lobed margins. Leaf length is 5-45 cm and width is 1-10 cm; margins are serrate. The adaxial surface is glabrous whereas the abaxial veins are hairy.

Microscopic Characteristics: Epidermal cells are rectangular to polygonal shaped cells. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Trichomes are segmented, flat and have multiple bends.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.4:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and the polar ends. The polar stems are relatively narrow.

Taraxacum officinale
common dandelion

Plate
145

***Tragopogon dubius*, yellow salsify;**

Family: Asteraceae (Plate 146)

Macroscopic Characteristics: Leaves are narrow, waxy and tapered with a length of 1-30 cm. The adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are rectangular to polygonal-shaped. Many cells are also slightly rounded. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The long axis of the guard cells is aligned with the leaf veins. The stoma has an approximately length to width ratio of 1.2:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and the polar ends. The polar stems are relatively narrow.

Tragopogon dubius
yellow salsify

Plate
146

***Trifolium pratense*, red clover;**

Family: Fabaceae (Plate 147)

Macroscopic Characteristics: Leaves are trifoliate; leaflets are 1.5-3 cm in length and 0.8-1.5 cm in width.

Microscopic Characteristics: Epidermal cells are irregular to polygonal-shaped. Anticlinal walls of are straight to straight-curved. Phytoliths are distinctive polygonal-shaped anisotropic crystals that are both aligned with leaf veins and randomly arranged. Trichomes are straight, hollow fibers with pointed apices and vertical striations. Bases are circular to hexangle.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.4:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and the polar ends. The polar stems are relatively narrow.

Trifolium pratense
red clover

Plate
147

Legend

Top Image: Epidermal cells are irregular to polygonal-shaped. Anticlinal walls of are straight to straight-curved. Phytoliths are distinctive polygonal-shaped anisotropic crystals that are aligned with leaf veins and randomly arranged.
(PLM, single polar)

Bottom Image: Trichomes are straight, hollow fibers with pointed apices. Bases are circular to hexangle.
(PLM, single polar)

***Trifolium repens*, white clover;**

Family: Fabaceae (Plate 148)

Macroscopic Characteristics: Leaves are trifoliate; leaflets are elliptic to ovate with serrate margins; length is approximately 2.5 cm.

Microscopic Characteristics: Epidermal cells are polygonal to rectangular-shaped. Anticlinal walls of are straight to straight-curved. Phytoliths are distinctive polygonal shaped anisotropic crystals that are aligned with leaf veins and randomly arranged. Trichomes are straight, flat fibers with pointed apexes.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.2:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and the polar ends. The polar stems are relatively narrow.

Trifolium repens
white clover

Plate
148

***Typha latifolia*, broadleaf cattail;**

Family: Typhaceae (Plate 149)

Macroscopic Characteristics: Leaves are long and narrow with a length of 75-100 cm.

Microscopic Characteristics: Epidermal cells are rectangular with rounded corners. Cells are aligned in near parallel rows. Cell length to width ratios range from 1:1 to 3:1 with straight anticlinal walls.

Brachyparacytic stomata are aligned in parallel rows and the long axis of the stoma pore is aligned with the leaf vein. Stomata consist of a pair of crescent-shaped guard cells surrounding a narrow pore. A pair of subsidiary cells surround the guard cells. The stoma has an approximately length to width ratio of 2.1:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and the polar ends. The polar stems are relatively wide.

Typha latifolia
boardleaf cattail

Plate
149

Legend

Epidermal cells are rectangular with rounded corners. Cells are aligned in near parallel rows. Stomata are aligned in parallel rows and the long axis of the stoma pore is aligned with the leaf veins. Stomata consist of a pair of crescent-shaped guard cells surrounding a narrow pore. A pair of subsidiary cells surround the guard cells.

(PLM, single polar)

***Vaccinium angustifolium*, lowbush blueberry;**

Family: Ericaceae (Plate 150)

Macroscopic Characteristics: Leaves are elliptic with finely serrated margins; length is approximately 2-4 cm and width is 0.6-2 cm.

Microscopic Characteristics: Epidermal cells are irregular-shaped cells. Cells are arranged in a jigsaw puzzle pattern. Anticlinal walls are straight to straight-curved. Calcium oxalate druses are randomly arranged in the epidermal cell matrix.

Brachyparacytic stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an oval to fusiform-shaped pore. The stoma has an approximately length to width ratio of 2.3:1. The separation between the upper wood lamella and the lower woody lamella is wide at the lateral sides and the polar ends. The polar stems are relatively wide.

Vaccinium angustifolium
lowbush blueberry

Plate
150

***Vaccinium membranaceum*, thinleaf huckleberry;**

Family: Ericaceae (Plate 151)

Macroscopic Characteristics: Leaves are membranous, serrated and oval with a length of 5 cm.

Microscopic Characteristics: Epidermal cells are rectangular to polygonal-shaped cells. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Calcium carbonates and calcium oxalate druses are randomly arranged in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an oval to fusiform-shaped pore. The stoma has an approximately length to width ratio of 2:1. The separation between the upper wood lamella and the lower woody lamella is wide at the lateral sides and the polar ends. The polar stems are wide.

Vaccinium membranaceum
thinleaf huckleberry

Plate
151

***Viola nuttallii*, Nuttall's violet;**

Family: Violaceae (Plate 152)

Macroscopic Characteristics: Leaves are ovate to lancet-shaped with a length of 6 cm and width of 2 cm.

Microscopic Characteristics: Epidermal cells are rectangular to polygonal-shaped cells. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Trichomes are flat, fat, short fibers with pointed apices. Globular calcium oxalate druses are randomly arranged in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an oval to fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.6:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and the polar ends. The polar stems are relatively wide.

Viola nuttallii
Nuttall's violet

Plate
152

Legend

Epidermal cells are rectangular to polygonal-shaped cells. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Trichomes are flat short fibers with pointed apices. Globular calcium oxalate druses are randomly arranged in the epidermal cell matrix.
(PLM, single polar)

***Wyethia amplexicaulis*, mule-ears;**

Family: Asteraceae (Plate 153)

Macroscopic Characteristics: Leaves are large lanceolate leaves with a length of 20-40 cm and width of 5-15 cm.

Microscopic Characteristics: Epidermal cells are irregular to polygonal-shaped cells. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Trichomes are flat fibers with irregular margins.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The stoma has an approximately length to width ratio of 2.1:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and the polar ends. The polar stems are relatively wide.

Wyethia amplexicaulis
mule-ears

Plate
153

***Xanthium strumarium*, rough cocklebur;**

Family: Asteraceae (Plate 154)

Macroscopic Characteristics: Leaves are cordate to ovate-cordate with lobed and serrated margins. Leaf length is approximately 20 cm and width is 15 cm wide.

Microscopic Characteristics: Epidermal cells are irregular to polygonal-shaped cells. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Trichomes are distinctive. Trichomes consist of two oval cells that are stacked. A short, triangle shaped cell with a pointed apex is atop the oval cells.

Stomata are randomly arranged and consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The outer margin of guard cells has pointed projections. The stoma has an approximately length to width ratio of 2:1.

Xanthium strumarium
rough cocklebur

Plate
154

***Zizia aptera*, meadow zizia;**

Family: Apiaceae (Plate 155)

Macroscopic Characteristics: Leaves are cordate to broadly ovate with rounded to blunt apices Leaf length is approximately 10 cm and width is 7.5 cm wide.

Microscopic Characteristics: Epidermal cells are polygonal-shaped cells. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Trichomes are short, straight, triangle-shaped fibers with serrated margins and pointed apices. Trichome bases are circular to oval.

Stomata are randomly arranged and consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. Polar ends project beyond the oval outline of the stomata complex. The stoma has an approximately length to width ratio of 2.4:1. The separation between the upper wood lamella and the lower woody lamella is wide at the lateral sides and relatively wide at the polar ends. The polar stems are relatively wide.

Zizia aptera
meadow zizia

Plate
155

4 Microhistology of some preferred North American woody plants

4.1 Introduction

4.1.1 Background

It is commonly accepted that the three basic needs for survival are food (and water), shelter and clothing (Denton 1990). Although this list focuses on human needs, it applies equally well to animals. Unlike humans, animal shelter is a function of their habitat and clothing is a function of their fur or body covering. Like humans, food is an essential need that must be acquired for survival. Animals are divided into three general groups, carnivores that are primarily meat eaters, omnivores that have a mixed diet of meat and plants and herbivores that are nearly exclusive vegetarian. Various techniques are employed to evaluate plant-based diets. These include direct observation, field measurements of forage consumed, esophageal or abdominal fistulas, postmortem stomach examination and fecal pellet examinations (Anthony and Smith 1974, Bjugstad et al. 1970, Fitzgerald and Waddington 1979, Holechek et al. 1982b, Holechek et al. 1982c, Rice 1970, Theurer 1970, Van Dyne and Torrell 1964). Each of these techniques have advantages and disadvantages.

The microscopic examination of fecal pellets is termed microhistology (Henderson, Phillips, and Springer 2014). The advantages of fecal pellet analysis is ease of sample collection, ability to sample endangered species without direct contact, sample

availability, and ability to sample multiple animals in the same habitat (Holechek et al. 1982b). Disadvantages include differential digestion and low accuracy because of sample preparation techniques or analyst error (Alipayo et al. 1992, Holechek and Vavra 1981, Johnson et al. 1983b, Holechek and Gross 1982b, Holechek and Vavra 1981, Vavra and Holechek 1980).

Differential digestion is less of an issue with woody plants (Samuel and Howard 1983). The lignin and hemicellulose epidermal layer of leaves are retained through digestion. Differential digestion is a major issue for plants like graminoids, mosses and algae. Graminoids have a higher percentage and mosses have less of lignin and hemicellulose in the epidermal layers (Samuel and Howard 1983). Algae have no lignin or hemicellulose in the cells walls and typically leave no microscopic trace in fecal pellets.

Sparks and Malechek (1968) published a standardized methodology for the preparation of microhistological materials that helps reduce the low accuracy. Sample calculations, analytical procedures and training needed for microhistological analysis have been addressed in a series of papers (Holechek and Gross 1982a, Holechek 1982, Holechek and Vavra 1981, and Holechek et al. 1982b).

For any fecal study, a reference collection of available forage must be obtained and analyzed. This entails time in the field and analytical expense for each project. If a central database of reference material was available, the analytical expense would be lessened for multiple projects. Few identification guides are published in the literature; the references that exist include Argentinian grasses (Lindstrom et al. 1998), grazer's atlas (Howard and Samuel 1979), Florida aquatic plants (Hurst and Beck 1988) and moose microhistology (Henderson, Grainger and Springer 2013). Each of these references are region specific. Carriere (2002) documented the first non-habitat specific guide for microhistology (Arctic vascular plants), however her focus for identification was limited to leaf trichomes and inclusions.

This guide details 232 common North America woody plants; these plants comprise 38 families and 94 genera. This document includes a dichotomous key for the identification of all fecal plant material. The purpose of this manuscript is to serve as a springboard for the development of a comprehensive microhistological database of North American plants, including not only woody plants but also forbs, graminoids, mosses, etc. Two previous studies used the same classification criteria (dichotomous key) as this

guide; these include two studies in the Greater Yellowstone Ecosystem, one of elk forage (Chapter 3 of this document) and the second of moose browse (Henderson, Grainger and Phillips 2014). When combined, these three studies make a significant contribution to the comprehensive microhistological database.

4.1.2 Nomenclature

Scientific plant names are relatively uniform however occasionally names are adjusted as research shows different genetic or other derivations. Many times, plants are known by many different common names. For this document, we used the USDA PLANTS database: A synonymized checklist of the vascular flora of the United States, Canada, and Greenland for scientific and common names (USDA, NRCS 2018). Stomata nomenclature is in accordance with Prabhakar (2004) and phytolith inclusions are in accordance with the ICPN Working Group (Madella, Alexandre and Ball 2005). Cellular structures and other epidermal features are in accordance with Metcalfe and Chalk (1979).

4.1.3 Microscopic examination

Microscopic examination of epidermal surfaces and surface features was in accordance with Henderson and Vucetich (2016) (chapter 5) and Henderson, Phillips, and Springer (2014). Diagnostic features include morphology and structure of epidermal cells, surface growths (trichomes and scales), inclusions (phytoliths, calcium carbonate, calcium oxalate, and starch), stomata and surrounding subsidiary cells, etc. Many diagnostic features are family and/or genera specific; the collection consist of 38 families and 94 genera. Families and genera are summarized in table 3.1. A total of 232 woody plants were collected, 50 of these plants were also documented in a previous study (Chapter 3). However, for continuity, those plants are included in this study. An additional 24 woody plants were collected and presented in a previous volume by the author and are not reproduced in this study (Henderson, Grainger and Phillips 2013).

4.2 Materials and Methods

4.2.1 Plant collection

Plant collection was conducted between May and October 2017. The field collection area extended from Michigan to Idaho and as far south as Iowa and Nebraska. Field collected clippings of each plant were obtained with pruning shears and stored in a one-gallon plastic bag with approximately 100 ml of water to prevent desiccation. After field collection, plants were pressed a minimum of a fortnight in a Bioquip 30x46 cm standard plant press. Each clipping was then pressed between sheets of newsprint and stored in a 12.5x23 cm envelope; site collection information was recorded for each clipping. Each plant clipping was viewed under a stereoscope and surface characteristics recorded.

Plants not represented in this geographic area were obtained from the University of Nebraska and Michigan Technological University herbarium collections. One or two leaves of each representative plant were obtained and each was stored in a 12.5X23cm envelope. Each plant clipping and herbarium specimens were viewed under a stereoscope and surface characteristics recorded.

4.2.2 Epidermal peel

Plant clippings and herbarium specimens were viewed under a Bausch & Lomb 1X stereoscope coupled with a pair of 10X W.F. oculars. A Bausch & Lomb 35-watt light source was used for illumination. Two additional lenses, 0.5 and 2X, were attached to the stereoscope objective yielding an effective magnification of 0.5-20X. Surface features such as hairs, texture, and morphology were recorded. Many times, abundances of stomata and trichomes differ on the adaxial (top) and abaxial (bottom) surfaces; however once digested, it is not possible to differentiate adaxial from abaxial (Steward, 1965). A leaf was boiled for 10 minutes in a distilled water bath to soften the epidermal surface (Carriere, 2002). Epidermal sections were peeled using fine-tipped forceps and a #10 scalpel blade. Epidermal sections were soaked in household bleach (3-8% sodium

hypochlorite) for five minutes followed by a five-minute soak in distilled water. The outer leaf surface of the epidermal peel was mounted toward the coverslip on microscope slides (Holechek 1982). Epidermal peels and tape samples were mounted using Hoyer's mounting medium (Hempstead Halide) to standard 25X75X1 mm microscope slides with 18X18 mm cover slips.

4.2.3 Equipment

An Olympus BH-2 BHS trinocular microscope coupled with a BH2-KP polarizing attachment was employed for microscopic examinations. An Omax 18-megapixel USB3.0 microscope camera was used for photomicrographs and Toup View software by ToupTek Photonics was used for image capture. The Omax camera was calibrated using a 0.1mm stage micrometer slide. The Omax camera was mated to a MSI 6QF Apache Pro i7 quad-core PC computer with NVIDIA GTX970M video card. Adobe Lightroom CC and Adobe Photoshop CC software were used for processing of digital images. Images were cropped and converted to JPEG format and no digital enhancement or alterations were performed. To preserve image detail, images were saved uncompressed at maximum resolution. Digital images were stored on a 1 terabyte hard drive and backed-up on a second hard drive. Measurements of epidermal or stomatal cells are based on limited measurements of cells within a single sample. Morphology of stomata are based on a single sample.

4.3 Results

Each of the 232 North America woody plants includes a description of macroscopic and microscopic characteristics. Plants are divided into two groups, gymnosperms and angiosperms or dicots. Laboratory specimens have the advantage of being larger and more intact than masticated specimens. Masticated specimens are typically smaller however epidermal structures, stomatal morphology and structure, and inclusions such as phytoliths and surface growths are typically evident (Carriere 1999, Larter 1999).

Nevertheless, sufficient characteristics are typically present to permit identification; at times to the genus level and other times to species.

Similar plant characteristics are combined into a series of eight groups identified as Groups A-H. The groups can be used like a dichotomous key to identify similar plants and occasionally individual species. The primary characteristic that should be used for any microhistological identification scheme is availability. A field biologist should always provide a listing of forage available for the study area. Any plant not available for consumption should be excluded from the identification key. The dichotomous key separates plant characteristic to general groups; at times ten or more plants share a common identification criterion however few of these plants will be available for consumption in a specific habit so can be eliminated from consideration as a dietary component. If a few plants are identified as available that share common characteristics, refer to the plant photographic for other intricate details. On occasion, it will not be possible to identify a plant fragment beyond the genera level.

Identification key for North American woody plants (including non-natives)

- Ia **Group A** -Graminoids)-skipped for this study
- Ib Stomata guard cells not bilobal (go to II)
- IIa Epidermal cells square, rectangular, or parallelogram shape; epidermal cells stacked brick-like, stomata in rows, stomata tetracytic (**Group B**-Gymnosperms)
- IIb Epidermal cells square, rectangular, parallelogram, polygonal or irregular shape; stomata in rows or random; stomata not tetracytic; druses present or absent (go to III)
- IIIa Stomata in rows; epidermal cells square, rectangular, parallelogram, polygonal or irregular shape; stomata not tetracytic; druses present or absent (**Group C**-Monocots other than graminoids)

- IIIb Stomata randomly arranged; epidermal cells square, rectangular, parallelogram, polygonal or irregular shape; stomata not tetracytic; druses present or absent (go to IV)
- IVa Stomata brachyparacytic, epidermal cells square, rectangular, parallelogram or polygonal shaped, anticlinal walls straight, straight-curved or sinuous, stomata randomly arranged; druses present or absent (**Group D**)
- IVb Stomata not brachyparacytic or tetracytic (go to V)
- Va Trichomes double-ended, multi-branched or stellate; stomata anomocytic and randomly arranged; epidermal cells square, rectangular, parallelogram, polygonal or irregular shaped, anticlinal walls straight, straight-curved, sinuous or wavy; druses present or absent (**Group E**)
- Vb Trichomes segmented; stomata anomocytic and randomly arranged; epidermal cells square, rectangular, parallelogram, polygonal or irregular shaped, anticlinal walls straight, straight-curved, sinuous or wavy; druses present or absent (**Group F**)
- Vc Trichomes absent or unbranched; stomata anomocytic and randomly arranged; epidermal cells square, rectangular, parallelogram, polygonal or irregular shaped, anticlinal walls straight, straight-curved, sinuous or wavy; druses present or absent (go to VI)
- VIa Trichomes unbranched; stomata anomocytic and randomly arranged; epidermal cells square, rectangular, parallelogram, polygonal or irregular shaped, anticlinal walls straight, straight-curved, sinuous or wavy; druses present or absent (**Group G**)
- VIb Trichomes absent; stomata anomocytic and randomly arranged; epidermal cells square, rectangular, parallelogram, polygonal or irregular shaped, anticlinal walls straight, straight-curved, sinuous or wavy; druses present or absent (**Group H**)

Group A-Graminoids: Stomata guard cells bilobal, epidermal cells square, rectangular or parallelogram shape; epidermal cells stacked brick-like; stomata in parallel rows.

This group is empty for this selection criteria, although there are woody plants that are graminoids in North America. This section is reserved for future expansion of this guide.

Group B-Gymnosperms: Epidermal cells square, rectangular, or parallelogram shape;
epidermal cells stacked brick-like, stomata in parallel rows and tetracytic

a. Stoma rectangular	
b. LWL-UWL wide, polar end wide,
polar stem narrow	<i>Abies balsamea, A. concolor,</i>
<i>A. fraseri, A. grandis,</i>
<i>A. lasiocarpa,</i>
<i>Tsuga canadensis, T.</i>
<i>mertensiana</i>
b. LWL-UWL narrow, polar end narrow,
polar stem narrow	<i>Juniperus communis,</i>
<i>J. scopulorum</i>
b. LWL-UWL narrow, polar end wide,
polar stem narrow	<i>Juniperus virginiana</i>
b. LWL-UWL wide, polar end wide,
polar stem wide	<i>Pinus albicaulis, P.</i>
<i>banksiana, P. contorta, P.</i>
<i>echinata, P. edulis, P.</i>
<i>elliottii, P. flexilis, P.</i>
<i>jeffreyi, P. lambertiana, P.</i>
<i>monticola, P. palustris, P.</i>
<i>ponderosa, P. resinosa, P.</i>
<i>rigida, P. sabiniana, P.</i>
<i>strobus, P. sylvestris, P.</i>
<i>taeda, P. virginiana</i>
a. Stoma rounded	
b. LWL-UWL narrow, polar area wide,
polar stem wide	<i>Picea abies, P. engelmannii,</i>
<i>P. glauca, P. mariana, P.</i>

	<i>pungens, P. sitchensis</i>
a. Stoma circular	
b. LWL-UWL wide, polar area wide, polar stem wide	
1. silica present	<i>Larix laricina</i>
2. silica absent	<i>Pseudotsuga menziesii</i> var. <i>glauca, Larix occidentalis</i>
b. LWL-UWL narrow, polar area wide, polar stem wide	<i>Callitropsis nootkatensis,</i> <i>Calocedrus decurrens, Taxus</i> <i>brevifolia, T. canadensis</i>
b. LWL-UWL narrow, polar area narrow, polar stem narrow	<i>Chamaecyparis thyoides,</i> <i>Thuja occidentalis, T. plicata</i>

Group C-Non-graminoid Monocots: Stomata in parallel rows and not tetracytic;
epidermal cells stacked or aligned.

This group is empty for this selection criteria, no monocot woody plants were
collected as part of this study.

Group D: Stomata brachyparacytic, stomata and epidermal cells randomly arranged.

a. trichomes unbranched	
b. calcium oxalate inclusions	
c. silica inclusions	<i>Magnolia acuminate, Smilax</i> <i>tamnoides</i>
c. silica absent	<i>Lonicera canadensis,</i> <i>Populus balsamifera, Salix</i> <i>fragilis</i>

- b. calcium oxalate absent, silica absent *Nyssa aquatica*
- a. trichomes absent
 - b. calcium oxalate inclusions
 - c. calcium carbonate inclusions *Nyssa sylvatica, Populus angustifolia*
 - c. calcium carbonate absent *Liquidambar styraciflua, Magnolia stellata*
 - b. calcium oxalate absent
 - c. calcium carbonate inclusions *Populus tremuloides*
 - c. calcium carbonate absent *Magnolia grandiflora, M. kobus, M. loebneri, Vaccinium angustifolium*

Group E: Trichomes double-ended, multi-branched or stellate, stomata and epidermal cells randomly arranged.

- a. trichomes double-ended
 - b. calcium oxalate present
 - c. starch present *Cornus sericea*
 - c. starch absent *Cornus canadensis*
 - b. calcium oxalate absent *Cornus florida*
- a. trichomes stellate
 - b. segmented trichomes present (also) *Juglans cinerea, J. nigra*
 - b. segmented trichomes absent *Elaeagnus commutata, Magnolia virginiana, Mahonia repens, Quercus bicolor, Q. stellata, Q. velutina, Q. virginiana*
- a. trichomes multiple joined on single base
 - b. calcium oxalate present *Physocarpus opulifolius,*

b. calcium oxalate absent

Quercus macrocarpa
Quercus gambelii, *Cornus*
nuttallii

Group F: Trichomes segmented, stomata and epidermal cells randomly arranged.

a. calcium oxalate raphides present

Vitis riparia

a. calcium oxalate globular druses present

Shepherdia canadensis,
Symphoricarpos occidentalis

a. calcium oxalate absent

b. silica present

Artemisia ludoviciana, *A.*
tridentata

b. silica absent

Rubus parviflorus

Group G: Trichomes unbranched, stomata and epidermal cells randomly arranged.

a. calcium oxalate present

b. calcium carbonate present

c. epidermal morphology irregular

Amelanchier alnifolia, *Carya*
lacintosa, *Celtis occidentalis*,
Cornus alternifolia, *Fagus*
grandifolia, *Toxicodendron*
radicans, *Ulmus thomasii*

c. epidermal morphology polygonal

d. silica present

Malus pumila, *Menziesia*
ferruginea,

d. silica absent

Acer negundo, *Cercocarpus*
ledifolius, *Populus alba*,
Prunus domestica, *P.*
serotina, *Ulmus rubra*

c. epidermal morphology square, rectangular or parallelogram	<i>Celtis laevigata</i> , <i>C. laevigata</i> var. <i>reticulata</i> , <i>Cercis</i> <i>canadensis</i> , <i>Cercocarpus</i> <i>montanus</i> , <i>Vaccinium</i> <i>membranaceum</i> , <i>Viburnum</i> <i>opulus</i>
b. calcium carbonate absent	
c. trichomes textured or striated	<i>Ilex montana</i> , <i>Lonicera</i> <i>involucrate</i> , <i>Myrica cerifera</i> , <i>Potamogeton gramineus</i> , <i>Ulmus glabra</i>
c. trichomes attached to veins	<i>Ribes viscosissimum</i>
c. trichomes smooth	
d. silica present	<i>Alnus rubra</i> , <i>Morus alba</i> , <i>Robinia pseudoacacia</i>
d. silica absent	
e. epidermal cells irregular	<i>Acer spicatum</i> , <i>Aesculus</i> <i>hippocastanum</i> , <i>Alnus</i> <i>rhombifolia</i> , <i>Carya ovata</i> , <i>Carya tomentosa</i> , <i>Cornus</i> <i>drummondii</i> , <i>Corylus</i> <i>cornuta</i> , <i>Pteridium</i> <i>squilinum</i> , <i>Sambucus</i> <i>racemosa</i>
e. epidermal cells polygonal	<i>Acer saccharinum</i> , <i>Alnus</i> <i>incana rugosa</i> , <i>Betula</i> <i>occidentalis</i> , <i>B. papyrifera</i> , <i>Ceanothus velutinus</i> , <i>Ilex</i>

	<i>opaca</i> , <i>Myriophyllum</i> spp., <i>Plantanus racemosa</i> , <i>Prunus</i> <i>persica</i> , <i>Purshia tridentata</i> , <i>Rhus copallinum</i> , <i>Ribes</i> <i>inermis</i> , <i>R. lacustre</i> , <i>R.</i> <i>oxyacanthoides</i> spp. <i>cognatum</i> , <i>Rosa woodsii</i> , <i>Rubus fruticosus</i> , <i>Rubus</i> <i>idaeus</i> ssp. <i>strigosus</i> , <i>Symphoricarpos albus</i> , <i>Carya glabra</i> , <i>C.</i> <i>illinoensis</i> , <i>Ceanothus</i> <i>americanus</i> , <i>Kalmia latifolia</i>
e. epidermal cells parallelogram	
a. calcium oxalate absent	
b. calcium carbonate present	
c. silica present	<i>Lonicera utahensis</i>
c. silica absent	
d. trichomes textured or striated	<i>Ulmus americana</i>
d. trichomes smooth	
e. epidermal cells irregular	<i>Acer grandidentatum</i> , <i>Sorbus</i> <i>torminalis</i>
e. epidermal cells polygonal	<i>Acer nigrum</i> , <i>Amorpha</i> <i>fruticosa</i> , <i>Ulmus alata</i>
e. epidermal cells square, rectangular parallelogram	<i>Tilia americana</i>
b. calcium carbonate absent	
c. silica present	
d. epidermal cells polygonal	<i>Arctostaphylos manzanita</i> , <i>Artemisia cana</i> , <i>A. frigida</i> , <i>A.</i> <i>triparita</i> , <i>Carpinus</i>

	<i>caroliniana</i> , <i>Cirsium vulgare</i> , <i>Fraxinus pennsylvanica</i> , <i>Lonicera morrowii</i>
d. epidermal cells square, rectangular parallelogram	<i>Comptonia peregrina</i>
c. silica absent	
d. trichomes textured or striated	<i>Ilex verticillata</i>
d. trichomes smooth	<i>Dasiphora fruticose</i> , <i>Ostraya</i> <i>virginiana</i> , <i>Symphoricarpos</i> <i>orbiculatus</i>

Group H: Trichomes absent, stomata and epidermal cells randomly arranged.

a. calcium oxalate present	
b. calcium carbonate present, silica absent	
d. epidermal morphology irregular	<i>Acer rubrum</i> , <i>Amelanchier</i> <i>arborea</i> , <i>A. stolonifera</i> , <i>Fagus sylvatica</i>
d. epidermal morphology polygonal	<i>Acer pensylvanicum</i> , <i>Betula</i> <i>alleghaniensis</i> , <i>B. lenta</i> , <i>Betula nigra</i> , <i>Platanus</i> <i>occidentalis</i> , <i>Quercus</i> <i>agrifolia</i> , <i>Q. alba</i> , <i>Q.</i> <i>chrysolepsis</i> , <i>Q. nigra</i> , <i>Q.</i> <i>palustris</i> , <i>Q. rubra</i> , <i>Rhamnus</i> <i>frangula</i> , <i>Sorbus americana</i>
b. calcium carbonate absent	
c. silica present	<i>Carya cordiformis</i> , <i>Fraxinus</i> <i>nigra</i> , <i>Ilex vomitoria</i> , <i>Morus</i> <i>rubra</i>

- c. silica absent
 - d. epidermal morphology irregular
 - Alnus viridis*, *Castanea dentata*, *Celastrus scandens*, *Spiraea betulifolia*, *Viburnum prunifolium*
 - d. epidermal morphology polygonal
 - Acer glabrum*, *Myrica gale*, *Parthenocissus vitacea*, *Philadelphus lewisii*, *Populus deltoids*, *Prunus americana*, *P. caroliniana*, *P. pensylvanica*, *Pyrola secunda*, *Quercus laurifolia*, *Rhododendron maximum*, *Ribes aureum*, *Ulmus pumila*
 - d. epidermal morphology rectangular
 - Prunus virginiana*
- a. calcium oxalate absent
 - b. calcium carbonate present
 - c. epidermal morphology irregular
 - Acer platanooides*, *Crateagus douglasii*
 - c. epidermal morphology polygonal
 - Acer macrophyllum*, *Arbutus menziesii*, *Arctostaphylos uva-ursi*, *Forsythia* sp., *Populus grandidentata*, *Populus nigra* 'Italica', *Tilia cordata*
 - b. calcium carbonate absent
 - c. silica present
 - Arctostaphylos glauca*, *Cephalanthus occidentalis*, *Fraxinus americana*, *Liriodendron tulipifera*,

c. silica absent

Prosopis juliflora

d. epidermal cells irregular

Berberis thunbergii, *Linnaea borealis*, *Sassafras albidum*,
Viburnum rufidulum

d. epidermal cells polygonal

Acer ginnala, *Chrysothamnus nauseosus*, *Cirsium scariosum*, *Ginkgo biloba*,
Quercus coccinea, *Rhamnus cathartica*, *Rhus aromatic*,
Rhododendron macrophyllum

Group H: Trichomes absent, stomata and epidermal cells randomly arranged.

a. calcium oxalate present

b. calcium carbonate present, silica absent

c. epidermal morphology irregular

Acer rubrum, *Amelanchier arborea*, *A. stolonifera*,
Fagus sylvatica

c. epidermal morphology polygonal

Acer pensylvanicum, *Betula alleghaniensis*, *B. lenta*,
Betula nigra, *Platanus occidentalis*, *Quercus agrifolia*, *Q. alba*, *Q. chrysolepsis*, *Q. nigra*, *Q. palustris*, *Q. rubra*, *Rhamnus frangula*, *Sorbus americana*

b. calcium carbonate absent

c. silica present	<i>Carya cordiformis</i> , <i>Fraxinus nigra</i> , <i>Ilex vomitoria</i> , <i>Morus rubra</i>
c. silica absent	
d. calcium oxalate raphide crystals	<i>Parthenocissus vitacea</i>
d. calcium oxalate globular	
e. epidermal cells irregular	<i>Alnus viridis</i> , <i>Castanea dentata</i> , <i>Celastrus scandens</i> , <i>Viburnum prunifolium</i>
e. epidermal cells polygonal	<i>Betula papyrifera</i> , <i>Myrica gale</i> , <i>Philadelphus lewisii</i> , <i>Populus deltoids</i> , <i>Prunus american</i> , <i>P. caroliniana</i> , <i>P. pensylvanica</i> , <i>P. virginiana</i> , <i>Pyrola secunda</i> , <i>Quercus laurifolia</i> , <i>Rhododendron maximum</i> , <i>Ulmus pumila</i>
a. calcium oxalate absent	
b. calcium carbonate present	<i>Acer macrophyllum</i> , <i>A. platanoides</i> , <i>Arbutus merziesii</i> , <i>Populus grandidentata</i> , <i>P. nigra</i> ‘Italica’, <i>Tilia cordata</i>
b. calcium carbonate absent	
c. silica present	<i>Arctostaphylos glauca</i> , <i>Cephalanthus occidentalis</i> , <i>Fraxinus americana</i> , <i>Liriodendron tulipifera</i> ,

	<i>Prosopis juliflora, Smilax tannoides</i>
c. silica absent	
d. epidermal cells irregular	<i>Berberis thunbergii, Sassafra albidum, Viburnum rufidulum</i>
d. epidermal cells polygonal	<i>Acer ginnala, Ginko biloba, Quercus coccinea, Rhododendron macrophyllum</i>

Plant characteristics have been summarized in a spreadsheet (Table 4.1). The characteristics are divided into eight categories; epidermal morphology, epidermal pattern, anticlinal walls, stomata morphology, stomata pattern, trichomes and inclusions. Epidermal morphology is the shape of the epidermal cell borders; they are characterized as square or rectangular, parallelogram, irregular and polygonal. Epidermal pattern refers to the arrangement of epidermal cells; stacked is ordered patterning with cells end-to-end and one-atop-another whereas random is similar to the jigsaw puzzle or flagstone type arrangement. Anticlinal walls are classified as wavy or verrucate, sinuous, straight and straight-curved.

Stomata morphology characterizes stomata based on the separation of the lower woody lamella and the upper woody lamella (LWL-UWL). A separation of less than 5 microns is a narrow LWL-UWL, greater than 5 microns is a wide LWL-UWL whereas moderate is between 4-6 microns. In addition, the polar region LWL-UWL separation is classified as narrow or wide (less than or greater than 5 microns). The polar stem is also classified as narrow or wide (less than or greater than 5 microns).

Stomata pattern refers to the arrangement of stomata in the cellular matrix (ordered into parallel rows or random) whereas stomata subsidiary cells refers to the subsidiary epidermal cell arrangement around stomata (anomocytic, brachyparacytic and tetracytic). Trichomes are prickles, hairs and scales on the surface of leaves; they are classified as unbranched, double-ended, segmented, multi (multiple fibers joined at a common base) or stellate.

Inclusions are typically plant defense mechanisms against herbivory. Inclusions include calcium carbonate rhombohedral crystals, calcium oxalate globular and raphide druses, isotropic or anisotropic (non-crystalline or crystalline) silica and starch. A more complete description of these plant characteristics is presented in Henderson and Vucetich (2014) (chapter 5).

The following abbreviations have been used in the spreadsheet to conserve space:

Cellular structures

s/r: square or rectangular

par: parallelogram

irr: irregular

pol: polygonal

Epidermal Pattern

stk: stacked brick-like

ran: random

Anticlinal walls

wav: wavy/verrucate

sin: sinuous

str: straight

s-c: straight-curved

Stomata morphology

LWL-UWL: lower woody lamella-upper woody lamella spacing

pol: polar region spacing

stm: stem width

Stomata pattern

par: parallel

ran: random

Stomata Subsidiary Cells

ano: anomocytic

bra: brachyparacytic

tet: tetracytic

Trichomes

unb: unbranched

d-e: double-ended

seg: segmented

mlt: multiple fibers per base

stl: stellate

Inclusions

crb: calcium carbonates

oxl: calcium oxalate

sil: silicate

sth: starch

Table 4.1 Woody Plant Characteristics (see text for abbreviations)

Plate #	Group	Plant Scientific Name	Common Name	Family	Epidermal Morphology				Epidermal Pattern		
					s/r	par	irr	pol	stk	ran	wav
156	B	<i>Abies balsamea</i>	Fir, Balsam	Pinaceae		x			x		x
157	B	<i>Abies concolor</i>	Fir, White	Pinaceae	x	x			x		x
158	B	<i>Abies fraseri</i>	Fir, Fraser	Pinaceae	x	x			x		x
159	B	<i>Abies grandis</i>	Fir, Grand	Pinaceae	x				x		x
160	B	<i>Abies lasiocarpa</i>	Fir, Subalpine	Pinaceae		x			x		x
161	H	<i>Acer ginnala</i>	Maple, Amur	Sapindaceae				x		x	
162	H	<i>Acer glabrum</i>	Maple, Mountain or Douglas	Sapindaceae				x		x	
163	G	<i>Acer grandidentatum</i>	Maple, Bigtooth	Sapindaceae			x			x	
164	H	<i>Acer macrophyllum</i>	Maple, Bigleaf	Sapindaceae				x		x	
165	G	<i>Acer negundo</i>	Boxelder	Sapindaceae				x		x	
166	G	<i>Acer nigrum</i>	Maple, Black	Sapindaceae				x		x	
167	H	<i>Acer pensylvanicum</i>	Maple, Striped	Sapindaceae				x		x	
168	H	<i>Acer platanoides</i>	Maple, Norway	Sapindaceae			x	x		x	
169	H	<i>Acer rubrum</i>	Maple, Red	Sapindaceae			x			x	
170	G	<i>Acer saccharinum</i>	Maple, Silver	Sapindaceae				x		x	
171	G	<i>Acer spicatum</i>	Maple, Mountain	Sapindaceae			x			x	
172	G	<i>Aesculus hippocastanum</i>	Horsechestnut	Hippocastanaceae			x	x		x	
173	G	<i>Alnus incana rugosa</i>	Alder, Speckled	Betulaceae				x		x	
174	G	<i>Alnus rhombifolia</i>	Alder, White	Betulaceae			x	x		x	
175	G	<i>Alnus rubra</i>	Alder, Red	Betulaceae	x					x	
176	H	<i>Alnus viridis</i>	Alder, Mountain	Betulaceae			x	x		x	
177	G	<i>Amelanchier alnifolia</i>	Serviceberry, Saskatoon	Rosaceae			x			x	x
178	H	<i>Amelanchier arborea</i>	Serviceberry, Downy	Rosaceae			x			x	
179	H	<i>Amelanchier stolonifera</i>	Serviceberry, Running	Rosaceae			x			x	
180	G	<i>Amorpha fruticosa</i>	Indigo, False	Fabaceae				x		x	
181	H	<i>Arbutus menziesii</i>	Pacific Madrone	Ericaceae				x		x	
182	H	<i>Arctostaphylos glauca</i>	Manzanita, Bigberry	Ericaceae				x		x	
183	G	<i>Arctostaphylos manzanita</i>	Manzanita, Common	Ericaceae				x		x	
184	H	<i>Arctostaphylos uva-ursi</i>	Kinnikinnick	Ericaceae				x		x	
185	G	<i>Artemisia cana</i>	Sagebrush, Silver	Asteraceae				x		x	
186	G	<i>Artemisia frigida</i>	Sagewort, Prairie	Asteraceae				x		x	
187	F	<i>Artemisia ludoviciana</i>	Sagebrush, White	Asteraceae				x		x	
188	F	<i>Artemisia tridentata</i>	Sagebrush, Big	Asteraceae				x		x	
189	G	<i>Artemisia tripartita</i>	Sagebrush, Threetip	Asteraceae				x		x	
190	H	<i>Berberis thunbergii</i>	Barberry, Japanese	Berberidaceae			x			x	
191	H	<i>Betula alleghaniensis</i>	Birch, Yellow	Betulaceae	x			x		x	
192	H	<i>Betula lenta</i>	Birch, Sweet	Betulaceae	x			x		x	
193	H	<i>Betula nigra</i>	Birch, River	Betulaceae	x			x		x	
194	G	<i>Betula occidentalis</i>	Birch, Water	Betulaceae	x			x		x	
195	G	<i>Betula papyrifera</i>	Birch, Paper	Betulaceae	x			x		x	
196	B	<i>Callitropsis nootkatensis</i>	Cedar, Alaska	Cupressaceae	x	x			x		
197	B	<i>Calocedrus decurrens</i>	Cedar, Incense	Cupressaceae	x				x		
198	G	<i>Carpinus caroliniana</i>	Hornbeam, American	Betulaceae	x			x		x	
199	H	<i>Carya cordiformis</i>	Hickory, Bitternut	Juglandaceae			x			x	
200	G	<i>Carya glabra</i>	Hickory, Pignut	Juglandaceae	x	x				x	
201	G	<i>Carya illinoensis</i>	Pecan	Juglandaceae	x	x				x	
202	G	<i>Carya laciniosa</i>	Hickory, Shellbark	Juglandaceae			x			x	
203	G	<i>Carya ovata</i>	Hickory, Shagbark	Juglandaceae			x			x	
204	G	<i>Carya tomentosa</i>	Hickory, Mockernut	Juglandaceae			x			x	
205	H	<i>Castanea dentata</i>	Chestnut, American	Fagaceae			x			x	
206	G	<i>Ceanothus americanus</i>	Ceanothus, Jerseytea	Rhamnaceae	x	x				x	
207	G	<i>Ceanothus velutinus</i>	Snowbrush	Rhamnaceae	x			x		x	
208	H	<i>Celastrus scandens</i>	Bittersweet	Celastraceae	x		x			x	
209	G	<i>Celtis laevigata</i>	Sugarberry	Ulmaceae	x	x				x	
210	G	<i>Celtis laevigata</i> var. <i>reticulata</i>	Hackberry, Netleaf	Ulmaceae	x	x				x	
211	G	<i>Celtis occidentalis</i>	Hackberry, Northern	Ulmaceae	x	x	x			x	
212	H	<i>Cephalanthus occidentalis</i>	Buttonbush	Rubiaceae	x	x				x	
213	G	<i>Cercis canadensis</i>	Redbud, Eastern	Fabaceae	x	x					
214	G	<i>Cercocarpus ledifolius</i>	Mountain Mahogany, Curl-leaf	Rosaceae				x		x	
215	G	<i>Cercocarpus montanus</i>	Mountain Mahogany	Rosaceae	x	x				x	
216	B	<i>Chamaecyparis thyoides</i>	White-Cedar, Atlantic	Cupressaceae	x				x		
217	H	<i>Chrysothamnus nauseosus</i>	Rabbitbrush, Rubber	Asteraceae				x		x	
218	H	<i>Cirsium scariosum</i>	Thistle, Meadow	Asteraceae				x		x	
219	G	<i>Cirsium vulgare</i>	Thistle, Bull	Asteraceae				x		x	
220	G	<i>Comptonia peregrina</i>	Sweetfern	Myricaceae	x	x				x	
221	G	<i>Cornus alternifolia</i>	Dogwood, Alternate-leaf	Cornaceae		x	x			x	
222	E	<i>Cornus canadensis</i>	Bunchberry	Cornaceae			x			x	
223	G	<i>Cornus drummondii</i>	Dogwood, Roughleaf	Cornaceae			x			x	
224	E	<i>Cornus florida</i>	Dogwood, Flowering	Cornaceae			x			x	
225	E	<i>Cornus nuttallii</i>	Dogwood, Pacific	Cornaceae			x			x	

Plate #	Group	Plant Scientific Name	nticlinal Walls			Stomata Morphology			Stomata Pattern		Stomata Subsidiary Cells			Trichon		
			sin	str	s-c	LWL-UWL	pol	stm	par	ran	ano	bra	tet	unb	d-e	seg
156	B	<i>Abies balsamea</i>				w	w	n	x				x			
157	B	<i>Abies concolor</i>		x		w	w	n	x				x			
158	B	<i>Abies fraseri</i>	x			w	w	n	x				x			
159	B	<i>Abies grandis</i>	x			w	w	n	x				x			
160	B	<i>Abies lasiocarpa</i>				w	w	m	x				x			
161	H	<i>Acer ginnala</i>		x	x	n	w	n		x	x					
162	H	<i>Acer glabrum</i>		x	x	n	w	n		x	x					
163	G	<i>Acer grandidentatum</i>		x	x	n	w	n		x	x			x		
164	H	<i>Acer macrophyllum</i>		x	x	n	w	n		x	x					
165	G	<i>Acer negundo</i>		x		n	w	n		x	x			x		
166	G	<i>Acer nigrum</i>		x	x	n	w	n		x	x			x		
167	H	<i>Acer pensylvanicum</i>		x	x	n	w	n		x	x					
168	H	<i>Acer platanoides</i>		x	x	n	w	n		x	x					
169	H	<i>Acer rubrum</i>		x	x	n	w	n		x	x					
170	G	<i>Acer saccharinum</i>		x	x	n	w	n		x	x			x		
171	G	<i>Acer spicatum</i>		x	x	n	w	n		x	x			x		
172	G	<i>Aesculus hippocastanum</i>		x	x	m	w	n		x	x			x		
173	G	<i>Alnus incana rugosa</i>			x	n	n	n		x				x		
174	G	<i>Alnus rhombifolia</i>								x				x		
175	G	<i>Alnus rubra</i>		x						x				x		
176	H	<i>Alnus viridis</i>				n	n	n		x						
177	G	<i>Amelanchier alnifolia</i>				n	w	n		x	x			x		
178	H	<i>Amelanchier arborea</i>			x	n	w	m		x	x					
179	H	<i>Amelanchier stolonifera</i>			x	n	w	m		x	x					
180	G	<i>Amorpha fruticosa</i>			x	n	n	n		x				x		
181	H	<i>Arbutus menziesii</i>			x	n	n	w		x						
182	H	<i>Arctostaphylos glauca</i>			x	n	n	w		x						
183	G	<i>Arctostaphylos manzanita</i>			x	n	n	w		x				x		
184	H	<i>Arctostaphylos uva-ursi</i>			x	n	n	w		x						
185	G	<i>Artemisia cana</i>		x	x	n	n	n		x				x		
186	G	<i>Artemisia frigida</i>		x	x	n	n	n		x				x		
187	F	<i>Artemisia ludoviciana</i>		x	x	n	n	n		x				x		x
188	F	<i>Artemisia tridentata</i>		x	x	n	n	n		x				x		x
189	G	<i>Artemisia tripartita</i>		x	x	n	n	n		x				x		
190	H	<i>Berberis thunbergii</i>		x	x	w	w	n		x						
191	H	<i>Betula alleghaniensis</i>		x	x	n	n	n		x						
192	H	<i>Betula lenta</i>		x	x	n	n	n		x						
193	H	<i>Betula nigra</i>		x	x	n	n	n		x						
194	G	<i>Betula occidentalis</i>		x	x	n	n	n		x				x		
195	G	<i>Betula papyrifera</i>		x	x	n	n	n		x				x		
196	B	<i>Callitropsis nootkatensis</i>			x	n	w	w	x				x			
197	B	<i>Calocedrus decurrens</i>			x	n	w	w	x				x			
198	G	<i>Carpinus caroliniana</i>		x	x	n	w	n		x				x		
199	H	<i>Carya cordiformis</i>		x	x	n	w	n		x						
200	G	<i>Carya glabra</i>		x	x	n	w	n		x				x		
201	G	<i>Carya illinoensis</i>		x	x	n	w	n		x				x		
202	G	<i>Carya laciniosa</i>		x	x	n	w	n		x				x		
203	G	<i>Carya ovata</i>		x	x	n	n	n		x				x		
204	G	<i>Carya tomentosa</i>		x	x	n	w	n		x				x		
205	H	<i>Castanea dentata</i>		x	x	n	n	w		x						
206	G	<i>Ceanothus americanus</i>		x	x	n	w	n		x				x		
207	G	<i>Ceanothus velutinus</i>		x	x					x				x		
208	H	<i>Celastrus scandens</i>		x	x	n	n	n		x						
209	G	<i>Celtis laevigata</i>		x	x					x				x		
210	G	<i>Celtis laevigata var. reticulata</i>			x	n	w	w		x				x		
211	G	<i>Celtis occidentalis</i>			x	n	w	w		x				x		
212	H	<i>Cephalanthus occidentalis</i>			x	w	w	w		x						
213	G	<i>Cercis canadensis</i>			x	w	w	w		x				x		
214	G	<i>Cercocarpus ledifolius</i>		x	x					x				x		
215	G	<i>Cercocarpus montanus</i>			x					x				x		
216	B	<i>Chamaecyparis thyoides</i>		x	x	n	n	n	x				x			
217	H	<i>Chrysothamnus nauseosus</i>			x	n	n	n		x						
218	H	<i>Cirsium scariosum</i>			x	m	w	w		x						
219	G	<i>Cirsium vulgare</i>			x	w	w	w		x	x			x		
220	G	<i>Comptonia peregrina</i>		x	x	n	n	w		x				x		
221	G	<i>Cornus alternifolia</i>			x					x				x		
222	E	<i>Cornus canadensis</i>			x	n	w	w		x	x				x	
223	G	<i>Cornus drummondii</i>			x	w	w	w		x				x		
224	E	<i>Cornus florida</i>			x	m	m	w		x					x	
225	E	<i>Cornus nuttallii</i>			x	m	m	w		x						

Plate #	Group	Plant Scientific Name	es		Inclusions			
			mlt	stl	crb	oxl	sil	sth
156	B	<i>Abies balsamea</i>						
157	B	<i>Abies concolor</i>						
158	B	<i>Abies fraseri</i>						
159	B	<i>Abies grandis</i>						
160	B	<i>Abies lasiocarpa</i>						
161	H	<i>Acer ginnala</i>						
162	H	<i>Acer glabrum</i>				x		
163	G	<i>Acer grandidentatum</i>			x			
164	H	<i>Acer macrophyllum</i>			x			
165	G	<i>Acer negundo</i>			x	x		
166	G	<i>Acer nigrum</i>			x			
167	H	<i>Acer pensylvanicum</i>			x	x		
168	H	<i>Acer platanoides</i>			x			
169	H	<i>Acer rubrum</i>			x	x		
170	G	<i>Acer saccharinum</i>				x		
171	G	<i>Acer spicatum</i>				x		
172	G	<i>Aesculus hippocastanum</i>				x		
173	G	<i>Alnus incana rugosa</i>				x		
174	G	<i>Alnus rhombifolia</i>				x		
175	G	<i>Alnus rubra</i>				x	x	
176	H	<i>Alnus viridis</i>				x		
177	G	<i>Amelanchier alnifolia</i>			x	x		
178	H	<i>Amelanchier arborea</i>			x	x		
179	H	<i>Amelanchier stolonifera</i>			x	x		
180	G	<i>Amorpha fruticosa</i>			x			
181	H	<i>Arbutus menziesii</i>			x			
182	H	<i>Arctostaphylos glauca</i>					x	
183	G	<i>Arctostaphylos manzanita</i>					x	
184	H	<i>Arctostaphylos uva-ursi</i>			x			
185	G	<i>Artemisia cana</i>					x	
186	G	<i>Artemisia frigida</i>					x	
187	F	<i>Artemisia ludoviciana</i>					x	
188	F	<i>Artemisia tridentata</i>					x	
189	G	<i>Artemisia tripartita</i>					x	
190	H	<i>Berberis thunbergii</i>						
191	H	<i>Betula alleghaniensis</i>			x	x		
192	H	<i>Betula lenta</i>			x	x		
193	H	<i>Betula nigra</i>			x	x		
194	G	<i>Betula occidentalis</i>				x		
195	G	<i>Betula papyrifera</i>				x		
196	B	<i>Callitropsis nootkatensis</i>						
197	B	<i>Calocedrus decurrens</i>						
198	G	<i>Carpinus caroliniana</i>					x	
199	H	<i>Carya cordiformis</i>				x	x	
200	G	<i>Carya glabra</i>				x		
201	G	<i>Carya illinoensis</i>				x		
202	G	<i>Carya laciniata</i>				x	x	
203	G	<i>Carya ovata</i>				x		
204	G	<i>Carya tomentosa</i>				x		
205	H	<i>Castanea dentata</i>				x		
206	G	<i>Ceanothus americanus</i>				x		
207	G	<i>Ceanothus velutinus</i>				x		
208	H	<i>Celastrus scandens</i>				x		
209	G	<i>Celtis laevigata</i>			x	x		
210	G	<i>Celtis laevigata</i> var. <i>reticulata</i>			x	x		
211	G	<i>Celtis occidentalis</i>			x	x		
212	H	<i>Cephalanthus occidentalis</i>					x	
213	G	<i>Cercis canadensis</i>			x	x		
214	G	<i>Cercocarpus ledifolius</i>			x	x		
215	G	<i>Cercocarpus montanus</i>			x	x	x	
216	B	<i>Chamaecyparis thyoides</i>						
217	H	<i>Chrysothamnus nauseosus</i>						
218	H	<i>Cirsium scariosum</i>						
219	G	<i>Cirsium vulgare</i>					x	
220	G	<i>Comptonia peregrina</i>					x	
221	G	<i>Cornus alternifolia</i>				x	x	
222	E	<i>Cornus canadensis</i>				x		
223	G	<i>Cornus drummondii</i>				x		
224	E	<i>Cornus florida</i>						
225	E	<i>Cornus nuttallii</i>	x					

Plate #	Group	Plant Scientific Name	Common Name	Family	Epidermal Morphology				Epidermal Pattern			A
					s/r	par	irr	pol	stk	ran	wav	
226	E	<i>Cornus sericea</i>	Dogwood, Red Osier	Cornaceae			x			x		
227	G	<i>Corylus cornuta</i>	Hazel, Beaked	Cornaceae			x			x		
228	H	<i>Crataegus douglasii</i>	Hawthorns, Black	Rosaceae			x			x		
229	G	<i>Dasiphora fruticosa</i>	Cinquefoil, Shrubby	Rosaceae				x		x		
230	E	<i>Elaeagnus commutata</i>	Silverberry	Elaeagnaceae			x			x		
231	G	<i>Fagus grandifolia</i>	Beech, American	Fagaceae			x			x		
232	H	<i>Fagus sylvatica</i>	Beech, European	Fagaceae			x			x		
233	H	<i>Forsythia sp.</i>	Forsythia	Oleaceae				x		x		
234	H	<i>Fraxinus americana</i>	Ash, White	Oleaceae				x		x		
235	H	<i>Fraxinus nigra</i>	Ash, Black	Oleaceae				x		x		
236	G	<i>Fraxinus pennsylvanica</i>	Ash, Green	Oleaceae	x			x		x		
237	H	<i>Ginkgo biloba</i>	Ginkgo	Ginkgoaceae	x			x		x		
238	G	<i>Ilex montana</i>	Winterberry, Mountain	Aquifoliaceae	x		x			x		
239	G	<i>Ilex opaca</i>	Holly, American	Aquifoliaceae	x			x		x		
240	G	<i>Ilex verticillata</i>	Winterberry, Common	Aquifoliaceae	x			x		x		
241	H	<i>Ilex vomitoria</i>	Yaupon	Aquifoliaceae				x		x		
242	E	<i>Juglans cinerea</i>	Butternut	Juglandaceae			x			x		
243	E	<i>Juglans nigra</i>	Walnut, Black	Juglandaceae			x			x		
244	B	<i>Juniperus communis</i>	Juniper, Common	Cupressaceae	x	x			x			
245	B	<i>Juniperus scopulorum</i>	Juniper, Rocky Mountain	Cupressaceae	x				x			
246	B	<i>Juniperus virginiana</i>	Redcedar, Eastern	Cupressaceae	x	x			x			
247	G	<i>Kalmia latifolia</i>	Mountain-laurel	Ericaceae	x	x			x			
248	B	<i>Larix laricina</i>	Larch, Eastern	Pinaceae	x				x			
249	B	<i>Larix occidentalis</i>	Larch, Western	Pinaceae	x				x			
250	H	<i>Linnaea borealis</i>	Twinflower	Caprifoliaceae			x	x		x	x	
251	D	<i>Liquidambar styraciflua</i>	Sweetgum	Altingiaceae	x			x		x		
252	H	<i>Liriodendron tulipifera</i>	Tuliptree	Magnoliaceae			x	x		x		
253	D	<i>Lonicera canadensis</i>	Honeysuckle, American	Caprifoliaceae				x		x		
254	G	<i>Lonicera involucrata</i>	Honeysuckle, Twinberry	Caprifoliaceae				x		x		
255	G	<i>Lonicera morrowii</i>	Honeysuckle, Marrow	Caprifoliaceae				x		x		
256	G	<i>Lonicera utahensis</i>	Honeysuckle, Utah	Caprifoliaceae				x		x		
257	D	<i>Magnolia acuminata</i>	Cucumber-tree	Magnoliaceae				x		x		
258	D	<i>Magnolia grandiflora</i>	Magnolia, Southern	Magnoliaceae				x		x		
259	D	<i>Magnolia kobus</i>	Magnolia, Kobus	Magnoliaceae				x		x		
260	D	<i>Magnolia loebneri</i>	Magnolia, Loebner	Magnoliaceae				x		x		
261	D	<i>Magnolia stellata</i>	Magnolia, Star	Magnoliaceae				x		x		
262	E	<i>Magnolia virginiana</i>	Sweetbay	Magnoliaceae				x		x		
263	E	<i>Mahonia repens</i>	Barberry, Creeping	Berberidaceae	x			x	x			
264	G	<i>Malus pumila</i>	Apple, Common	Rosaceae				x		x		
265	G	<i>Menziesia ferruginea</i>	Menziesia, Rusty	Ericaceae				x		x		
266	G	<i>Morus alba</i>	Mulberry, White	Moraceae				x		x		
267	H	<i>Morus rubra</i>	Mulberry, Red	Moraceae				x		x		
268	G	<i>Myrica cerifera</i>	Bayberry, Southern	Myricaceae				x		x		
269	H	<i>Myrica gale</i>	Sweetgale	Myricaceae				x		x		
270	G	<i>Myriophyllum spp.</i>	Watermilfoil	Haloragaceae				x		x		
271	H	<i>Nymphaea advena</i>	Waterlily, Yellow	Nymphaeaceae				x		x		
272	D	<i>Nyssa aquatica</i>	Tupelo, Water	Cornaceae				x		x		
273	D	<i>Nyssa sylvatica</i>	Tupelo, Black	Cornaceae				x		x		
274	G	<i>Ostrya virginiana</i>	Hophornbeam, Eastern	Betulaceae				x		x		
275	H	<i>Parthenocissus vitacea</i>	Virginia Creepers	Vitaceae				x		x		
276	H	<i>Philadelphus lewisii</i>	Mock Orange, Lewis'	Hydrangeaceae				x		x		
277	E	<i>Physocarpus opulifolius</i>	Ninebark	Rosaceae				x		x		
278	B	<i>Picea abies</i>	Spruce, Norway	Pinaceae	x	x			x		x	
279	B	<i>Picea engelmannii</i>	Spruce, Engelmann	Pinaceae	x	x			x		x	
280	B	<i>Picea glauca</i>	Spruce, White	Pinaceae	x				x			
281	B	<i>Picea mariana</i>	Spruce, Black	Pinaceae	x	x			x		x	
282	B	<i>Picea pungens</i>	Spruce, Blue	Pinaceae	x	x			x		x	
283	B	<i>Larix laricina</i>	Spruce, Red	Pinaceae	x				x		x	
284	B	<i>Picea sitchensis</i>	Spruce, Sitka	Pinaceae	x				x		x	
285	B	<i>Pinus albicaulis</i>	Pine, Whitebark	Pinaceae	x	x			x			
286	B	<i>Pinus banksiana</i>	Pine, Jack	Pinaceae	x	x			x		x	
287	B	<i>Pinus contorta</i>	Pine, Lodgepole	Pinaceae	x				x		x	
288	B	<i>Pinus echinata</i>	Pine, Shortleaf	Pinaceae	x				x		x	
289	B	<i>Pinus edulis</i>	Pine, Pinyon	Pinaceae	x	x			x		x	
290	B	<i>Pinus eliottii</i>	Pine, Slash	Pinaceae	x	x			x			
291	B	<i>Pinus flexilis</i>	Pine, Limber	Pinaceae	x	x			x			
292	B	<i>Pinus jeffreyi</i>	Pine, Jeffrey	Pinaceae	x				x		x	
293	B	<i>Pinus lambertiana</i>	Pine, Sugar	Pinaceae	x	x			x		x	
294	B	<i>Pinus monticola</i>	Pine, Western White	Pinaceae	x	x			x		x	
295	B	<i>Pinus palustris</i>	Pine, Longleaf	Pinaceae	x	x			x		x	

Plate #	Group	Plant Scientific Name	nticlinal Walls			Stomata Morphology			Stomata Pattern		Stomata Subsidiary Cells				Trichon		
			sin	str	s-c	LWL-UWL	pol	stm	par	ran	ano	bra	tet	unb	d-e	seg	
226	E	<i>Cornus sericea</i>			x	n	w	w		x	x					x	
227	G	<i>Corylus cornuta</i>			x	n	n	n		x				x			
228	H	<i>Crataegus douglasii</i>	x		x	w	n	n		x	x						
229	G	<i>Dasiphora fruticosa</i>			x					x				x			
230	E	<i>Elaeagnus commutata</i>	x			w	w	n		x	x						
231	G	<i>Fagus grandifolia</i>			x	w	w	n		x				x			
232	H	<i>Fagus sylvatica</i>			x	w	w	n		x							
233	H	<i>Forsythia sp.</i>			x	w	w	n		x							
234	H	<i>Fraxinus americana</i>			x	w	w	n		x							
235	H	<i>Fraxinus nigra</i>			x	w	w	w		x							
236	G	<i>Fraxinus pennsylvanica</i>			x					x					x		
237	H	<i>Ginkgo biloba</i>			x	n	w	m		x							
238	G	<i>Ilex montana</i>			x	n	n	w		x				x			
239	G	<i>Ilex opaca</i>			x	n	n	w		x				x			
240	G	<i>Ilex verticillata</i>			x	n	n	w		x				x			
241	H	<i>Ilex vomitoria</i>			x	w	w	n		x							
242	E	<i>Juglans cinerea</i>		x	x					x							x
243	E	<i>Juglans nigra</i>		x	x	w	n	w		x							x
244	B	<i>Juniperus communis</i>			x	n	n	n	x				x				
245	B	<i>Juniperus scopulorum</i>			x	n	n	n	x				x				
246	B	<i>Juniperus virginiana</i>			x	n	w	n	x				x				
247	G	<i>Kalmia latifolia</i>			x	w	w	w		x					x		
248	B	<i>Larix laricina</i>		x		w	w	n	x				x				
249	B	<i>Larix occidentalis</i>		x		w	w	n	x				x				
250	H	<i>Linnaea borealis</i>				w	w	w		x							
251	D	<i>Liquidambar styraciflua</i>			x	n	n	w		x		x					
252	H	<i>Liriodendron tulipifera</i>			x	w	w	n		x							
253	D	<i>Lonicera canadensis</i>			x	n	n	n				x			x		
254	G	<i>Lonicera involucrata</i>			x	n	w	w		x					x		
255	G	<i>Lonicera morrowii</i>			x	n	w	n		x					x		
256	G	<i>Lonicera utahensis</i>			x	n	w	w		x					x		
257	D	<i>Magnolia acuminata</i>			x	n	w	w		x		x			x		
258	D	<i>Magnolia grandiflora</i>			x	m	w	w		x		x					
259	D	<i>Magnolia kobus</i>			x	n	w	w		x		x					
260	D	<i>Magnolia loebneri</i>			x	n	w	w		x		x					
261	D	<i>Magnolia stellata</i>			x	n	w	w		x		x					
262	E	<i>Magnolia virginiana</i>			x	n	w	w		x							
263	E	<i>Mahonia repens</i>		x	x	n	w	w	x			x					
264	G	<i>Malus pumila</i>			x	w	w	w		x					x		
265	G	<i>Menziesia ferruginea</i>			x					x					x		
266	G	<i>Morus alba</i>			x	n	n	n		x					x		
267	H	<i>Morus rubra</i>			x	n	n	n		x							
268	G	<i>Myrica cerifera</i>			x	n	w	w		x					x		
269	H	<i>Myrica gale</i>			x	n	w	w		x							
270	G	<i>Myriophyllum spp.</i>			x	n	n	n		x					x		
271	H	<i>Nymphaea advena</i>			x	n	n	w		x							
272	D	<i>Nyssa aquatica</i>			x	n	w	w		x		x			x		
273	D	<i>Nyssa sylvatica</i>			x	n	n	w		x		x					
274	G	<i>Ostrya virginiana</i>			x	n	w	w		x					x		
275	H	<i>Parthenocissus vitacea</i>			x	w	n	n		x							
276	H	<i>Philadelphus lewisii</i>			x	n	w	w		x							
277	E	<i>Physocarpus opulifolius</i>			x	n	w	n		x							
278	B	<i>Picea abies</i>	x			n	n	w	x					x			
279	B	<i>Picea engelmannii</i>			x	n	n	w	x						x		
280	B	<i>Picea glauca</i>	x	x		n	n	w	x						x		
281	B	<i>Picea mariana</i>	x			n	n	w	x						x		
282	B	<i>Picea pungens</i>			x	n	n	w	x						x		
283	B	<i>Larix laricina</i>		x		n	n	w	x								
284	B	<i>Picea sitchensis</i>		x		n	n	w	x						x		
285	B	<i>Pinus albicaulis</i>	x			w	w	w	x						x		
286	B	<i>Pinus banksiana</i>		x		w	w	w	x						x		
287	B	<i>Pinus contorta</i>	x			w	w	w	x						x		
288	B	<i>Pinus echinata</i>	x			w	w	w	x						x		
289	B	<i>Pinus edulis</i>				w	w	w	x						x		
290	B	<i>Pinus elliottii</i>		x		w	w	w	x						x		
291	B	<i>Pinus flexilis</i>			x	w	w	w	x						x		
292	B	<i>Pinus jeffreyi</i>	x			w	w	w	x						x		
293	B	<i>Pinus lambertiana</i>				w	w	w	x						x		
294	B	<i>Pinus monticola</i>				w	w	w	x						x		
295	B	<i>Pinus palustris</i>		x		w	w	w	x						x		

Plate #	Group	Plant Scientific Name	es		Inclusions			
			mlt	stl	crb	oxl	sil	sth
226	E	<i>Cornus sericea</i>				x		x
227	G	<i>Corylus cornuta</i>				x		
228	H	<i>Crataegus douglasii</i>			x			
229	G	<i>Dasiphora fruticosa</i>						
230	E	<i>Elaeagnus commutata</i>		x				
231	G	<i>Fagus grandifolia</i>			x	x	x	
232	H	<i>Fagus sylvatica</i>			x	x		
233	H	<i>Forsythia sp.</i>			x		x	
234	H	<i>Fraxinus americana</i>					x	
235	H	<i>Fraxinus nigra</i>				x	x	
236	G	<i>Fraxinus pennsylvanica</i>					x	
237	H	<i>Ginkgo biloba</i>						
238	G	<i>Ilex montana</i>				x		
239	G	<i>Ilex opaca</i>				x		
240	G	<i>Ilex verticillata</i>						
241	H	<i>Ilex vomitoria</i>				x	x	
242	E	<i>Juglans cinerea</i>		x		x		
243	E	<i>Juglans nigra</i>		x		x		
244	B	<i>Juniperus communis</i>						
245	B	<i>Juniperus scopulorum</i>						
246	B	<i>Juniperus virginiana</i>						
247	G	<i>Kalmia latifolia</i>				x		
248	B	<i>Larix laricina</i>					x	
249	B	<i>Larix occidentalis</i>						
250	H	<i>Linnaea borealis</i>						
251	D	<i>Liquidambar styraciflua</i>				x		
252	H	<i>Liriodendron tulipifera</i>					x	
253	D	<i>Lonicera canadensis</i>				x		
254	G	<i>Lonicera involucrata</i>				x		
255	G	<i>Lonicera morrowii</i>					x	
256	G	<i>Lonicera utahensis</i>			x		x	
257	D	<i>Magnolia acuminata</i>				x	x	
258	D	<i>Magnolia grandiflora</i>					x	
259	D	<i>Magnolia kobus</i>					x	
260	D	<i>Magnolia loebneri</i>					x	
261	D	<i>Magnolia stellata</i>				x	x	
262	E	<i>Magnolia virginiana</i>		x		x	x	
263	E	<i>Mahonia repens</i>		x				
264	G	<i>Malus pumila</i>			x	x	x	
265	G	<i>Menziesia ferruginea</i>			x	x	x	
266	G	<i>Morus alba</i>				x	x	
267	H	<i>Morus rubra</i>				x	x	
268	G	<i>Myrica cerifera</i>				x		
269	H	<i>Myrica gale</i>				x		
270	G	<i>Myriophyllum spp.</i>				x		
271	H	<i>Nymphaea advena</i>						
272	D	<i>Nyssa aquatica</i>						
273	D	<i>Nyssa sylvatica</i>			x	x	x	
274	G	<i>Ostrya virginiana</i>						
275	H	<i>Parthenocissus vitacea</i>				x		
276	H	<i>Philadelphus lewisii</i>				x		
277	E	<i>Physocarpus opulifolius</i>	x		x	x		
278	B	<i>Picea abies</i>						
279	B	<i>Picea engelmannii</i>						
280	B	<i>Picea glauca</i>						
281	B	<i>Picea mariana</i>						
282	B	<i>Picea pungens</i>						
283	B	<i>Larix laricina</i>						
284	B	<i>Picea sitchensis</i>						
285	B	<i>Pinus albicaulis</i>			x			
286	B	<i>Pinus banksiana</i>						
287	B	<i>Pinus contorta</i>						
288	B	<i>Pinus echinata</i>						
289	B	<i>Pinus edulis</i>						
290	B	<i>Pinus elliotii</i>						
291	B	<i>Pinus flexilis</i>						
292	B	<i>Pinus jeffreyi</i>						
293	B	<i>Pinus lambertiana</i>						
294	B	<i>Pinus monticola</i>						
295	B	<i>Pinus palustris</i>						

Plate #	Group	Plant Scientific Name	Common Name	Family	Epidermal Morphology				Epidermal Pattern			A
					s/r	par	irr	pol	stk	ran	wav	
296	B	<i>Pinus ponderosa</i>	Pine, Ponderosa	Pinaceae	x	x			x			x
297	B	<i>Pinus resinosa</i>	Pine, Red	Pinaceae	x	x			x			x
298	B	<i>Pinus rigida</i>	Pine, Pitch	Pinaceae	x	x			x			x
299	B	<i>Pinus sabiniana</i>	Pine, Gray	Pinaceae	x	x			x			x
300	B	<i>Pinus strobus</i>	Pine, Eastern White	Pinaceae	x	x			x			x
301	B	<i>Pinus sylvestris</i>	Pine, Scots	Pinaceae	x	x			x			x
302	B	<i>Pinus taeda</i>	Pine, Loblolly	Pinaceae	x	x			x			x
303	B	<i>Pinus virginiana</i>	Pine, Virginia	Pinaceae	x	x			x			x
304	H	<i>Platanus occidentalis</i>	Sycamore, American	Platanaceae				x		x		
305	G	<i>Platanus racemosa</i>	Sycamore, California	Platanaceae				x		x		
306	G	<i>Populus alba</i>	Poplar, White	Salicaceae	x			x		x		
307	D	<i>Populus angustifolia</i>	Cottonwood, Narrowleaf	Salicaceae				x		x		
308	D	<i>Populus balsamifera</i>	Poplar, Balsam	Salicaceae				x		x		
309	H	<i>Populus deltoides</i>	Cottonwood, Eastern	Salicaceae				x		x		
310	H	<i>Populus grandidentata</i>	Aspen, Bigtooth	Salicaceae				x		x		
311	H	<i>Populus nigra</i> 'Italica'	Poplar, Lombardy	Salicaceae				x		x		
312	D	<i>Populus tremuloides</i>	Aspen, Quaking	Salicaceae	x			x		x		
313	G	<i>Potamogeton gramineus</i>	Pondweed	Potamogetonaceae	x			x		x		
314	H	<i>Prosopis juliflora</i>	Mesquite	Fabaceae				x		x		
315	H	<i>Prunus americana</i>	Apricot	Rosaceae				x		x		
316	H	<i>Prunus caroliniana</i>	Laurelcherry, Carolina	Rosaceae				x		x		
317	G	<i>Prunus domestica</i>	Plum, European	Rosaceae				x		x		
318	H	<i>Prunus pensylvanica</i>	Cherry, Pin	Rosaceae				x		x		
319	G	<i>Prunus persica</i>	Peach	Rosaceae				x		x		
320	G	<i>Prunus serotina</i>	Cherry, Black	Rosaceae				x		x		
321	H	<i>Prunus virginiana</i>	Chokecherry	Rosaceae	x					x		
322	B	<i>Pseudotsuga menziesii</i> var. <i>glauca</i>	Douglas-Fir	Pinaceae	x				x			
323	G	<i>Pteridium aquilinum</i>	Bracken, Western	Dennstaedtiaceae			x		x			x
324	G	<i>Purshia tridentata</i>	Bitterbrush, Antelope	Rosaceae				x		x		
325	H	<i>Pyrola secunda</i>	Wintergreen, Checkerberry	Rosaceae				x		x		
326	H	<i>Quercus agrifolia</i>	Oak, Coast Live	Fagaceae				x		x		
327	H	<i>Quercus alba</i>	Oak, White	Fagaceae	x			x		x		
328	E	<i>Quercus bicolor</i>	Oak, Swamp White	Fagaceae				x		x		
329	H	<i>Quercus chrysolepis</i>	Oak, Canyon Live	Fagaceae				x		x		
330	H	<i>Quercus coccinea</i>	Oak, Scarlet	Fagaceae				x		x		
331	E	<i>Quercus gambelii</i>	Oak, Gambel	Fagaceae				x		x		
332	H	<i>Quercus laurifolia</i>	Oak, Laurel	Fagaceae				x		x		
333	E	<i>Quercus macrocarpa</i>	Oak, Burr	Fagaceae				x		x		
334	H	<i>Quercus nigra</i>	Oak, Water	Fagaceae				x		x		
335	H	<i>Quercus palustris</i>	Oak, Pin	Fagaceae	x			x		x		
336	H	<i>Quercus rubra</i>	Oak, Northern Red	Fagaceae	x			x		x		
337	E	<i>Quercus stellata</i>	Oak, Post	Fagaceae	x			x		x		
338	E	<i>Quercus velutina</i>	Oak, Black	Fagaceae	x			x		x		
339	E	<i>Quercus virginiana</i>	Oak, Live	Fagaceae				x		x		
340	H	<i>Rhamnus cathartica</i>	Buckthorn, European	Rhamnaceae				x		x		
341	H	<i>Rhamnus frangula</i>	Buckthorn, Glossy	Rhamnaceae				x		x		
342	H	<i>Rhododendron macrophyllum</i>	Rhododendron, Pacific	Ericaceae				x		x		
343	H	<i>Rhododendron maximum</i>	Laurel, Great	Ericaceae				x		x		
344	H	<i>Rhus aromatica</i>	Sumac, Fragrant	Anacardiaceae				x		x		
345	G	<i>Rhus copallinum</i>	Sumac, Winged	Anacardiaceae				x		x		
346	H	<i>Ribes aureum</i>	Currant, Golden	Grossulariaceae				x		x		
347	G	<i>Ribes inerme</i>	Gooseberry, White-Stemmed	Grossulariaceae				x		x		
348	G	<i>Ribes lacustre</i>	Currant, Prickly	Grossulariaceae				x		x		
349	G	<i>Ribes oxycanthoides</i> spp. <i>cognatum</i>	Currant, Stream	Grossulariaceae				x		x		
350	G	<i>Ribes viscosissimum</i>	Currant, Sticky	Grossulariaceae				x		x		
351	G	<i>Robinia pseudoacacia</i>	Locust, Black	Fabaceae				x		x		
352	G	<i>Rosa woodsii</i>	Rose, Woods (Prairie)	Rosaceae	x			x		x		
353	G	<i>Rubus fruticosus</i>	Blackberry, Wild	Rosaceae				x		x		
354	G	<i>Rubus idaeus</i> ssp. <i>strigosus</i>	Raspberry, Grayleaf Red	Rosaceae	x			x		x		
355	F	<i>Rubus parviflorus</i>	Thimbleberry, Western	Rosaceae	x			x		x		
356	D	<i>Salix fragilis</i>	Willow, Crack	Salicaceae	x			x		x		
357	G	<i>Sambucus racemosa</i>	Elderberry	Caprifoliaceae			x			x		
358	H	<i>Sassafras albidum</i>	Sassafras	Lauraceae			x	x		x		
359	F	<i>Shepherdia canadensis</i>	Buffaloberry	Elaeagnaceae				x	x			
360	D	<i>Smilax tamnoides</i>	Greenbriers	Liliaceae			x			x		
361	H	<i>Sorbus americana</i>	Ash, Mountain	Rosaceae	x			x		x		
362	G	<i>Sorbus torminalis</i>	Checkertree	Rosaceae				x		x		
363	H	<i>Spiraea betulifolia</i>	Spirea, White	Rosaceae			x			x		
364	G	<i>Symphoricarpos albus</i>	Snowberry, Common	Caprifoliaceae	x			x		x		
365	F	<i>Symphoricarpos occidentalis</i>	Snowberry, Western	Caprifoliaceae	x			x		x		

Plate #	Group	Plant Scientific Name	nticlinal Walls			Stomata Morphology			Stomata Pattern		Stomata Subsidiary Cells			Trichon		
			sin	str	s-c	LWL-UWL	pol	stm	par	ran	ano	bra	tet	unb	d-e	seg
296	B	<i>Pinus ponderosa</i>	x			w	w	w	x				x			
297	B	<i>Pinus resinosa</i>	x			w	w	w	x				x			
298	B	<i>Pinus rigida</i>				w	w	w	x				x			
299	B	<i>Pinus sabiniana</i>				w	w	w	x				x			
300	B	<i>Pinus strobus</i>				w	w	w	x				x			
301	B	<i>Pinus sylvestris</i>				w	w	w	x				x			
302	B	<i>Pinus taeda</i>				w	w	w	x				x			
303	B	<i>Pinus virginiana</i>				w	w	w	x				x			
304	H	<i>Platanus occidentalis</i>			x	w	w	n		x						
305	G	<i>Platanus racemosa</i>			x	w	w	w		x					x	
306	G	<i>Populus alba</i>			x	w	m	w		x					x	
307	D	<i>Populus angustifolia</i>			x	w	w	n		x		x				
308	D	<i>Populus balsamifera</i>			x	w	w	n		x		x			x	
309	H	<i>Populus deltoides</i>		x	x	w	m	n		x						
310	H	<i>Populus grandidentata</i>		x	x	w	m	n		x						
311	H	<i>Populus nigra</i> 'Italica'		x	x	w	m	n		x						
312	D	<i>Populus tremuloides</i>		x	x	w	w	n		x		x				
313	G	<i>Potamogeton gramineus</i>			x	n	w	n		x					x	
314	H	<i>Prosopis juliflora</i>			x	w	w	n		x						
315	H	<i>Prunus americana</i>			x	w	w	n		x						
316	H	<i>Prunus caroliniana</i>			x	n	w	w		x						
317	G	<i>Prunus domestica</i>			x	n	w	w		x					x	
318	H	<i>Prunus pensylvanica</i>		x	x	n	w	w		x						
319	G	<i>Prunus persica</i>		x	x	n	w	w		x					x	
320	G	<i>Prunus serotina</i>		x	x	n	w	w		x					x	
321	H	<i>Prunus virginiana</i>		x	x	n	w	w		x						
322	B	<i>Pseudotsuga menziesii</i> var. <i>glauca</i>		x	x	m	w	w	x				x			
323	G	<i>Pteridium aquilinum</i>			x	w	w	w	x						x	
324	G	<i>Purshia tridentata</i>			x	n	n	w		x					x	
325	H	<i>Pyrola secunda</i>			x	n	w	w		x						
326	H	<i>Quercus agrifolia</i>			x	m	w	w		x						
327	H	<i>Quercus alba</i>		x	x	m	w	w		x						
328	E	<i>Quercus bicolor</i>		x	x	m	w	w		x						
329	H	<i>Quercus chrysolepis</i>		x	x	m	w	w		x						
330	H	<i>Quercus coccinea</i>		x	x	m	w	w		x						
331	E	<i>Quercus gambelii</i>		x	x	m	w	w		x					x	
332	H	<i>Quercus laurifolia</i>		x	x	w	w	w		x						
333	E	<i>Quercus macrocarpa</i>		x	x	w	w	w		x					x	
334	H	<i>Quercus nigra</i>		x	x	w	w	w		x						
335	H	<i>Quercus palustris</i>		x	x	n	n	w		x						
336	H	<i>Quercus rubra</i>		x	x	w	w	w		x						
337	E	<i>Quercus stellata</i>		x	x	w	w	w		x						
338	E	<i>Quercus velutina</i>		x	x	w	w	w		x						
339	E	<i>Quercus virginiana</i>		x	x	w	w	w		x						
340	H	<i>Rhamnus cathartica</i>	x			x	w	n	w	x						
341	H	<i>Rhamnus frangula</i>				x	m	m	w	x						
342	H	<i>Rhododendron macrophyllum</i>				x	n	m	w	x						
343	H	<i>Rhododendron maximum</i>				x	n	m	w	x						
344	H	<i>Rhus aromatica</i>				x	n	w	n	x						
345	G	<i>Rhus copallinum</i>				x	w	n	n	x					x	
346	H	<i>Ribes aureum</i>				x	w	w	w		x					
347	G	<i>Ribes inerme</i>				x	n	w	w		x				x	
348	G	<i>Ribes lacustre</i>		x	x	n	w	w		x					x	
349	G	<i>Ribes oxycanthoides</i> spp. <i>cognatum</i>		x	x	n	w	w		x					x	
350	G	<i>Ribes viscosissimum</i>				x	n	w	n		x				x	
351	G	<i>Robinia pseudoacacia</i>		x	x	n	n	n		x					x	
352	G	<i>Rosa woodsii</i>		x	x	n	w	m		x					x	
353	G	<i>Rubus fruticosus</i>		x	x	n	w	w		x					x	
354	G	<i>Rubus idaeus</i> ssp. <i>strigosus</i>		x	x	n	w	w		x					x	
355	F	<i>Rubus parviflorus</i>		x	x	n	w	w		x						x
356	D	<i>Salix fragilis</i>		x	x	w	w	w		x		x			x	
357	G	<i>Sambucus racemosa</i>		x	x	w	w	w		x					x	
358	H	<i>Sassafras albidum</i>		x	x	m	m	w		x						
359	F	<i>Shepherdia canadensis</i>		x	x	m	w	w		x					x	
360	D	<i>Smilax tamnoides</i>		x	x	w	n	w		x		x			x	
361	H	<i>Sorbus americana</i>		x	x	w	w	n		x						
362	G	<i>Sorbus torminalis</i>		x	x	n	w	w		x					x	
363	H	<i>Spiraea betulifolia</i>		x	x	n	m	w		x						
364	G	<i>Symphoricarpos albus</i>		x	x	n	w	w		x					x	
365	F	<i>Symphoricarpos occidentalis</i>		x	x	n	w	n		x					x	

Plate #	Group	Plant Scientific Name	es		Inclusions				
			mlt	stl	crb	oxl	sil	sth	
296	B	<i>Pinus ponderosa</i>					x		
297	B	<i>Pinus resinosa</i>							
298	B	<i>Pinus rigida</i>							
299	B	<i>Pinus sabiniana</i>							
300	B	<i>Pinus strobus</i>							
301	B	<i>Pinus sylvestris</i>							
302	B	<i>Pinus taeda</i>							
303	B	<i>Pinus virginiana</i>							
304	H	<i>Platanus occidentalis</i>			x	x			
305	G	<i>Platanus racemosa</i>				x			
306	G	<i>Populus alba</i>			x	x			
307	D	<i>Populus angustifolia</i>			x	x			
308	D	<i>Populus balsamifera</i>				x			
309	H	<i>Populus deltoides</i>				x			
310	H	<i>Populus grandidentata</i>			x				
311	H	<i>Populus nigra</i> 'Italica'			x				
312	D	<i>Populus tremuloides</i>			x				
313	G	<i>Potamogeton gramineus</i>				x			
314	H	<i>Prosopis juliflora</i>					x		
315	H	<i>Prunus americana</i>				x			
316	H	<i>Prunus caroliniana</i>				x			
317	G	<i>Prunus domestica</i>			x	x			
318	H	<i>Prunus pensylvanica</i>				x			
319	G	<i>Prunus persica</i>				x			
320	G	<i>Prunus serotina</i>			x	x			
321	H	<i>Prunus virginiana</i>				x			
322	B	<i>Pseudotsuga menziesii</i> var. <i>glauca</i>							
323	G	<i>Pteridium aquilinum</i>				x			
324	G	<i>Purshia tridentata</i>				x			
325	H	<i>Pyrola secunda</i>				x			
326	H	<i>Quercus agrifolia</i>			x	x			
327	H	<i>Quercus alba</i>			x	x			
328	E	<i>Quercus bicolor</i>		x	x	x			
329	H	<i>Quercus chrysolepis</i>			x	x			
330	H	<i>Quercus coccinea</i>							
331	E	<i>Quercus gambelii</i>	x		x				
332	H	<i>Quercus laurifolia</i>				x			
333	E	<i>Quercus macrocarpa</i>	x		x	x			
334	H	<i>Quercus nigra</i>			x	x			
335	H	<i>Quercus palustris</i>			x	x			
336	H	<i>Quercus rubra</i>			x	x			
337	E	<i>Quercus stellata</i>		x	x				
338	E	<i>Quercus velutina</i>		x	x	x			
339	E	<i>Quercus virginiana</i>		x	x	x			
340	H	<i>Rhamnus cathartica</i>							
341	H	<i>Rhamnus frangula</i>			x	x			
342	H	<i>Rhododendron macrophyllum</i>							
343	H	<i>Rhododendron maximum</i>				x			
344	H	<i>Rhus aromatica</i>							
345	G	<i>Rhus copallinum</i>				x			
346	H	<i>Ribes aureum</i>				x			
347	G	<i>Ribes inerme</i>				x			
348	G	<i>Ribes lacustre</i>				x			
349	G	<i>Ribes oxycanthoides</i> spp. <i>cognatum</i>				x			
350	G	<i>Ribes viscosissimum</i>				x			
351	G	<i>Robinia pseudoacacia</i>				x	x		
352	G	<i>Rosa woodsii</i>				x			
353	G	<i>Rubus fruticosus</i>				x			
354	G	<i>Rubus idaeus</i> ssp. <i>strigosus</i>				x			
355	F	<i>Rubus parviflorus</i>				x			
356	D	<i>Salix fragilis</i>			x	x			
357	G	<i>Sambucus racemosa</i>				x			
358	H	<i>Sassafras albidum</i>							
359	F	<i>Shepherdia canadensis</i>				x			
360	D	<i>Smilax tamnoides</i>					x		
361	H	<i>Sorbus americana</i>			x	x			
362	G	<i>Sorbus torminalis</i>			x				
363	H	<i>Spiraea betulifolia</i>				x			
364	G	<i>Symphoricarpos albus</i>				x			
365	F	<i>Symphoricarpos occidentalis</i>				x			

Plate #	Group	Plant Scientific Name	Common Name	Family	Epidermal Morphology				Epidermal Pattern			A
					s/r	par	irr	pol	stk	ran	wav	
366	G	<i>Symphoricarpos orbiculatus</i>	Coralberry, Indiancurrant	Caprifoliaceae	x			x		x		
367	B	<i>Taxus brevifolia</i>	Yew, Pacific	Taxaceae	x	x			x			
368	B	<i>Taxus canadensis</i>	Yew, Canada	Taxaceae	x	x			x			
369	B	<i>Thuja occidentalis</i>	White-cedar, Northern	Cupressaceae		x			x			
370	B	<i>Thuja plicata</i>	Redcedar, Western	Cupressaceae	x	x			x			
371	G	<i>Tilia americana</i>	Basswood, American	Tiliaceae	x	x				x		
372	H	<i>Tilia cordata</i>	Linden, Littleleaf	Tiliaceae	x			x		x		
373	G	<i>Toxicodendron radicans</i>	Ivy, Poison	Anacardiaceae			x			x		
374	B	<i>Tsuga canadensis</i>	Hemlock, Eastern	Pinaceae	x				x			
375	B	<i>Tsuga mertensiana</i>	Hemlock, Mountain	Pinaceae	x				x			
376	G	<i>Ulmus alata</i>	Elm, Winged	Ulmaceae	x			x		x		
377	G	<i>Ulmus americana</i>	Elm, American	Ulmaceae	x			x		x		
378	G	<i>Ulmus glabra</i>	Elm, Wych	Ulmaceae	x			x		x		
379	H	<i>Ulmus pumila</i>	Siberian Elm	Ulmaceae	x			x		x		
380	G	<i>Ulmus rubra</i>	Elm, Slippery	Ulmaceae	x			x		x		
381	G	<i>Ulmus thomasi</i>	Elm, Rock	Ulmaceae			x	x		x		
382	D	<i>Vaccinium angustifolium</i>	Blueberry, Lowbush	Ericaceae	x			x		x		
383	G	<i>Vaccinium membranaceum</i>	Huckleberry, Thinleaf	Ericaceae	x			x		x		
384	G	<i>Viburnum opulus</i>	Cranberrybush, European	Caprifoliaceae	x			x		x		
385	H	<i>Viburnum prunifolium</i>	Blackhaw	Caprifoliaceae			x	x		x		
386	H	<i>Viburnum rufidulum</i>	Rusty Blackhaw	Caprifoliaceae			x	x		x		
387	F	<i>Vitis riparia</i>	Grape, Riverbank	Vitaceae	x			x		x		

Plate #	Group	Plant Scientific Name	nticlinial Walls			Stomata Morphology			Stomata Pattern		Stomata Subsidiary Cells			Trichon		
			sin	str	s-c	LWL-UWL	pol	stm	par	ran	ano	bra	tet	unb	d-e	seg
366	G	<i>Symphoricarpos orbiculatus</i>		x	x	n	w	n		x				x		
367	B	<i>Taxus brevifolia</i>		x	x	n	m	n	x				x			
368	B	<i>Taxus canadensis</i>		x	x	n	m	n	x				x			
369	B	<i>Thuja occidentalis</i>			x	n	n	n	x	\			x			
370	B	<i>Thuja plicata</i>			x	n	n	n	x				x			
371	G	<i>Tilia americana</i>		x	x					x					x	
372	H	<i>Tilia cordata</i>		x	x	w	w	w		x						
373	G	<i>Toxicodendron radicans</i>		x	x	n	w	w		x					x	
374	B	<i>Tsuga canadensis</i>		x	x	w	w	n	x				x			
375	B	<i>Tsuga mertensiana</i>		x	x	w	w	n	x				x			
376	G	<i>Ulmus alata</i>			x	n	n	w		x					x	
377	G	<i>Ulmus americana</i>			x	n	n	n		x					x	
378	G	<i>Ulmus glabra</i>		x	x	n	w	n		x					x	
379	H	<i>Ulmus pumila</i>		x	x	w	n	n		x						
380	G	<i>Ulmus rubra</i>		x	x	w	n	n		x					x	
381	G	<i>Ulmus thomasii</i>		x	x	w	n	n		x					x	
382	D	<i>Vaccinium angustifolium</i>		x	x	w	w	w		x		x				
383	G	<i>Vaccinium membranaceum</i>		x	x	w	w	w		x					x	
384	G	<i>Viburnum opulus</i>		x	x	n	n	n		x					x	
385	H	<i>Viburnum prunifolium</i>		x	x	n	w	n		x						
386	H	<i>Viburnum rufidulum</i>		x	x	n	w	n		x						
387	F	<i>Vitis riparia</i>		x	x	n	n	n		x						x

Plate #	Group	Plant Scientific Name	es		Inclusions			
			mlt	stl	crb	oxl	sil	sth
366	G	<i>Symphoricarpos orbiculatus</i>						
367	B	<i>Taxus brevifolia</i>						
368	B	<i>Taxus canadensis</i>						
369	B	<i>Thuja occidentalis</i>						
370	B	<i>Thuja plicata</i>						
371	G	<i>Tilia americana</i>			x			
372	H	<i>Tilia cordata</i>			x			
373	G	<i>Toxicodendron radicans</i>			x	x		
374	B	<i>Tsuga canadensis</i>						
375	B	<i>Tsuga mertensiana</i>						
376	G	<i>Ulmus alata</i>			x			
377	G	<i>Ulmus americana</i>			x			
378	G	<i>Ulmus glabra</i>				x		
379	H	<i>Ulmus pumila</i>				x		
380	G	<i>Ulmus rubra</i>			x	x		
381	G	<i>Ulmus thomasi</i>			x	x		
382	D	<i>Vaccinium angustifolium</i>						
383	G	<i>Vaccinium membranaceum</i>			x	x		
384	G	<i>Viburnum opulus</i>			x	x		
385	H	<i>Viburnum prunifolium</i>				x		
386	H	<i>Viburnum rufidulum</i>						
387	F	<i>Vitis riparia</i>				x	x	

4.4 Description and Photographic Plates

The plant descriptions and photographic plates are arranged in alphabetic order by scientific name. A total of 231 samples are presented of which 47 are gymnosperms, one monilophyte (fern) and 183 angiosperms. Generally, gymnosperms consist of parallel rows of stomata and epidermal cells that are arranged end-to-end and stacked brick-like. Genera of gymnosperms are differentiated by stomata shape (parallel sides, rounded, etc), stomata subsidiary cells (tetracytic) and stomata morphology. The primary method to differentiate gymnosperm genera is by stomatal morphology. True firs have a wide separation between the lower woody lamella and the upper woody lamella (LWL-UWL) and have moderately wide polar stems. The spacing between the LWL-UWL is moderate for false firs however the polar stems are wider. Junipers have a narrow LWL-UWL spacing and narrow polar stems. LWL-UWL spacing is similar for spruces however polar stems are wide. Pines have a wide LWL-UWL spacing and wide polar stems.

Monilophytes and angiosperms generally consist of irregular to polygonal epidermal cells in a random pattern and anticlinal walls that are straight, straight-curved or irregular shaped. Stomatal patterning is random except for monocots which have parallel stomatal patterning. Stomata subsidiary cells are usually randomly arranged (anomocytic) and occasionally brachyparacytic (pair of subsidiary cells on each side of the long axis of the stoma pore). Trichomes, when present, range from unbranched to double-ended, multiple fibers join at a single base, or stellate. Inclusions, when present, include calcium carbonates, calcium oxalate, starch and silica. Plants may have multiple varieties of trichomes and/or inclusions. Many times, multiple characteristics are used to differentiate genera and species. The primary determinant should be availability; if a plant is not available to be foraged, it will not be a part of the fecal pellet.

***Abies balsamea*, balsam fir;**

Family: Pinaceae (Plate 156)

Macroscopic Characteristics: Needles are grooved, flattened and linear, approximately 1.3-3.2 cm in length with parallel sides (Kershner, Nelson and Spellenberg 2008). A pair of distinctive stomatal lines occur on each side of the central rib of the abaxial surface. Scattered stomatal dots are near the midline on the adaxial surface.

Microscopic Characteristics: Epidermal cells are elongated parallelogram shaped structures with a length/width ratio of 1:1 to 3:1. Anticlinal walls are thick and verrucate; the long axis of epidermal cells are stacked in parallel brick-like rows. No phytoliths or trichomes were observed.

Stomata patterning is ordered into parallel rows; stoma pores are aligned parallel to the long axis of epidermal cells. The stoma is roughly rectangular in outline with nearly straight lateral sides and polar ends are angular. A pair of crescent guard cells surround an oval to fusiform shaped stoma pore with a thickened inner wall. The lower woody lamella is 5-10 microns longer than the upper woody lamella. The polar stems are relatively narrow.

Abies balsamea
balsam fir

Plate
156

Legend

Epidermal cells are parallelogram to rectangular shaped with verrucate anticlinal walls. Cells are arranged end-to-end and are stacked brick-like. Stomata are in parallel rows with crescent shaped guard cells surrounding an oblong to fusiform shaped pore. The spacing between lower and upper woody lamella is greater than 5 microns, polar stems are relatively narrow.
(PLM, single polar)

Abies concolor, white fir;

Family: Pinaceae (Plate 157)

Macroscopic Characteristics: Needles are grooved, flattened and linear, approximately 3.8-6.4 cm in length with parallel sides and rounded tip (Kershner, Nelson and Spellenberg 2008). Rows of stomatal dots are visible on the adaxial and abaxial surfaces. Three to seven rows were observed on each side of the central groove.

Microscopic Characteristics: Epidermal cells are elongated rectangular to parallelogram shaped structures with a length/width ratio of 1:1 to greater than 5:1. Anticlinal walls are straight to verrucate; the long axis of epidermal cells are stacked in parallel brick-like rows. No phytoliths or trichomes were observed.

Stomata patterning is ordered into parallel rows. Stoma pores are axially aligned to the long axis of epidermal cells. The stoma is roughly rectangular in outline with nearly straight lateral sides and angular polar ends. A pair of crescent guard cells, with three to five circular chloroplasts per cell, surround an oval to round stoma pore. The lower woody lamella is 5-10 microns longer than the upper woody lamella. The polar stems are relatively narrow.

Abies concolor
white fir

Plate
157

***Abies fraseri*, Fraser fir;**

Family: Pinaceae (Plate 158)

Macroscopic Characteristics: Needles are grooved, flattened and linear, approximately 1.3-2.5 cm in length with parallel sides and blunt tip (Kershner, Nelson and Spellenberg 2008). Abaxial surface consists of two white stomatal lines on either side of the central groove.

Microscopic Characteristics: Epidermal cells are elongated rectangular to parallelogram shaped structures. Abaxial cells around the stomata rows have a length to width ratio of 1:1 to 5:1; epidermal cells on adaxial surface have a length to width ratio greater than 5:1. Anticlinal walls are sinuous to verrucate; the long axis of epidermal cells are stacked in parallel brick-like rows. No phytoliths or trichomes were observed.

Stomata patterning is ordered into parallel rows; stoma pores are aligned parallel to the long axis of epidermal cells. The stoma is roughly rectangular in outline with nearly straight lateral sides and polar ends are angular. A pair of guard cells surround a flattened oval stoma pore. Stomata are oriented in linear closely-spaced rows. The lower woody lamella is 5-10 microns longer than the upper woody lamella. The polar stems are relatively narrow.

Abies fraseri
Fraser fir

Plate
158

***Abies grandis*, grand fir;**

Family: Pinaceae (Plate 159)

Macroscopic Characteristics: Needles are grooved, flattened and linear, approximately 3.2-5 cm in length with parallel sides and notched tip sides (Kershner, Nelson and Spellenberg 2008). A pair of white stomatal lines are prominent on either side of the central groove of the abaxial surface; no stomatal pores were observed on the adaxial surface.

Microscopic Characteristics: Epidermal cells within stomatal rows are square with occasional rectangular shaped structures. Length to width ratio ranges from 1:1 to 3:1. Epidermal cells outside the stomatal rows are rectangular shaped structures with length; to width ratios of 5:1 and greater. Anticlinal walls are sinuous to verrucate; the long axis of epidermal cells are stacked in parallel brick-like rows. No phytoliths or trichomes were observed.

Stomata, nearly circular, are oriented in linear closely-spaced rows. The stoma is roughly rectangular in outline with nearly straight lateral sides and polar ends are angular. A pair of crescent guard cells surround an oval to fusiform shaped stoma pore with a thickened inner wall. Stoma pores are aligned parallel to the stomata row axis and the long axis of epidermal cells. The inner walls of guard cells are nearly straight and parallel. The lower woody lamella is 5-10 microns longer than the upper woody lamella. The polar stems are relatively narrow.

Abies grandis
grand fir

Plate
159

***Abies lasiocarpa*, subalpine fir;**

Family: Pinaceae (Plate 160)

Macroscopic Characteristics: Needles are flattened and linear, approximately 1.9-3.8 cm in length and 0.2 cm thick with parallel sides and rounded apex (Kershner, Nelson and Spellenberg 2008). A pair of stomatal lines occur on each side of the central rib of the abaxial surface. A central stomatal line occurs on the adaxial surface along the central groove.

Microscopic Characteristics: Epidermal cells are elongated parallelogram shaped structures with a length/width ratio of 1:1 to greater than 5:1. Anticlinal walls are wavy to verrucate; the long axis of epidermal cells are stacked in parallel brick-like rows. No phytoliths or trichomes were observed.

Stomata patterning is ordered into parallel rows; stoma pores are aligned axially to the long axis of epidermal cells. A pair of crescent shaped guard cells surround a cigar shaped stoma pore. Spacing between the lower woody lamellae and upper woody lamella is greater than 5 microns. The stoma is roughly rectangular in outline. The lower woody lamella is 5-10 microns longer than the upper woody lamella. The polar stems are relatively narrow.

Abies lasiocarpa
subalpine fir

Plate
160

Legend

Top Image: Epidermal cells are rectangular to parallelogram shaped with square ends. Anticlinal walls are wavy to verrucate. Stomata are aligned into parallel rows.
(PLM, single polar)

Bottom Image: Stomata with a pair of crescent shaped guard cells surrounding a fusiform shaped pore. The LWL-UWL spacing is wide. The polar stems are relatively narrow
(PLM, single polar)

Acer ginnala, Amur maple;

Family: Sapindaceae (Plate 161)

Macroscopic Characteristics: Leaves are three lobed with coarsely serrated margins, leaves are approximately 7.5 cm in length (Kershner, Nelson and Spellenberg 2008). The adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are polygonal shaped with an approximately length to width aspect ratio of 1:1. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. No trichomes or phytoliths were observed.

Anomocytic stomata occur randomly among the epidermal cells. The stoma consists of a pair of crescent shaped guard cells surrounding an oval pore. The stoma is slightly oblong with a length to width ratio of 1.4:1. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides but wide at polar ends. Polar stems are narrow.

Acer ginnala
Amur maple

Plate
161

Legend

Top Image: Anomocytic stomata are randomly arranged in the epidermal cell matrix. Stomata consist of two crescent shaped guard cells surrounding an oval pore. The length to width ratio of the stoma is approximately 1.4:1.
(PLM, single polar)

Bottom Image: Epidermal cells are polygonal shaped with a length to width ratio of approximately 1:1. Anticlinal walls are straight to straight-curved.
(PLM, single polar)

***Acer glabrum*, mountain maple;**

Family: Sapindaceae (Plate 162)

Macroscopic Characteristics: Leaves are three to five lobed with double serrated margins. Leaves are approximately 7.5-12.5 cm in length and width (Kershner, Nelson and Spellenberg 2008). The adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are polygonal shaped with an approximately length to width ratio that ranges from 1:1 to 2:1. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Globular shaped calcium oxalate druses are randomly arranged in the epidermal cell matrix. No trichomes were observed.

Anomocytic stomata occur randomly among the epidermal cells. The stoma consists of a pair of crescent shaped guard cells surrounding an oval pore. The stoma is slightly oblong with a length to width ratio of 1.3:1. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides but wide at polar ends. Polar stems are narrow.

Acer glabrum
mountain maple

Plate
162

Legend

Top image: Polygonal shaped epidermal cells with straight anticlinal walls are arranged in a flagstone pattern. Anomocytic stomata are randomly arranged in the epidermal cell matrix. The stoma consists of two crescent shaped guard cells surrounding an oval pore.
(PLM, single polar)

Bottom image: Globular shaped calcium oxalate crystals are randomly arranged in the epidermal cell matrix.
(PLM, single polar)

***Acer grandidentatum*, bigtooth maple;**

Family: Sapindaceae (Plate 163)

Macroscopic Characteristics: Leaves are three to five lobed with double serrate margins. Overall leaf length is approximately 5-12.5 cm (Kershner, Nelson and Spellenberg 2008). Hairs are abundant on the abaxial surface, especially along leaf veins.

Microscopic Characteristics: Epidermal cells are irregular shaped. Cells are arranged in a flagstone or jigsaw puzzle pattern. Anticlinal walls are straight to straight-curved. Abundant calcium carbonate rhombohedral druses are aligned with leaf veins. Trichomes are straight spears with straight sides and pointed apices. Most trichome bases are near or overlie the veins. Those bases that are located in the epidermal cell matrix are circular with reinforcing rays.

Anomocytic stomata are randomly located in the epidermal cell fields. Stomata consist of two crescent guard cells surrounding an oval pore. The stoma is nearly circular with a length to width ratio of 1.1:1. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides but wide at polar ends. Polar stems are narrow.

Acer grandidentatum
bigtooth maple

Plate
163

***Acer macrophyllum*, bigleaf maple;**

Family: Sapindaceae (Plate 164)

Macroscopic Characteristics: Leaves consist of five deeply divided lobes that are bluntly pointed. Margins are untoothed and the approximately length is 15-30 cm (Kershner, Nelson and Spellenberg 2008).

Microscopic Characteristics: Epidermal cells are polygonal shaped with an approximately length to width ratio that ranges from 1:1 to 2:1. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Abundant calcium carbonate rhombohedral druses are aligned with leaf veins.

Anomocytic stomata are randomly located in the epidermal cell matrix. Stomata consist of two crescent guard cells surrounding an oblong pore. The stoma is slightly oblong with a length to width ratio that ranges from 1.3:1 to 1.6:1. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides but wide at polar ends. Polar stems are narrow.

Acer macrophyllum
bigleaf maple

Plate
164

***Acer negundo*, boxelder;**

Family: Sapindaceae (Plate 165)

Macroscopic Characteristics: Leaves are pinnately compound with three to five leaflets per stem. Each leaflet is three-lobed with the central lobe longer than the two side lobes. Leaflet length is approximately 5-10 cm (Kershner, Nelson and Spellenberg 2008). Hairs are abundant along leaf veins of the abaxial surface.

Microscopic Characteristics: Epidermal cells are polygonal shaped with an approximately length to width ratio of 1:1. Cells are arranged in a flagstone pattern. Anticlinal walls are straight. Abundant globular calcium oxalate druses and occasional calcium carbonate rhombohedrals are located along leaf veins. Hollow curved trichomes with a pointed apex are attached to epidermal cells. Trichomes have a bulbous end with a hexangle base; a rosette of epidermal cells surrounds the base attachment.

Anomocytic stomata are randomly located in the epidermal cell matrix. Stomata consist of two crescent guard cells surrounding an oval pore. The stoma is nearly circular with a length to width ratio of 1.3:1. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides but wide at polar ends. Polar stems are narrow

Acer negundo
boxelder

Plate
165

Legend

Top image: Epidermal cells are polygonal shaped and arranged in a flagstone pattern. Anticlinal walls are straight. Anomocytic stomata are randomly located in the epidermal cell matrix. Stomata consist of two crescent shaped guard cells that surround an oval pore.
(PLM, single polar)

Bottom image: Trichomes are hollow with wavy to straight sides; they are attached to a hexangle epidermal base.
(PLM, single polar)

***Acer nigrum*, black maple;**

Family: Sapindaceae (Plate 166)

Macroscopic Characteristics: Leaves are three-lobed with moderately divided lobes. Width is approximately 10-15 cm; length is slightly less (Kershner, Nelson and Spellenberg 2008). Numerous hairs are present on abaxial surface.

Microscopic Characteristics: Epidermal cells are polygonal shaped and arranged in a flagstone or jigsaw puzzle pattern. Anticlinal walls are straight to straight-curved. Abundant calcium carbonates rhombohedral druses are located along leaf veins. Trichomes are slightly curved spears with straight sides and pointed apexes. Most trichome bases are near or overlie the veins. Bases located in the epidermal cell matrix are hexangle and surrounded by a rosette ring of epidermal cells.

Anomocytic stomata are randomly located in the epidermal cell fields. Stomata consist of two crescent guard cells surrounding an oval pore. The stoma is nearly circular with a length to width ratio of 1.3:1. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides but wide at polar ends. Polar stems are narrow.

Acer nigrum
black maple

Plate
166

Legend

Top Image: Abundant calcium carbonate rhombohedral druses are aligned with leaf veins. Trichomes are slightly curved with straight sides and pointed apices.
(PLM, crossed polars)

Bottom Image: Polygonal shaped epidermal cells with straight to straight-curved anti-clinal walls are arranged in a flagstone pattern. Trichome bases consist of a central cell surrounded by a rosette of epidermal cells.
(PLM, single polar)

Acer pensylvanicum, striped maple;

Family: Sapindaceae (Plate 167)

Macroscopic Characteristics: Leaves are tri-lobed with an approximately length and width of 13-23 cm (Kershner, Nelson and Spellenberg 2008). Margin are finely serrate; adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are polygonal with a length to width ratio of 1:1. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Abundant globular calcium oxalate druses are randomly arranged in the epidermal cell matrix. Occasional calcium carbonates rhombohedral druses are located along leaf veins and in the epidermal cell matrix.

Anomocytic stomata are randomly located in the epidermal cell fields. Stomata consist of two crescent shaped guard cells surrounding an oval to fusiform shaped pore. The lateral margins are curved and the polar ends project beyond the margins of the guard cells. A pair of phytoliths are located at the polar ends of many guard cells. The stoma is oblong with a length to width ratio of 1.7:1. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides but wider at polar ends. Polar stems are narrow.

Acer pensylvanicum
striped maple

Plate
167

Legend

Top Image: Polygonal shaped epidermal cells with straight to straight-curved anticlinal walls are arranged in a flagstone pattern. Oblong stomata with a pair of crescent shaped guard cells surrounding an oval to fusiform pore. Stomata are randomly arranged. Many of the stomata have phytoliths at polar ends.
(PLM, single polar)

Bottom Image: Abundant calcium oxalate druses are present.
(PLM, single polar)

Acer platanoides, Norway maple;

Family: Sapindaceae (Plate 168)

Macroscopic Characteristics: Leaves are palmately lobed with five moderately divided lobes. Length is approximately 13-20 cm in length cm (Kershner, Nelson and Spellenberg 2008). Lobes are partially toothed; adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are irregular to polygonal shaped and arranged in a flagstone or jigsaw puzzle pattern. Anticlinal walls are straight to straight-curved. Abundant calcium carbonates rhombohedral druses are located along leaf veins.

Anomocytic stomata are randomly located in the epidermal cell fields. Stomata consist of two crescent shaped guard cells surrounding an oval to fusiform shaped pore. The stoma shape is roughly circular to oval. The stoma length to width ratio ranges from 1.2:1 to 1.5:1. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides but wider at polar ends. Polar stems are narrow.

Acer platanoides
Norway maple

Plate
168

Legend

Top Image: Irregular shaped epidermal cells with straight to straight-curved anticlinal walls are arranged in a flagstone pattern. Oval stomata with a pair of crescent shaped guard cells surrounding an oval to fusiform pore, stomata are randomly arranged. (PLM, single polar)

Bottom Image: Abundant calcium carbonate rhombohedral druses are aligned with leaf veins. (PLM, single polar)

***Acer rubrum*, red maple;**

Family: Sapindaceae (Plate 169)

Macroscopic Characteristics: Leaves are palmate and consist of three to five shallowly divided lobes. Length is approximately 6-13 cm with coarsely toothed margins (Kershner, Nelson and Spellenberg 2008). Leaves are glabrous except for some hairs on abaxial veins.

Microscopic Characteristics: Epidermal cells are irregular shaped and arranged in a jigsaw puzzle pattern. Anticlinal walls are straight to straight-curved. Calcium oxalate and calcium carbonates druses are randomly located in the epidermal cell matrix.

Anomocytic stomata are randomly located in the epidermal cell fields. Stomata consist of two crescent shaped guard cells surrounding an oval to fusiform shaped pore. The stoma shape is roughly circular to oval. The stoma length to width ratio is approximately 1.4:1. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides but wider at polar ends. Polar stems are narrow.

Acer rubrum
red maple

Plate
169

Legend

Top Image: Oblong stomata with a pair of crescent shaped guard cells surround an oval to fusiform shaped pore. Stomata are randomly arranged.
(PLM, single polar)

Bottom Image: Irregular shaped epidermal cells with straight to straight-curved anticlinal walls are arranged in a flagstone pattern. Calcium oxalate and calcium carbonate druses are randomly arranged in the epidermal cell matrix.
(PLM, single polar)

***Acer saccharinum*, silver maple;**

Family: Sapindaceae (Plate 170)

Macroscopic Characteristics: Leaves are palmate with five deeply divided lobes. Length is approximately 13-18 cm with coarsely toothed margins (Kershner, Nelson and Spellenberg 2008). Leaves are glabrous with a glossy adaxial surface and dull abaxial surface.

Microscopic Characteristics: Epidermal cells are polygonal shaped with a length to width ratio that ranges from 1:1 to 2:1. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Occasional calcium oxalate druses are randomly located in the epidermal cell matrix. Abundant slight hooked trichomes are attached to veins and epidermal cells. Trichomes attached to veins radiate inward toward a common center. When attached to epidermal cells, the base is oval to hexangle with a rosette of epidermal cells surrounding the base.

Anomocytic stomata are randomly located in the epidermal cell fields. Stomata consist of two crescent shaped guard cells surrounding an oval to fusiform shaped pore. The stoma shape is roughly circular to oval. The stoma length to width ratio is approximately 1.3:1. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides but wider at polar ends. Polar stems are narrow.

Acer saccharinum
silver maple

Plate
170

Legend

Top Image: Polygonal shaped epidermal cells with straight to straight-curved anticlinal walls are arranged in a flag-stone pattern. Calcium oxalate druses are randomly arranged in the epidermal cell matrix. Slightly curved trichomes are attached to veins and epidermal cells.
(PLM, single polar)

Bottom Image: Stomata consist of a pair of crescent shaped guard cells that surround a fusiform pore.
(PLM, single polar)

***Acer spicatum*, mountain maple;**

Family: Sapindaceae (Plate 171)

Macroscopic Characteristics: Leaves are palmate with three to five shallowly divided lobes. Length and width is approximately 6-13 cm with coarsely toothed margins (Kershner, Nelson and Spellenberg 2008). The adaxial surface is glabrous however scattered hairs were observed on the abaxial surface and on veins.

Microscopic Characteristics: Epidermal cells are irregular shaped and arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Calcium oxalate druses are randomly located in the epidermal cell matrix. Trichomes are fat and short with sharp apexes.

Anomocytic oblong stomata are randomly located in the epidermal cell fields. Stomata consist of two crescent shaped guard cells surrounding an oval to fusiform shaped pore. The stoma length to width ratio is approximately 2:1. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides but wider at polar ends. Polar stems are narrow.

Acer spicatum
mountain maple

Plate
171

Legend

Top Image: Irregular shaped epidermal cells with straight to straight-curved anticlinal walls are arranged in a flag-stone pattern. Calcium oxalate druses are randomly arranged in the epidermal cell matrix. Trichomes are attached to epidermal cells.
(PLM, single polar)

Bottom Image: Stomata consist of a pair of crescent shaped guard cells that surround an oval to fusiform shaped pore.
(PLM, single polar)

Aesculus hippocastanum, horsechestnut;

Family: Hippocastanaceae (Plate 172)

Macroscopic Characteristics: Leaves are palmately compound with 5-7 leaflets per stalk. Leaflets are ovoid to obovate with a length of approximately 10-25 cm and width of 5-13 cm (Kershner, Nelson and Spellenberg 2008). Margins are finely serrate. The adaxial surface is glabrous whereas the abaxial surface has a few hair and abundant hairs on the veins.

Microscopic Characteristics: Epidermal cells are polygonal to irregular shaped and arranged in a flagstone pattern. Calcium oxalate druses are scattered randomly in the epidermal cell matrix. Oblong cells with sharp apexes are randomly located in the epidermal cell matrix. These cells are approximately 30 microns by 15 microns; the outer margin is bordered by sharp spines. Vein hairs are flat and twisted with a tan to brown coloration.

Anomocytic stomata are randomly arranged in the epidermal cell matrix. The stomata consist of a pair of crescent shaped guard cells surrounding a fusiform pore. The length to width ratio of the stomatal complex is approximately 1.1:1. The separation between the upper woody lamella and lower woody lamella is relatively wide on the lateral sides but wide at polar ends. Polar stems are narrow.

Aesculus hippocastanum
horsechestnut

Plate
172

***Alnus incana rugosa*, speckled alder;**

Family: Betulaceae (Plate 173)

Macroscopic Characteristics: Leaves are ovate to elliptic shaped with pointed tip. Leaf length is approximately 5-12.5 cm. (Kershner, Nelson and Spellenberg 2008). Margins are doubly serrate. Occasional hairs were observed along the adaxial leaf veins; the abaxial surface was hairy.

Microscopic Characteristics: Epidermal cells are polygonal shaped and arranged in a flagstone pattern. Anticlinal walls are straight-curved. Calcium oxalate druses are mostly aligned with veins but also scattered randomly in the epidermal cell matrix. Trichomes are straight sided spears with pointed apexes.

Stomata are randomly arranged in the epidermal cell matrix and consist of a pair of crescent shaped guard cells surrounding a fusiform pore. The length to width ratio of the stomatal complex is approximately 1:1.

Alnus incana rugosa
speckled alder

Plate
173

Legend

Top Image: Epidermal cells are polygonal with straight-curved anticlinal walls. Stomata are nearly circular and consist of a pair of crescent shaped guard cells surrounding a fusiform shaped pore. (PLM, single polar)

Bottom Image: Trichomes are straight sided spears with pointed apices. Calcium oxalate druses are mostly aligned with veins. (PLM, slightly crossed polars)

***Alnus rhombifolia*, white alder;**

Family: Betulaceae (Plate 174)

Macroscopic Characteristics: Leaves are elliptic to rectangular with a length of approximately 5-10 cm and width of 2-5 cm (Kershner, Nelson and Spellenberg 2008). Leaf margins are finely serrate. The adaxial surface is glabrous whereas the abaxial surface has occasional hairs with abundant hairs on leaf veins.

Microscopic Characteristics: Epidermal cells are polygonal to irregular shaped and arranged in a flagstone pattern. The length to width ratio of cells range from 1:1 to 3:1. Calcium oxalate druses are scattered randomly in the epidermal cell matrix. Trichomes are straight spears with hollow interiors. The trichome bases are oval to hexangle. Surrounding the base is a rosette of epidermal cells.

Stomata are randomly arranged in the epidermal cell matrix and consist of a pair of crescent shaped guard cells surrounding a wide fusiform pore. The length to width ratio of the stomatal complex is approximately 1.8:1.

Alnus rhombifolia
white alder

Plate
174

Legend

Epidermal cells are polygonal shaped with straight-curved anticlinal walls. The length to width ratio of cells range from 1:1 to 3:1. Abundant calcium oxalate druses are randomly arranged in the epidermal cell matrix. Trichomes are straight spears with hollow interiors. The trichome bases are oval to hexangle bases with a rosette of epidermal cells surrounding the base. (PLM, single polar)

Alnus rubra, red alder;

Family: Betulaceae (Plate 175)

Macroscopic Characteristics: Leaves are elliptic to ovate with a length of approximately 7.5-15 cm (Kershner, Nelson and Spellenberg 2008). Margins are doubly serrate. Occasional hairs were observed along the adaxial leaf veins; the abaxial surface was hairy.

Microscopic Characteristics: Epidermal cells are rectangular shaped with square to slightly rounded ends. Cells are arranged end-to-end in a brick-like pattern. Anticlinal walls are straight. The length to width ratio ranges from 3:1 to 5:1. Anticlinal walls are straight. Globular calcium oxalate druses are abundant along leaf veins and scattered in the epidermal cell matrix. Isotropic phytoliths are occasionally observed. Trichomes are abundant and consist of curved fibers with segmented interior medulla.

Stomata are randomly arranged in the epidermal cell matrix and consist of a pair of crescent shaped guard cells surrounding a narrow pore. The length to width ratio of the stomatal complex is approximately 1.4:1.

Alnus rubra
red alder

Plate
175

Legend

Epidermal cells are rectangular with square to slightly rounded ends. The length to width ratio ranges from 3:1 to 5:1. Anticlinal walls are straight. Globular calcium oxalate druses are abundant along leaf veins and scattered in the epidermal cell matrix. Isotropic phytoliths are occasionally observed. Trichomes are abundant and consist of curved fibers with segmented interior medulla.
(PLM, single polar)

***Alnus viridis*, mountain alder;**

Family: Betulaceae (Plate 176)

Macroscopic Characteristics: Leaves are ovoid with a length of approximately 5-11 cm and width of 4-8 cm. Margins are doubly serrate.

Microscopic Characteristics: Epidermal cells are polygonal to irregular shaped and arranged in a flagstone pattern. Calcium oxalate druses are scattered randomly in the epidermal cell matrix. No trichomes were observed.

Stomata are randomly arranged in the epidermal cell matrix. The stomata consist of a pair of crescent shaped guard cells surrounding a fusiform pore. Stoma lateral sides are curved and polar ends are bluntly pointed. The inner lamella is thick. The length to width ratio of the stoma is approximately 1.1:1.

Alnus viridis
mountain alder

Plate
176

***Amelanchier alnifolia*, Saskatoon;**

Family: Rosaceae (Plate 177)

Macroscopic Characteristics: Leaves are round to oval with a rounded tip. The length is approximately 2-5 cm; the upper half of the leaves are coarsely serrate (Kershaw, MacKinnon, and Pojar 1998).

Microscopic Characteristics: Epidermal cells are irregular shaped with wavy anticlinal walls. Cells are arranged in a jigsaw puzzle type pattern. Phytoliths include globular calcium oxalate druses and calcium carbonates rhombohedral crystals. The rhombohedral crystals are aligned with the leaf veins; calcium oxalate druses are aligned with veins and in the epidermal cell field. Trichome bases consist of 5-7 cells arranged in a rosette pattern around a central attachment point.

Numerous anomocytic stomata are randomly arranged in the epidermal cell matrix. Stomata consists of a pair of crescent guard cells surrounding an oval pore. The length to width ratio of the stomatal complex is approximately 1.6:1. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides but wide at polar ends. Polar stems are moderately narrow. No pattern of subsidiary cells was observed.

Amelanchier alnifolia
saskatoon

Plate
177

Legend

Top image: Epidermal cells are irregular in shape with wavy anticlinal walls. Stomata are randomly arranged in the epidermal cell matrix. Guard cells have a crescent shape surrounding a narrow pore. (PLM, single polar)

Bottom image: Rhombohedral calcium carbonates are aligned with leaf veins; calcium oxalate globular crystals are aligned with veins and in the epidermal cell matrix. (PLM, single polar)

***Amelanchier arborea*, downy serviceberry;**

Family: Rosaceae (Plate 178)

Macroscopic Characteristics: Leaves are ovate with an approximate length 5-11 cm (Kershner, Nelson and Spellenberg 2008). Margins are serrate. Occasional hairs were observed along the adaxial leaf veins; the abaxial surface was hairy.

Microscopic Characteristics: Epidermal cells are irregular in shape with straight-curved anticlinal walls. Abundant calcium carbonates rhombohedral druses are aligned with veins whereas occasional calcium oxalate druses are randomly arranged in the epidermal cell matrix.

Anomocytic stomata are randomly arranged in the epidermal cell matrix. Guard cells have a crescent shape surrounding an oval pore. The length to width ratio of the stomatal complex is approximately 1.3:1. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides but wide at polar ends. Polar stems are moderately narrow. No pattern of subsidiary cells was observed.

Amelanchier arborea
downy serviceberry

Plate
178

Legend

Epidermal cells are irregular in shape with straight-angled anticlinal walls. Abundant calcium carbonate rhombohedral druses are aligned with veins and occasional calcium oxalate druses are randomly arranged in the epidermal cell matrix. Stomata are randomly arranged in the epidermal cell matrix. Guard cells have a crescent shape and surround an oval pore. (PLM, single polar)

***Amelanchier stolonifera*, running serviceberry;**

Family: Rosaceae (Plate 179)

Macroscopic Characteristics: Leaves are oval to circular with coarse serration on the lower half and finer serrations on the upper. The approximate leaf length is 2.5-7.5 cm. The adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are irregular in shape with straight-curved anticlinal walls. Calcium carbonates rhombohedrals and calcium oxalate globular druses are aligned with veins. No trichomes were observed

Abundant anomocytic stomata are randomly arranged in the epidermal cell matrix. Guard cells have a crescent shape surrounding a cigar-shaped oval pore. The length to width ratio of the stomatal complex is approximately 1.6:1. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides but wide at polar ends. Polar stems are moderately narrow. No pattern of subsidiary cells was observed.

Amelanchier stolonifera
running serviceberry

Plate
179

***Amorpha fruticosa*, false indigo;**

Family: Fabaceae (Plate 180)

Macroscopic Characteristics: Leaves are oval with an approximately length of 0.5-3 cm. Abundant hairs cover the abaxial surface with less hairs on margins and the adaxial surface. Margins are entire.

Microscopic Characteristics: Epidermal cells are polygonal in shape. The length to width ratio ranges from 1:1 to 2:1. Anticlinal walls are straight-curved. Calcium carbonate rhombohedral druses are aligned with veins. Trichomes are spines with straight sides, vertical striations and pointed apices. Trichomes are attached with circular to hexangle bases. Occasionally the bases are surrounded by a rosette of epidermal cells.

Stomata are randomly arranged in the epidermal cell matrix. Guard cells have a crescent shape surrounding an oval pore. The overall shape of the stoma is nearly circular with curved lateral sides and polar ends. The length to width ratio of the stoma ranges from 1.2:1-1.5:1. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides and polar ends. Polar stems are narrow.

Amorpha fruticosa
false indigo

Plate
180

***Arbutus menziesii*, Pacific madrone;**

Family: Ericaceae (Plate 181)

Macroscopic Characteristics: Leaves are thick, waxy and oval with a length of approximately 7.5-15 cm and width of 4-8 cm apex (Kershner, Nelson and Spellenberg 2008). Margins are entire and the leaves are glabrous. Veins are prominent on the abaxial surface.

Microscopic Characteristics: Epidermal cells are polygonal shaped with at length to width ratio that ranges from 1:1 to 2:1. The anticlinal walls are straight-curved and the cells are arranged in a flagstone type pattern. Calcium carbonates rhombohedral druses are aligned with leaf veins.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consists of a pair of crescent guard cells surrounding an oblong to fat fusiform shaped pore. The overall shape of the stoma is nearly oblong with curved lateral sides and polar ends. The length to width ratio of the stomatal complex is approximately 1.5:1. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides and polar ends. Polar stems are wide.

Arbutus menziesii
Pacific madrone

Plate
181

***Arctostaphylos glauca*, bigberry manzanita;**

Family: Ericaceae (Plate 182)

Macroscopic Characteristics: Leaves are waxy and oval with a length of approximately 2.5-5 cm and width of 4 cm apex (Kershner, Nelson and Spellenberg 2008). The adaxial and abaxial surfaces are glabrous; leaf margins are entire.

Microscopic Characteristics: Epidermal cells are polygonal shaped with at length to width ratio that ranges from 1:1 to 2:1. Cells are arranged in a flagstone type pattern. Anticlinal walls are straight-curved. Anisotropic unconsolidated phytoliths are in the epidermal cell matrix and overlie veins.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consists of a pair of crescent guard cells surrounding an oblong to fat fusiform shaped pore. Many pores are lignified. The overall shape of the stoma is nearly circular with curved lateral sides and polar ends. The length to width ratio of the stomatal complex is approximately 1.3:1. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides and polar ends. Polar stems are wide.

Arctostaphylos glauca
bigberry manzanita

Plate
182

***Arctostaphylos manzanita*, common manzanita;**

Family: Ericaceae (Plate 183)

Macroscopic Characteristics: Evergreen leaves are wedge-shaped, shiny with a pointed apex; the length is approximately 2.5-5 cm (Kershner, Nelson and Spellenberg 2008). The adaxial surface is glabrous whereas the abaxial surface is hairy; leaf margins are entire.

Microscopic Characteristics: Epidermal cells are polygonal shaped with at length to width ratio that ranges from 1:1 to 2:1. Cells are arranged in a flagstone type pattern. Anticlinal walls are straight-curved. Anisotropic unconsolidated phytoliths are in the epidermal cell matrix and overlie veins. Trichomes are straight sided long fibers with textured surface and pointed apices.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consists of a pair of crescent guard cells surrounding an oblong to fat fusiform shaped pore. Many pores are lignified. The overall shape of the stoma is nearly circular with curved lateral sides and polar ends. The length to width ratio of the stomatal complex is approximately 1.1:1. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides and polar ends. Polar stems are wide.

Arctostaphylos manzanita
common manzanita

Plate
183

Arctostaphylos uva-ursi, kinnikinnick;

Family: Ericaceae (Plate 184)

Macroscopic Characteristics: Leaves are evergreen, thick, paddle-shaped and stiff with a length of approximately 1-3 cm (Kershaw, MacKinnon and Pojar 1998). Margins are entire with glabrous adaxial and abaxial surfaces.

Microscopic Characteristics: Epidermal cells are polygonal shaped with at length to width ratio that ranges from 1:1 to 2:1. Cells are arranged in a flagstone type pattern. Anticlinal walls are straight-curved. Calcium carbonate rhombohedral druses are aligned with veins and some in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consists of a pair of crescent guard cells surrounding an oblong to fusiform shaped pore. The overall shape of the stoma is nearly circular with curved lateral sides and polar ends. The length to width ratio of the stomatal complex is approximately 1.2:1. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides and polar ends. Polar stems are wide.

Arctostaphylos uva-ursi
kinnikinnick

Plate
184

Legend

Polygonal epidermal cells are arranged in a flagstone pattern. Anticlinal walls are straight-curved. Calcium carbonate rhombohedral druses are aligned with veins and some in the epidermal cell matrix. Stomata consist of a pair of fat guard cells surrounding an oblong to fusiform shaped pore. . The separation between the upper and lower woody lamella is narrow on the lateral sides and polar ends. Polar stems are wide.
(PLM, single polar)

***Artemisia cana*, silver sagebrush;**

Family: Asteraceae (Plate 185)

Macroscopic Characteristics: Leaves are linear, approximately 2-9 cm long and 0.2-0.7 cm wide. Margins are entire; the adaxial and abaxial surfaces have a grayish-white pubescence.

Microscopic Characteristics: Epidermal cells are polygonal shaped with straight to straight-curved anticlinal walls. Abundant trichomes are long fibers with straight sides. Occasional anisotropic phytoliths are square to rectangular.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consists of a pair of crescent guard cells surrounding a fusiform pore. The length to width ratio of the stomatal complex is approximately 1.2:1. The overall shape of the stoma is nearly circular with curved lateral sides and polar ends. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides and polar ends. Polar stems are narrow.

Artemisia cana
silver sagebrush

Plate
185

***Artemisia frigida*, prairie sagewort;**

Family: Asteraceae (Plate 186)

Macroscopic Characteristics: Leaves pinnately divided with 2-3 lobes, lancet shaped, and with a length of approximately 1.2 cm. Margins are entire; the adaxial and abaxial surfaces have a grayish-white pubescence.

Microscopic Characteristics: Epidermal cells are polygonal shaped with straight to straight-curved anticlinal walls. Trichomes are long fibers with straight sides. Occasional phytoliths are fusiform to oblong.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consists of a pair of crescent guard cells surrounding a fusiform pore. The length to width ratio of the stomatal complex is approximately 1.3:1. The overall shape of the stoma is nearly circular with curved lateral sides and polar ends. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides and polar ends. Polar stems are narrow.

Artemisia frigida
prairie sagewort

Plate
186

***Artemisia ludoviciana*, white sagebrush;**

Family: Asteraceae (Plate 187)

Macroscopic Characteristics: Leaves are lancet shaped with a length of approximately 3-11 cm. Margins are entire; the adaxial and abaxial surfaces have a grayish-white pubescence.

Microscopic Characteristics: Epidermal cells are polygonal shaped with straight to straight-curved anticlinal walls. Two types of trichomes are present. Long fibers with straight sides and short stalk-like fibers with globular ends. Occasional phytoliths are fusiform to oblong.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consists of a pair of crescent guard cells surrounding a fusiform to oblong pore. The length to width ratio of the stomatal complex is approximately 1.4:1. The overall shape of the stoma is oval with curved lateral sides and polar ends. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides and polar ends. Polar stems are narrow.

Artemisia ludoviciana
white sagebrush

Plate
187

***Artemisia tridentata*, big sagebrush;**

Family: Asteraceae (Plate 188)

Macroscopic Characteristics: Leaves are wedge shaped with three teeth and have a length of approximately 1-2 cm (Kershaw, MacKinnon and Pojar 1998). Margins are entire; the adaxial and abaxial surfaces have a grayish-white pubescence.

Microscopic Characteristics: Epidermal cells are polygonal shaped with straight to straight-curved anticlinal walls. Two types of trichomes are present. Long fibers with straight sides and short stalk-like fibers with globular ends. Occasional phytoliths are fusiform to oblong.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consists of a pair of crescent guard cells surrounding a fusiform to oblong pore. The length to width ratio of the stomatal complex is approximately 1.2:1. The overall shape of the stoma is round with curved lateral sides and polar ends. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides and polar ends. Polar stems are narrow.

Artemisia tridentata
big sagebrush

Plate
188

***Artemisia tripartita*, threetip sagebrush;**

Family: Asteraceae (Plate 189)

Macroscopic Characteristics: Leaves are wedge shaped and have a length of 0.5-0.4 cm. Margins are entire; the adaxial and abaxial surfaces have a grayish-white pubescence.

Microscopic Characteristics: Epidermal cells are polygonal shaped with straight to straight-curved anticlinal walls. Trichomes are long fibers with straight sides. Occasional phytoliths are fusiform to oblong.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform to oblong pore. The length to width ratio of the stoma is approximately 1.3:1. The overall shape of the stoma is round to oval with curved lateral sides and polar ends. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides and polar ends. Polar stems are narrow.

Artemisia tripartita
threetip sagebrush

Plate
189

***Berberis thunbergii*, Japanese barberry;**

Family: Berberidaceae (Plate 190)

Macroscopic Characteristics: Leaves are spatula to oval shaped with length of 1-2.5 cm and width of 0.3-1.5 cm. Margins are entire.

Microscopic Characteristics: Epidermal cells are irregular shaped with straight to straight-curved anticlinal walls. Cells are arranged in a jigsaw puzzle pattern.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a round to fusiform pore. The length to width ratio of the stoma is approximately 1.4:1. The overall shape of the stoma is round to oval with curved lateral sides and polar ends. The separation between the upper woody lamella and lower woody lamella is relatively wide on the lateral sides and polar ends. Polar stems are narrow.

Berberis thunbergii
Japanese barberry

Plate
190

***Betula alleghaniensis*, yellow birch;**

Family: Betulaceae (Plate 191)

Macroscopic Characteristics: Leaves are oval with pointed apex with a length of approximately 7.5-13 cm and width of 2.5-6 cm (Kershner, Nelson and Spellenberg 2008). They have doubly serrate margins with abaxial vein hairs. Occasional vein hairs were observed on the adaxial surface.

Microscopic Characteristics: Epidermal cells are rectangular to polygonal shaped with straight to straight-curved anticlinal walls. Numerous globular calcium oxalate druses and calcium carbonate rhombohedral crystals are aligned with leaf veins and randomly scattered in the epidermal matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a narrow pore. The length to width ratio of the stoma is approximately 1.6:1. The overall shape of the stoma is oval with curved lateral sides and polar ends. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides and polar ends. Polar stems are narrow and bifurcated.

Betula alleghaniensis
yellow birch

Plate
191

Legend

Epidermal cells include polygonal and rectangular cells arranged in a flagstone pattern. Calcium oxalate and calcium carbonates rhombohedrals druses are aligned with leaf veins and randomly arranged in epidermal cell matrix. Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent shaped guard cells surrounding a narrow pore.
(PLM, single polar)

***Betula lenta*, sweet birch;**

Family: Betulaceae (Plate 192)

Macroscopic Characteristics: Leaves with ovate to elliptic with pointed apex. The leaf length approximately 7.5-13 cm and width of 4-8 cm (Kershner, Nelson and Spellenberg 2008). Margins are finely double-serrate; hairs overlie the abaxial veins.

Microscopic Characteristics: Epidermal cells are rectangular to polygonal shaped with straight to straight-curved anticlinal walls. Numerous calcium oxalate druses and calcium carbonate rhombohedral crystals are aligned with leaf veins and randomly scattered in the epidermal matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform to narrow pore. The length to width ratio of the stoma is approximately 1.4:1. The overall shape of the stoma is oval with curved lateral sides and polar ends. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides and polar ends. Polar stems are narrow.

Betula lenta
sweet birch

Plate
192

***Betula nigra*, river birch;**

Family: Betulaceae (Plate 193)

Macroscopic Characteristics: Leaves are ovate to elliptic with a length of approximately 3.7-7.5 cm (Kershner, Nelson and Spellenberg 2008). Margins are finely double-serrate; hairs overlie the abaxial veins. Occasional hairs are on the adaxial veins.

Microscopic Characteristics: Epidermal cells are rectangular to polygonal shaped with straight to straight-curved anticlinal walls. Numerous globular calcium oxalate druses and calcium carbonate rhombohedral crystals are aligned with leaf veins and randomly scattered in the epidermal matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform to narrow pore. The length to width ratio of the stoma is approximately 1.3:1. The overall shape of the stoma is circular to oval with curved lateral sides and polar ends. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides and polar ends. Polar stems are narrow.

Betula nigra
river birch

Plate
193

***Betula occidentalis*, water birch;**

Family: Betulaceae (Plate 194)

Macroscopic Characteristics: Leaves are ovate with an approximately length of 2-5 cm (Kershner, Nelson and Spellenberg 2008). Margins are single to doubly serrate. Fine hairs cover the abaxial surface and overlie abaxial and abaxial veins.

Microscopic Characteristics: Epidermal cells are rectangular to polygonal shaped with straight to straight-curved anticlinal walls. Short trichomes have straight sides with a pointed apex; epidermal cells at base are arranged in a rosette. Numerous calcium oxalate druses are randomly scattered in the epidermal matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an oblong to fusiform-shaped pore. The length to width ratio of the stoma is approximately 1.6:1. The overall shape of the stoma is oval with curved lateral sides and polar ends. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides and polar ends. Polar stems are narrow.

Betula occidentalis
water birch

Plate
194

Legend

Top Image: Epidermal cells are rectangular to polygonal shaped with straight-curved to straight anticlinal walls. Calcium oxalate druses are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of oblong guard cells and a rectangular pore. (PLM, single polar)

Bottom Image: Trichomes consist of straight sided fibers with a pointed apex; epidermal cells surrounding the base are in rosette pattern. (PLM, single polar)

***Betula papyrifera*, paper birch;**

Family: Betulaceae (Plate 195)

Macroscopic Characteristics: Leaves are oval to triangular with an approximate length of 5-12.5 cm (Kershner, Nelson and Spellenberg 2008). Margins are doubly serrate and hairs are on the abaxial veins.

Microscopic Characteristics:

Epidermal cells are rectangular to polygonal shaped with straight to straight-curved anticlinal walls. Short trichomes with straight sides with a pointed apex; epidermal cells at base are arranged in a rosette. Numerous calcium oxalate druses are randomly scattered in the epidermal matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a wide oblong to fusiform pore. The length to width ratio of the stoma is approximately 1.6:1. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides and polar ends. Polar stems are narrow.

Betula papyrifera
paper birch

Plate
195

Callitropsis nootkatensis, Alaska-cedar;

Family: Pinaceae (Plate 196)

Macroscopic Characteristics: Scale-like leaves are approximately 0.3 cm in length with prominent resin glands (Kershner, Nelson and Spellenberg 2008). The adaxial surface is glossy however no stomatal lines were visible.

Microscopic Characteristics: Epidermal cells are rectangular to parallelogram shaped. Cell length to width ratio ranges from approximately 1:1 to greater than 5:1. Anticlinal walls are straight-curved. No phytoliths or trichomes were observed.

Stomata are arranged in parallel rows in the epidermal cell matrix. Stomata are oval with rounded lateral sides and polar ends. A pair of crescent-shaped guard cells surround a stoma pore that is fusiform to flattened oval shaped. The thickened inner wall extends from the stoma pore to the ends of the guard cells, ends of inner wall are bifurcated at end of guard cells. Stoma is slightly elongated with an approximate length to width aspect ratio of 1.3:1. Spacing between the lower woody lamellae and upper woody lamella is less than 5 microns. The polar stems are wide.

Callitropsis nootkatensis
Alaska cedar

Plate
196

***Calocedrus decurrens*, incense cedar;**

Family: Pinaceae (Plate 197)

Macroscopic Characteristics: Scale-like leaves are approximately 0.3 to 0.6 cm in length; twice as long as wide. The adaxial surface is glossy however no stomatal lines were visible.

Microscopic Characteristics: Epidermal cells are oblong to circular shaped. Cell length to width ratio ranges from approximately 1:1 to greater than 5:1. Anticlinal walls are straight-curved. No phytoliths or trichomes were observed.

Stomata are arranged in parallel rows in the epidermal cell matrix. Stomata are oval with rounded lateral sides and polar ends. A pair of crescent-shaped guard cells surround a stoma pore that is fusiform to flattened oval shaped. The thickened inner wall extends from the stoma pore to the ends of the guard cells, ends of inner wall are bowtie shaped. Stoma is slightly elongated with an approximate length to width aspect ratio of 1.4:1. Spacing between the lower woody lamellae and upper woody lamella is less than 5 microns. The polar stems are wide.

Calocedrus decurrens
incense cedar

Plate
197

Legend

Epidermal cells are oblong to circular shaped. Oblong to circular epidermal cells have straight-curved anticlinal walls. Stomata are in parallel rows. Stomata consist of crescent shaped guard cells surrounding an oblong pore. Spacing between the lower woody lamella and upper woody lamella is less than 5 microns. The polar stems are wide.
(PLM, single polar)

***Carpinus caroliniana*, American hornbeam;**

Family: Betulaceae (Plate 198)

Macroscopic Characteristics: Leaves are elliptic and pointed apex with a length of 5-10 cm (Kershner, Nelson and Spellenberg 2008). Margins are doubly serrate. Veins are prominent on the abaxial surface and lightly covered with hairs.

Microscopic Characteristics: Epidermal cells are rectangular to polygonal shaped with straight to straight-curved anticlinal walls. Phytoliths are large crystals randomly arranged in the epidermal cell matrix. Occasional trichomes are straight-sided slightly curved fibers with pointed apex.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an elongated pore. The length to width ratio of the stoma is approximately 1.1:1. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides and wide at the polar ends. Polar stems are narrow.

Carpinus caroliniana
American hornbeam

Plate
198

Legend

Top Image: Epidermal cells are rectangular to parallelogram shaped with straight-curved anticlinal walls. Phytoliths are large crystals randomly arranged in the epidermal cell matrix.
(PLM, single polar)

Bottom Image: Trichomes consist of slightly curved straight sided fibers with pointed apices.
(PLM, single polar)

***Carya cordiformis*, bitternut hickory;**

Family: Juglandaceae (Plate 199)

Macroscopic Characteristics: Leaves are pinnately compound with 7-11 lanceolate leaflets. Leaflet length is approximately 7-13 cm (Kershner, Nelson and Spellenberg 2008). Hairs are on the abaxial veins and the margins are serrate.

Microscopic Characteristics: Epidermal cells are irregular shaped with straight to straight-curved anticlinal walls. Cells are arranged in a jigsaw puzzle pattern. Globular calcium oxalate druses and isotropic silicate phytoliths are randomly arranged in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an elongated pore. The length to width ratio of the stoma is approximately 1.2:1. The overall shape of the stoma is round with curved lateral sides and polar ends. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides and wide at the polar ends. Polar stems are narrow.

Carya cordiformis
bitternut hickory

Plate
199

Legend

Top Image: Globular calcium oxalate druses are randomly arranged in the epidermal cell matrix.
(PLM, crossed polars)

Bottom Image: Epidermal cells are irregular shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Silicate phytoliths are small crystals randomly arranged in the epidermal cell matrix.
(PLM, single polar)

***Carya glabra*, pignut hickory;**

Family: Juglandaceae (Plate 200)

Macroscopic Characteristics: Leaves are compound with five lanceolate to elliptic shaped leaflets. Leaflets have a length of approximately 7-15 cm and 2.5-5 cm wide (Kershner, Nelson and Spellenberg 2008). Hairs are on the abaxial veins and the margins are serrate.

Microscopic Characteristics: Epidermal cells are rectangular to parallelogram shaped with straight to straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Calcium oxalate druses are randomly arranged in the epidermal cell matrix. Trichomes are straight-sided fibers that are slightly curved with pointed apexes.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an oval pore. The length to width ratio of the stoma is approximately 1.3:1. The overall shape of the stoma is round to slightly oval with curved lateral sides and polar ends. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides and wide at the polar ends. Polar stems are narrow.

Carya glabra
pignut hickory

Plate
200

***Carya illinoensis*, pecan;**

Family: Juglandaceae (Plate 201)

Macroscopic Characteristics: Leaves are pinnately compound with 9-17 leaflets. Leaflet length is approximately 5-12 cm and 2-6 cm wide (Kershner, Nelson and Spellenberg 2008).

Microscopic Characteristics: Epidermal cells are rectangular to parallelogram shaped with straight to straight-curved anticlinal walls. Calcium oxalate druses are randomly arranged in the epidermal cell matrix. Trichomes are short straight-sided fibers that are slightly curved with rounded apexes.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an oval pore. The length to width ratio of the stoma is approximately 1.2:1. The overall shape of the stoma is round to slightly oval with curved lateral sides and polar ends. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides and wide at the polar ends. Polar stems are narrow.

Carya illinoensis
pecan

Plate
201

***Carya laciniosa*, shellbark hickory;**

Family: Juglandaceae (Plate 202)

Macroscopic Characteristics: Leaves are pinnately compound with 5-11 leaflets per leaf. Leaflet length is approximately 13-20 cm and 5-12.5 cm wide (Kershner, Nelson and Spellenberg 2008).

Microscopic Characteristics: Epidermal cells are irregular shaped with straight to straight-curved anticlinal walls. Cells are arranged in a jigsaw puzzle pattern. Calcium oxalate druses are randomly arranged in the epidermal cell matrix. Rectangular isotropic phytoliths are aligned with leaf veins. Trichomes are straight-sided fibers with a hooked apex.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an oval pore. The length to width ratio of the stoma is approximately 1.3:1. The overall shape of the stoma is round to slightly oval with curved lateral sides and polar ends. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides and wide at the polar ends. Polar stems are narrow.

Carya laciniosa
shellback hickory

Plate
202

***Carya ovata*, shagbark hickory;**

Family: Juglandaceae (Plate 203)

Macroscopic Characteristics: Leaves are pinnately compound with 5-7 ovate leaflets. Leaflet length is approximately 12.5-18 cm and 5-7.5 cm wide (Kershner, Nelson and Spellenberg 2008). Margins are finely serrate with hairs along the margin.

Microscopic Characteristics: Epidermal cells are irregular shaped with straight to straight-curved anticlinal walls. Cells are arranged in a flagstone or jigsaw puzzle pattern. Calcium oxalate druses are randomly arranged in the epidermal cell matrix. Trichomes are straight-sided fibers with a pointed apex.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an oval pore. The length to width ratio of the stoma is approximately 1.3:1. The overall shape of the stoma is round to slightly oval with curved lateral sides and polar ends. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides and polar ends. Polar stems are narrow.

Carya ovata
shagbark hickory

Plate
203

***Carya tomentosa*, mockernut hickory;**

Family: Juglandaceae (Plate 204)

Macroscopic Characteristics: Leaves are pinnately compound with 7-9 ovate leaflets. Leaflets are ovate to obovate with a length of approximately 10-20 cm and width of 5-12.5 cm (Kershner, Nelson and Spellenberg 2008). Margins are serrate and teeth tips are hairy.

Microscopic Characteristics: Epidermal cells are irregular shaped with straight to straight-curved anticlinal walls. Globular calcium oxalate druses are randomly arranged in the epidermal cell matrix. Trichomes are long fibers with coarsely textured margins and blunt apices.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an oval pore. The length to width ratio of the stoma is approximately 1.2:1. The overall shape of the stoma is round to slightly oval with curved lateral sides and polar ends. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides and wide at the polar ends. Polar stems are narrow.

Carya tomentosa
mockernut hickory

Plate
204

Legend

Epidermal cells are irregular shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Globular calcium oxalate druses are randomly arranged in the epidermal cell matrix. Stomata are oval with crescent-shaped guard cells surrounding an oval pore.
(PLM, crossed polars)

***Castanea dentata*, American chestnut;**

Family: Fagaceae (Plate 205)

Macroscopic Characteristics: Leaves are narrowly elliptic with a pointed tip; length is approximately 14-20 cm and 7-10 cm wide (Kershner, Nelson and Spellenberg 2008). Margins consist of large, sharp, incurved teeth; occasional hairs overlie the straight-sided veins.

Microscopic Characteristics: Epidermal cells are irregular shaped with straight to straight-curved anticlinal walls. Cells are arranged in a flagstone or jigsaw puzzle pattern. Globular calcium oxalate druses are randomly arranged in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an oval pore. The length to width ratio of the stoma is approximately 1.2:1. The overall shape of the stoma is round with curved lateral sides and polar ends. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides and polar ends. Polar stems are relatively wide.

Castanea dentata
American chestnut

Plate
205

***Ceanothus americanus*, jerseytea Ceanothus;**

Family: Rhamnaceae (Plate 206)

Macroscopic Characteristics: Leaves are ovate with an approximate length of 7.5 cm and 5 cm wide. Margins are with smooth to finely serrate. Abundant hairs cover the adaxial and abaxial veins with less hairs observed on the surfaces.

Microscopic Characteristics: Epidermal cells are rectangular to parallelogram shaped with straight to straight-curved anticlinal walls. The length to width ratio ranges from 2:1 to 5:1. Trichomes are straight-sided, slightly curved fibers and a pointed apex. Trichome bases are round to oval with a rosette of epidermal cells surrounding the base. Globular calcium oxalate druses are randomly arranged in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an elongated pore. The length to width ratio of the stoma is approximately 1.4:1. The overall shape of the stoma is oval with curved lateral sides and polar ends. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides and wide at the polar ends. Polar stems are relatively wide.

Ceanothus americanus
jerseytea ceanothus

Plate
206

Legend

Top Image: Epidermal cells are rectangular to parallelogram shaped with straight-curved anticlinal walls. Stomata are slightly oblong and consist of a pair of crescent shaped guard cells surrounding an oval to fusiform pore. The polar ends are wide.
(PLM, single polar)

Bottom Image: Trichomes are straight-sided, smooth fibers with slightly pointed apices.
(PLM, single polar)

***Ceanothus velutinus*, snowbush;**

Family: Rhamnaceae (Plate 207)

Macroscopic Characteristics: Leaves are oval and glaucous with an approximate length of 4-8 cm.

Microscopic Characteristics: Epidermal cells are square to polygonal shaped with straight to straight-curved anticlinal walls. The length to width ratio ranges from 2:1 to 4:1. Trichomes are curved, unbranched fibers with straight-walls and a pointed apex. Globular calcium oxalate druses are aligned with leave veins with some scattered in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an elongated pore. The length to width ratio of the stoma is approximately 1.4:1.

Ceanothus velutinus
snowbush

Plate
207

***Celastrus scandens*, bittersweet;**

Family: Celastraceae (Plate 208)

Macroscopic Characteristics: Leaves are ovate to elliptic that are approximately 10 cm long. Margins are bluntly serrate.

Microscopic Characteristics:

Epidermal cells are irregular shaped except in the area of leaf veins. Square to rectangular shaped cells are in the region of veins. Cells consist of straight to straight-curved anticlinal walls. Globular and unconsolidated calcium oxalate druses are randomly arranged in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an elongated pore. Some pores are lignified. The length to width ratio of the stoma is approximately 1.2:1. The overall shape of the stoma is round with curved lateral sides and polar ends. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides and polar ends. Polar stems are narrow.

Celastrus scandens
bittersweet

Plate
208

***Celtis laevigata*, sugarberry;**

Family: Ulmaceae (Plate 209)

Macroscopic Characteristics: Leaves narrowly ovate with a long, curved apex and asymmetrical base. Length is approximately 6.4-13 cm wide (Kershner, Nelson and Spellenberg 2008). Margins are entire with prominent abaxial veins that are covered with hairs.

Microscopic Characteristics: Epidermal cells are rectangular to parallelogram shaped. Cells consist of straight to straight-curved anticlinal walls. The length to width ratio ranges from 1:1 to 3:1. Calcium carbonates rhombohedral crystals are aligned with leaf veins with crystals in the epidermal cell matrix. Globular calcium oxalate druses are randomly arranged in the epidermal cell matrix.

Trichomes consist of short prickly fibers and longer smooth-sided fibers with pointed apices. Trichomes bases are oval and elevated above the epidermal cell matrix with a rosette of epidermal cells surrounding the base.

Celtis laevigata
sugarberry

Plate
209

Legend

Top Image: Epidermal cells are rectangular to parallelogram shaped with straight to straight-curved anticlinal walls. Calcium carbonates rhombohedral druses are aligned with leaf veins. Calcium oxalate druses are randomly arranged in the epidermal cell matrix. Trichome bases are roughly oval on elevated areas. (PLM, single polar)

Bottom Image: Trichomes range from prickles to longer fibers with smooth sides. (PLM, single polar)

***Celtis laevigata* var. *reticulata*, netleaf hackberry;**

Family: Ulmaceae (Plate 210)

Macroscopic Characteristics: Leaves are broadly ovate with a length of approximately 2.5-7.5.

Microscopic Characteristics: Epidermal cells are rectangular to parallelogram shaped. Cells have straight-curved anticlinal walls. Calcium carbonate rhombohedral druses are aligned with leaf veins with some in the epidermal cell matrix. Globular calcium oxalate druses are randomly arranged in the epidermal cell matrix. Trichomes consist of straight-sided fibers and pointed apexes. Trichomes bases are round to hexangle.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an elongated pore. The length to width ratio of the stoma is approximately 1.7:1. The overall shape of the stoma is oval with curved lateral sides and polar ends. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides and wide at the polar ends. Polar stems are wide forming a bilobal shape.

Celtis laevigata var. *reticulata*
netleaf hackberry

Plate
210

Legend

Top Image: Epidermal cells are rectangular to parallelgram shaped. Anticlinal walls are straight-curved. Trichomes consist of fibers with straight sides and pointed apices. Bases are round to hexangle. (PLM, single polar)

Bottom Image: Calcium carbonate rhombohedrals and globular calcium oxalate druses are aligned with veins and scattered in the epidermal cell matrix. (PLM, crossed polars)

***Celtis occidentalis*, common hackberry;**

Family: Ulmaceae (Plate 211)

Macroscopic Characteristics: Leaves are narrowly ovate with serrate margins; length is approximately 5-13 cm with asymmetrical bases. Hairs are common on veins and scattered about the adaxial and abaxial surfaces.

Microscopic Characteristics: Epidermal cells are rectangular to parallelogram with some tending toward irregular shaped. Cells consist of straight-curved anticlinal walls. Calcium carbonates rhombohedral druses are aligned with leaf veins with some in the epidermal cell matrix. Calcium oxalate druses are randomly arranged in the epidermal cell matrix. Trichomes consist of straight-sided fibers with vertical striations and pointed apexes. Trichomes bases form hexangles.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an elongated pore. The length to width ratio of the stoma is approximately 1.8:1. The overall shape of the stoma is oval with curved lateral sides and polar ends. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides and wide at the polar ends. Polar stems are wide forming a bilobal shape

Celtis occidentalis
common hackberry

Plate
211

***Cephalanthus occidentalis*, buttonbush;**

Family: Rubiaceae (Plate 212)

Macroscopic Characteristics: Leaves are elliptic to lancet-shaped with a length of approximately 5-15 cm. The adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are rectangular to parallelogram shaped. Cells consist of straight-curved anticlinal walls. Phytoliths are mostly unconsolidated and are randomly arranged in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of thin crescent-shaped guard cells surrounding an elongated pore. A pair of subsidiary cells surround the guard cells. The length to width ratio of the stoma is approximately 1:1. The overall shape of the stoma is round with curved lateral sides and polar ends. The separation between the upper woody lamella and lower woody lamella is wide on the lateral sides and at the polar ends. Polar stems are wide.

Cephalanthus occidentalis
buttonbush

Plate
212

Legend

Top Image: Epidermal cells are rectangular to parallelogram shaped with straight to straight-curved anticlinal walls. Phytoliths are scattered randomly in the epidermal cell matrix.
(PLM, single polar)

Bottom Image: Stomata are randomly arranged in the epidermal cell matrix and consist of a pair of thin crescent guard cells surrounding an oblong to fusiform shaped pore.
(PLM, single polar)

***Cercis canadensis*, eastern redbud;**

Family: Fabaceae (Plate 213)

Macroscopic Characteristics: Leaves are broadly heart-shaped with a length of 12.5-20 cm. Margins are entire and the apex is pointed. Hairs are present on the abaxial veins.

Microscopic Characteristics: Epidermal cells are rectangular to parallelogram shaped with straight-curved anticlinal walls. Calcium carbonate rhombohedral crystals are aligned with veins and globular calcium oxalate druses are randomly arranged in the epidermal cell matrix. Trichomes are straight-sided fibers with pointed apices. Bases are round to hexangle with rosette ring of epidermal cells.

Stomata are randomly arranged in the epidermal cell matrix with a pair of thin crescent-shaped guard cells and thin pores. The length to width ratio of the stoma is approximately 1.4:1. The overall shape of the stoma is oval with curved lateral sides and polar ends. The separation between the upper woody lamella and lower woody lamella is wide on the lateral sides and at the polar ends. Polar stems are wide.

Cercis canadensis
eastern redbud

Plate
213

***Cercocarpus ledifolius*, curl-leaf mountain mahogany;**

Family: Rosaceae (Plate 214)

Macroscopic Characteristics: Leaves are narrowly elliptic with a length of 1.3-4 cm wide (Kershner, Nelson and Spellenberg 2008). Margins are entire and strongly rolled toward abaxial surface. The adaxial surface is glabrous whereas the abaxial surface is hairy.

Microscopic Characteristics: Epidermal cells are polygonal shaped with straight to straight-curved anticlinal walls. Trichomes are curved unbranched straight wall fibers with a pointed apex. Globular calcium oxalate and calcium carbonates rhombohedrals are aligned with leave veins.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an elongated pore. The length to width ratio of the stoma is approximately 1.4:1.

Cercocarpus ledifolius
curl-leaf mountain mahogany

Plate
214

***Cercocarpus montanus*, alderleaf mountain mahogany;**

Family: Rosaceae (Plate 215)

Macroscopic Characteristics: Leaves are obovate to elliptic with a length of 1.3-3 cm (Kershner, Nelson and Spellenberg 2008). Leaves have smooth margins from the base to half-way up leaf then serrated or wavy margins to rounded tip. Veins are prominent.

Microscopic Characteristics: Epidermal cells are rectangular to parallelogram shaped with straight-curved anticlinal walls. The length to width ratio of the cells ranges from 1:1 to 2:1. Calcium carbonate rhombohedral crystals are aligned with veins. Globular calcium oxalate and unconsolidated phytolith druses are randomly arranged in the epidermal cell matrix. Trichomes are straight-sided fibers with pointed apices.

Stomata are randomly arranged in the epidermal cell matrix with a pair crescent-shaped guard cells and thin pores. The length to width ratio of the stoma is approximately 1.2:1.

Cercocarpus montanus
alderleaf mountain mahogany

Plate
215

***Chamaecyparis thyoides*, Atlantic white cedar;**

Family: Cupressaceae (Plate 216)

Macroscopic Characteristics: Mature leaves are scale-like with a length of approximately 0.3 cm; immature leaves are needlelike (Kershner, Nelson and Spellenberg 2008). Each leaf has a resin gland near the base. The adaxial surface is glossy; no stomatal lines were observed.

Microscopic Characteristics: Epidermal cells are rectangular with square ends; each cell is oriented end-to-end and stacked brick-like. Anticlinal walls are straight to straight-curved.

Stomata patterning is ordered into parallel rows; stoma pores are aligned axially to the long axis of epidermal cells. Stomata consist of two crescent-shaped guard cells surrounding an oval to fusiform pore. The stoma is oval in outline with a length to width ratio of approximately 1.4:1. The polar stem is bifurcated with a width of approximately 3-4 microns. No phytoliths or trichomes were observed. No subsidiary cell patterning was observed however Lacourse, Beer and Hoffman (2016) found that a floricol ring of 5-8 subsidiary cells were typical for the *Chamaecyparis* genera.

Chamaecyparis thyoides
Atlantic white cedar

Plate
216

***Chrysothamnus nauseosus*, rubber rabbitbush;**

Family: Asteraceae (Plate 217)

Macroscopic Characteristics: Rabbitbush leaves are oblong to lancet shaped with a length of 3-6 cm and width of 1 cm (Kershaw, MacKinnon and Pojar 1998). Adaxial and abaxial leaf surfaces are hairy.

Microscopic Characteristics: Epidermal cells are polygonal shaped with straight-curved anticlinal walls. Leaves are arranged in a flagstone pattern. No trichomes or phytoliths were observed.

Stomata are randomly arranged in the epidermal cell matrix with crescent-shaped guard cells surrounding a fusiform-shaped pore. The length to width ratio of the stoma ranges from 1.2:1 to 1.5:1. The overall shape of the stoma is circular to oval with curved lateral sides and polar ends. The separation between the upper woody lamella and lower woody lamella is narrow on the lateral sides and at the polar ends. Polar stems are narrow.

Chrysothamnus nauseosus
rubber rabbitbush

Plate
217

Legend

Epidermal cells are polygonal with straight to straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Stomata are circular to oblong with a pair of crescent shaped guard cells surrounding a fat fusiform pore. The separation between the upper and lower woody lamella is narrow on the lateral sides and the polar ends. The polar stem is narrow.
(PLM, single polar)

***Cirsium scariosum*, meadow thistle;**

Family: Asteraceae (Plate 218)

Macroscopic Characteristics: Leaves are lobed, hairless and oblong with an approximately length of 10-30 cm and width of 1.25-5 cm. Stout spines are located at tips of each lobe.

Microscopic Characteristics: Epidermal cells are rounded polygons arranged in a flagstone pattern with thick straight-curved anticlinal walls. The length to width ratio ranges from 1:1 to 3:1. Cells are arranged in a flagstone pattern.

Stomata are randomly arranged in the epidermal cell matrix with crescent-shaped guard cells surrounding an oval to fusiform-shaped pore. The length to width ratio of the stoma is approximately 1.5:1. The separation between the upper woody lamella and the lower woody lamella is moderately wide on the lateral sides and wider at the polar ends. The polar stems are relatively wide.

Cirsium scariosum
meadow thistle

Plate
218

***Cirsium vulgare*, bull thistle;**

Family: Asteraceae (Plate 219)

Macroscopic Characteristics: Leaves are lancet-shaped with an approximately length of 7-30 cm. Margins are rimmed with stout spines.

Microscopic Characteristics: Epidermal cells are polygonal shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Trichomes are long flat fibers. A few phytoliths are scattered among the epidermal cells.

Stomata are randomly arranged in the epidermal cell matrix with a pair of crescent-shaped guard cells surrounding an oval to fusiform-shaped pore. The length to width ratio of the stoma is approximately 1.4:1. The separation between the upper woody lamella and the lower woody lamella is wide at the lateral sides and polar ends. The polar stems are wide.

Cirsium vulgare
bull thistle

Plate
219

Legend

Top Image: Epidermal cells are polygonal with straight-curved anticlinal walls. Stomata are circular to slightly oblong with a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The separation between the upper and lower woody lamella is wide at the lateral sides and the polar ends.
(PLM, single polar)

Bottom Image: Trichomes are long flat fibers that form a thick mat.
(PLM, single polar)

***Comptonia peregrina*, sweet fern;**

Family: Myricaceae (Plate 220)

Macroscopic Characteristics: Leaves are simple, narrow, deeply notched with an approximately length of 10 cm. Hairs were observed on the adaxial and abaxial surfaces.

Microscopic Characteristics: Epidermal cells are rectangular to parallelogram shaped with straight to straight-curved anticlinal walls. Phytoliths are randomly arranged in the epidermal cell matrix. Trichomes are long with straight sides and pointed apices.

Stomata are randomly arranged in the epidermal cell matrix with crescent-shaped guard cells surrounding a short oblong to fusiform pore. The length to width ratio of the stoma is approximately 1.2:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and the polar ends. The polar stems are wide.

Comptonia peregrina
sweet fern

Plate
220

Legend

Top Image: Epidermal cells are rectangular to parallelogram shaped with straight-curved anticlinal walls. Phytoliths are randomly arranged in the epidermal cell matrix. Stomata consist of crescent-shaped guard cells with an oblong to fusiform-shaped pore. (PLM, single polar)

Bottom Image: Trichomes are long fibers with straight sides and pointed apices. (PLM, single polar)

***Cornus alternifolia*, alternate-leaf dogwood;**

Family: Cornaceae (Plate 221)

Macroscopic Characteristics: Leaves are elliptic with slightly wavy margins and pointed apices, length is approximately 6-10 cm. The adaxial surface is glabrous however the abaxial surface is hairy.

Microscopic Characteristics: Epidermal cells in the epidermal cell matrix are irregular-shaped with straight-curved anticlinal walls. Cells near veins are parallelogram-shaped with straight anticlinal walls. Phytoliths are randomly arranged in the epidermal cell matrix. Phytoliths include calcium oxalate and rectangular isotropic silica druses. Trichomes are long flat fibers.

Stomata are randomly arranged in the epidermal cell matrix with crescent-shaped guard cells surrounding fusiform pore. The length to width ratio of the stoma is approximately 1.4:1.

Cornus alternifolia
alternateleaf dogwood

Plate
221

Legend

Top Image: Phytoliths are randomly arranged in the epidermal cell matrix. Phytoliths include calcium oxalate and rectangular silica druses. Stomata consist of crescent-shaped guard cells with fusiform-shaped pores. (PLM, single polar)

Bottom Image: Epidermal cells are paralogram to irregular shaped with straight-curved anticlinal walls. (PLM, single polar)

***Cornus canadensis*, bunchberry;**

Family: Cornaceae (Plate 222)

Macroscopic Characteristics: Four obovate leaves are arranged around a central stem. Leaf margins are entire with a length of approximately 2-8 cm and width of 5 cm (Kershaw, MacKinnon and Pojar 1998).

Microscopic Characteristics: Epidermal cells are irregular shaped and arranged in a jigsaw puzzle pattern. Anticlinal walls are straight-curved. Trichomes are straight-sided with pointed apex. The bases are oval to hexangle, each base is surrounded by a rosette of epidermal cells. Cells surround the bases are polygonal with straight anticlinal walls. Calcium oxalate druses are scattered randomly in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix; crescent-shaped guard cells surround a fusiform-shaped pore. The length to width ratio of the stoma is approximately 1.3:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are wide.

Cornus canadensis
bunchberry

Plate
222

Legend

Top Image: Epidermal cells are irregular-shaped with straight-curved anticlinal walls. Cells are arranged in flagstone pattern. Trichomes have straight margins with pointed apices.
(PLM, single polar)

Bottom Image: Trichome bases are oval to hexangle with a rosette of epidermal cells. The cells surround the base are polygonal.
(PLM, single polar)

***Cornus drummondii*, roughleaf dogwood;**

Family: Cornaceae (Plate 223)

Macroscopic Characteristics: Leaves are elliptic to oval-shaped with a length of approximately 12.5 cm. The adaxial surface is scabrous and the abaxial downy.

Microscopic Characteristics: Epidermal cells are irregular shaped and arranged in a jigsaw puzzle pattern. Anticlinal walls are straight-curved. Trichomes are textured to straight-sided with pointed apex. The bases are oval to hexangle and surrounded by a rosette of epidermal cells. Calcium oxalate druses are scattered randomly in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of oblong crescent-shaped guard cells surrounding a thin fusiform-shaped pore. The length to width ratio of the stoma is approximately 1.6:1. The separation between the upper woody lamella and the lower woody lamella is wide at the lateral sides and the polar ends. The polar stems are wide.

Cornus drummondii
roughleaf dogwood

Plate
223

Legend

Top Image: Epidermal cells are irregular-shaped with straight-curved anticlinal walls. Stomata consist of a pair of crescent-shaped guard cells surrounding a thin fusiform pore.
(PLM, single polar)

Bottom Image: Trichomes are textured to straight-sided fibers with pointed apices. Base is round to hexangle with a rosette of epidermal cells. Calcium oxalate druses are randomly arranged.
(PLM, single polar)

***Cornus florida*, flowering dogwood;**

Family: Cornaceae (Plate 224)

Macroscopic Characteristics: Leaves are elliptic with pointed tip and parallel veins; length is approximately 5-15 cm. Occasional hairs were noted on adaxial veins; hairs were observed on the abaxial side.

Microscopic Characteristics: Epidermal cells are irregular shaped and arranged in a flagstone or jigsaw puzzle pattern. Anticlinal walls are straight-curved. Trichomes are double-ended with pointed apices. The bases are oval to hexangle and surrounded by a rosette of epidermal cells. Cells surround the bases are polygonal with straight-sided anticlinal walls.

Stomata are randomly arranged in the epidermal cell matrix; crescent-shaped guard cells surround an oval to fusiform-shaped pore. The length to width ratio of the stoma is approximately 1.4:1. The separation between the upper woody lamella and the lower woody lamella is relatively wide at the lateral sides and the polar ends. The polar stems are wide.

Cornus florida
flowering dogwood

Plate
224

Legend

Top Image: Epidermal cells are irregular shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Trichomes are double-ended with a central oval attachment on a raised structure. The base is surrounded by a rosette of epidermal cells
(PLM, single polar)

Bottom Image: Stomata consist of a pair of crescent shaped guard cells surrounding an oval to fusiform pore.
(PLM, single polar)

***Cornus nuttallii*, Pacific dogwood;**

Family: Cornaceae (Plate 225)

Macroscopic Characteristics: Leaves are broadly elliptic with pointed tip and parallel veins; length is approximately 7.5-15 cm.

Microscopic Characteristics: Epidermal cells are irregular shaped and arranged in a jigsaw puzzle pattern. Anticlinal walls are straight-curved. Pairs of trichomes are joined at the bases with pointed apices, the bases oval to hexangle surrounded by a rosette of epidermal cells. Cells surround the bases are polygonal with straight-sided anticlinal walls.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an oval to fusiform-shaped pore. The length to width ratio of the stoma is approximately 1.8:1. The separation between the upper woody lamella and the lower woody lamella is relatively wide at the lateral sides and the polar ends. The polar stems are wide.

Cornus nuttallii
Pacific dogwood

Plate
225

Legend

Top Image: Epidermal cells are irregular shaped with straight-curved anticlinal walls. Stomata consist of a pair of crescent-shaped guard cells surrounding an oval to fusiform pore.
(PLM, single polar)

Bottom Image: Trichomes consist of double fibers joined at the base with pointed apices. Bases are oval to hexangle with a rosette of epidermal cells.
(PLM, single polar)

***Cornus sericea*, red-osier dogwood;**

Family: Cornaceae (Plate 226)

Macroscopic Characteristics: Red-osier dogwood leaves are ovate to oblong with an approximate length of 2-10 cm (Kershaw, MacKinnon and Pojar 1998). Five to seven prominent veins converge toward the pointed tip.

Microscopic Characteristics: Epidermal cells are irregular shaped and arranged in a flagstone or jigsaw puzzle pattern. Anticlinal walls are straight-curved. Trichomes are double-ended and straight-sided with pointed apexes and a central core that is oval to hexangle. Calcium oxalate druses and starch grains are scattered randomly in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix; crescent-shaped guard cells surround a fusiform-shaped pore. The length to width ratio of the stoma is approximately 1.2:1.

Cornus sericea
red-osier dogwood

Plate
226

***Corylus cornuta*, beaked hazel;**

Family: Cornaceae (Plate 227)

Macroscopic Characteristics: Leaves are oval with double serrate margins. Leaf length is approximately 5-11 cm and width is 3-8 cm. Hairs are observed on the abaxial surface however the adaxial surface is glabrous.

Microscopic Characteristics:

Epidermal cells are irregular shaped are arranged in a flagstone or jigsaw puzzle pattern. Anticlinal walls are straight-curved. Calcium oxalate druses are randomly scattered in the epidermal cell matrix. Trichomes are straight spears with smooth sides and hollow interiors. Bases are oval with a rosette of epidermal cells surrounding the base. Epidermal cells surrounding the bases are polygonal shaped.

Stomata are randomly arranged in the epidermal cell matrix; crescent-shaped guard cells surround an oval to fusiform-shaped pore. The length to width ratio of the stoma is approximately 1.2:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and the polar ends. The polar stems are narrow.

Corylus cornuta
beaked hazel

Plate
227

Legend

Epidermal cells are irregular shaped with straight-curved anticlinal walls. Cells are arranged in a flagson pattern. Calcium oxalate druses are randomly scattered in the epidermal cell matrix. Trichomes are straight-sided spears with smooth sides and hollow interiors. Bases are oval with a rosette of epidermal cells surrounding the base. Stomata are oblong with a pair of crescent-shaped guard cells surrounding a thin pore.
(PLM, single polar)

***Crataegus douglasii*, hawthorn;**

Family: Rosaceae (Plate 228)

Macroscopic Characteristics: Hawthorne leaves are obovate to round with an approximately length of 2.5-10 cm. Hairs are present on the adaxial and abaxial surfaces and veins.

Microscopic Characteristics: Epidermal cells are irregular shaped and arranged in a flagstone pattern. Anticlinal walls are straight-curved to sinuous. Calcium carbonate rhombohedral druses are aligned with the leaf veins.

Anomocytic stomata are randomly arranged in the epidermal cell matrix. Stomata consist of crescent-shaped guard cells surrounding a fusiform-shaped pore. The length to width ratio of the stoma is approximately 1.6:1. The separation between the upper woody lamella and the lower woody lamella is wide at the lateral sides and narrower at the polar ends. The polar stems are narrow.

Crataegus douglasii
black hawthorn

Plate
228

Legend

Top Image: Epidermal cells are irregular-shaped with straight-curved to sinuous anticlinal walls. Multiple randomly arranged stomata consist of a pair of crescent-shaped guard cells surround a fusiform-shaped pore. (PLM, single polar)

Bottom Image: Calcium carbonate rhombohedral druses are aligned with leaf veins.. (PLM, single polar)

***Dasiphora fruticosa*, shrubby cinquefoil;**

Family: Rosaceae (Plate 229)

Macroscopic Characteristics: Leaves have smooth margins that are revolute. The leaf length and width is approximately 1.2-2.5 cm. Abundant hairs coat the adaxial and abaxial surfaces.

Microscopic Characteristics: Epidermal cells are polygonal shaped and arranged in a flagstone pattern. Anticlinal walls are straight-curved. Abundant long trichomes are flat; bases are oval to hexangle with a rosette of epidermal cells surrounding the base.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surround a fusiform-shaped pore. The length to width ratio of the stoma is approximately 1.4:1.

Dasiphora fruticosa
shrubby cinquefoil

Plate
229

***Elaeagnus commutata*, silverberry;**

Family: Elaeagnaceae (Plate 230)

Macroscopic Characteristics: Leaves are egg to lancet-shaped with an approximately length of 2-6 cm. The adaxial and abaxial surfaces are punctuated with numerous scales and stellate hairs.

Microscopic Characteristics: Epidermal cells are irregular shaped and arranged in a flagstone pattern. Anticlinal walls are sinuous. Stellate trichomes and stellate scales are scattered randomly.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surround a fusiform-shaped pore. The length to width ratio of the stoma is approximately 1.3:1. The separation between the upper woody lamella and the lower woody lamella is wide at the lateral sides and the polar ends. The polar stems are narrow.

Elaeagnus commutata
silverberry

Plate
230

Legend

Top Image: Epidermal cells are irregular shaped and arranged in a flagstone pattern with sinuous anticlinal walls. Stellate trichomes are scattered randomly. Stellate scales are also observed. (PLM, single polar)

Bottom Image: Stomata are randomly arranged in the epidermal cell matrix; crescent-shaped guard cells surround a fusiform-shaped pore. (PLM, single polar)

***Fagus grandifolia*, American beech;**

Family: Fagaceae (Plate 231)

Macroscopic Characteristics: Leaves are dark green, elliptic with small teeth at end of each vein. Leaf length is approximately 6-12 cm with 9-14 prominent side veins (Kershner, Nelson and Spellenberg 2008). Tufts of hairs are on the abaxial veins.

Microscopic Characteristics: Epidermal cells are irregular-shaped with straight-curved anticlinal walls. Cells are arranged in flagstone pattern. Phytoliths and calcium oxalate druses are randomly located in the epidermal cell matrix. Calcium carbonate rhombohedral druses are aligned with leaf veins. Trichomes are straight to curved spears with hollow interiors and pointed apexes. Bases are hexangle.

Stomata are nearly circular with a pair of crescent-shaped guard cells and fusiform-shaped pore. The length to width ratio of the stoma is approximately 1.2:1. The separation between the upper woody lamella and the lower woody lamella is wide at the lateral sides and the polar ends. The polar stems are narrow.

Fagus grandifolia
American beech

Plate
231

Legend

Epidermal cells are irregular-shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Calcium carbonates rhombohedral druses are aligned with the leaf veins. Calcium oxalate and silica phytoliths are randomly arranged in the epidermal cell matrix. Trichomes have hexangle bases and hollow fibers with parallel sides and pointed apices.
(PLM, single polar)

***Fagus sylvatica*, European beech;**

Family: Fagaceae (Plate 232)

Macroscopic Characteristics: Leaves have crenate to entire margins with a length of 5-10 cm and width of 3-6 cm (Kershner, Nelson and Spellenberg 2008). Tufts of hairs are on the abaxial veins.

Microscopic Characteristics: Epidermal cells are irregular-shaped with straight-curved anticlinal walls. Cells are arranged in flagstone or jigsaw puzzle pattern. Calcium oxalate druses are randomly located in the epidermal cell matrix. Calcium carbonate rhombohedral druses are aligned with leaf veins.

Stomata are nearly circular with a pair of crescent-shaped guard cells and a fusiform-shaped pore. The length to width ratio of the stoma is approximately 1.2:1. The separation between the upper woody lamella and the lower woody lamella is wide at the lateral sides and the polar ends. The polar stems are narrow.

Fagus sylvatica
European beech

Plate
232

Legend

Epidermal cells are irregular shaped with straight-curved anticlinal walls. Calcium oxalate druses are randomly arranged in the epidermal cell matrix. Calcium carbonate rhombohedral druses are aligned with veins. Stomata are nearly circular with a pair of crescent shaped guard cells and fusiform shaped pore.
(brightfield, single polar)

***Forsythia sp.*, Forsythia;**

Family: Oleaceae (Plate 233)

Macroscopic Characteristics: Leaves are trifoliate with serrate to entire margin that range in length from 2-10 cm. Adaxial surface is glabrous however abaxial surface is hairy.

Microscopic Characteristics: Epidermal cells are polygonal-shaped with straight-curved anticlinal walls. Cells are arranged in flagstone pattern. Calcium carbonate rhombohedral druses and silica phytoliths are randomly arranged in the epidermal cell matrix.

Trichomes are long with smooth margins and reinforced bases.

Stomata are nearly circular with a pair of crescent-shaped guard cells and a narrow-shaped pore. The length to width ratio of the stoma is approximately 1.4:1. The separation between the upper woody lamella and the lower woody lamella is wide at the lateral sides and the polar ends. The polar stems are narrow.

Forsythia sp.
Forsythia

Plate
233

Legend

Epidermal cells are polygonal-shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Calcium carbonate rhombohedral druses and silica phytoliths are randomly arranged in the epidermal cell matrix. Trichomes are long with smooth margins and reinforced bases. Stomata are nearly circular with a pair of crescent-shaped guard cells and narrow-shaped pore.
(PLM, single polar)

***Fraxinus americana*, white ash;**

Family: Oleaceae (Plate 234)

Macroscopic Characteristics: Leaves are compound, 7-9 leaflets per leaf. Leaflets are coarsely serrate with a length of approximately 7.5-13 cm and width of 2-7.5 cm (Kershner, Nelson and Spellenberg 2008). Tufts of hairs are on the abaxial veins.

Microscopic Characteristics: Epidermal cells are polygonal-shaped with straight-curved anticlinal walls. Cells are arranged in flagstone pattern. Abundant rectangular phytoliths are aligned with the leaf veins and scattered in epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of an oval to fusiform pore surrounded by guard cells. The length to width ratio of the stoma is approximately 1.7.1. The separation between the upper woody lamella and the lower woody lamella is wide at the lateral sides and the polar ends. The polar stems are narrow.

Fraxinus americana
white ash

Plate
234

Legend

Epidermal cells are polygonal-shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Abundant rectangular phytoliths are aligned with the leaf veins and scattered in epidermal cell matrix. Stomata are randomly arranged and consist of a pair of crescent-shaped guard cells with fusiform-shaped pore. The separation between the upper and the lower woody lamella is narrow at the lateral sides and the polar ends.
(PLM, single polar)

***Fraxinus nigra*, black ash;**

Family: Oleaceae (Plate 235)

Macroscopic Characteristics: Leaves are compound with 7-11 leaflets per leaf. Leaflet are narrowly elliptic with a length of approximately 10-12.5 cm (Kershner, Nelson and Spellenberg 2008). Margins are finely serrate; the adaxial surface is glabrous however tufts of hair are on the abaxial veins.

Microscopic Characteristics: Epidermal cells are polygonal-shaped with straight-curved anticlinal walls. Cells are arranged in flagstone pattern. Calcium oxalate druses and phytoliths are aligned with the leaf veins and scattered in epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of an oval to fusiform-shaped pore surrounded by a pair of guard cells. The length to width ratio of the stoma is approximately 1.3.1. The separation between the upper woody lamella and the lower woody lamella is wide at the lateral sides and the polar ends. The polar stems are relatively wide.

Fraxinus nigra
black ash

Plate
235

***Fraxinus pennsylvanica*, green ash;**

Family: Oleaceae (Plate 236)

Macroscopic Characteristics: Leaves are compound with 7-9 leaflets per leaf. Leaflet length is approximately 5-15 cm and 1-9 cm wide (Kershner, Nelson and Spellenberg 2008). Adaxial surface is glabrous however occasional hairs are scattered on the abaxial surface.

Microscopic Characteristics: Epidermal cells are rectangular to polygonal-shaped with straight-curved anticlinal walls. Cells are arranged in flagstone pattern. Phytoliths are randomly arranged in the epidermal cell matrix. Prickle trichome bases are large circular pads with a rosette of epidermal cells.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of an oval to fusiform-shaped pore surrounded by guard cells. The length to width ratio of the stoma is approximately 1.3.1.

Fraxinus pennsylvanica
green ash

Plate
236

***Ginkgo biloba*, Ginkgo;**

Family: Ginkgoaceae (Plate 237)

Macroscopic Characteristics: Leaves are fan-shaped with radiating veins; length is approximately 5-10 cm long.

Microscopic Characteristics: Epidermal cells are rectangular to polygonal-shaped with straight-curved anticlinal walls. Rectangular cells are aligned with leaf veins, polygonal cells are between the leaf veins. Polygonal cells are arranged in flagstone pattern.

Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. Stomata are partially aligned in parallel rows. The length to width ratio of the stoma is approximately 1.2-1.4. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are relatively wide.

Ginkgo biloba
Ginkgo

Plate
237

***Ilex montana*, mountain winterberry;**

Family: Aquifoliaceae (Plate 238)

Macroscopic Characteristics: Leaves are ovate to oblong with rounded base and acute apex. Leaf length is approximately 3-9 cm and width is 2-5 cm.

Microscopic Characteristics: Epidermal cells are rectangular to irregular shaped with straight-curved anticlinal walls. Rectangular cells are aligned with leaf veins. The irregular shaped cells are arranged like jigsaw puzzle pattern in the epidermal cell matrix. Trichomes are abundant and consist of slightly curved fibers with textured margins. Calcium oxalate druses are randomly arranged in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of an oval to fusiform-shaped pore surrounded by a pair of crescent-shaped guard cells. The length to width ratio of the stoma is approximately 1.3.1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and the polar ends. The polar stems are relatively wide.

Ilex montana
mountain winterberry

Plate
238

Legend

Top Image: Epidermal cells are rectangular to irregular shaped with straight-curved anticlinal walls. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. (PLM, single polar)

Bottom Image: Trichomes are abundant and consist of slightly curved fibers with textured margins. Calcium oxalate druses are randomly arranged in the epidermal cell matrix. (PLM, single polar)

***Ilex opaca*, American holly;**

Family: Aquifoliaceae (Plate 239)

Macroscopic Characteristics: Leaves are stiff with a wedge-shaped base and sharp spike-like leaf spines. Leaf length is approximately 5-8 cm and width is 2-4 cm.

Microscopic Characteristics: Epidermal cells are rectangular to polygonal-shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone or jigsaw puzzle pattern. Trichomes are smooth-sided spears with hollow interior and pointed apices. Calcium oxalate druses are randomly arranged in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a fusiform-shaped pore surrounded by guard cells. The length to width ratio of the stoma is 1.3:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and the polar ends. The polar stems are relatively wide.

Ilex opaca
American holly

Plate
239

***Ilex verticillata*, common winterberry;**

Family: Aquifoliaceae (Plate 240)

Macroscopic Characteristics: Leaves are obovate to elliptic with toothed margins. Leaf length is approximately 5-7.5 cm.

Microscopic Characteristics: Epidermal cells are rectangular to polygonal-shaped with straight-curved anticlinal walls. Trichomes are rough-sided spears with pointed apices.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a fusiform-shaped pore surrounded by crescent-shaped guard cells. The length to width ratio of the stoma is 1.4:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and the polar ends. The polar stems are relatively wide.

Ilex verticillata
common winterberry

Plate
240

Legend

Epidermal cells are rectangular to polygonal-shaped with straight-curved anticlinal walls. Cells are randomly arranged in a flagstone pattern. Trichomes have rough sides with pointed apices. Stomata consist of a pair of guard cells surrounding an oval to fusi-form-shaped pore. The separation between the upper and lower woody lamella is narrow at the lateral sides and the polar ends.
(PLM, single polar)

***Ilex vomitoria*, yaupon;**

Family: Aquifoliaceae (Plate 241)

Macroscopic Characteristics: Leaves are oval and leathery with crenate margins. Leaf length is approximately 0.6-2.5 cm

Microscopic Characteristics: Epidermal cells are polygonal-shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Calcium oxalate and phytoliths are randomly arranged in the epidermal cell matrix.

Stomata are circular and randomly arranged in the epidermal cell matrix. Stomata consist of a fusiform pore surrounded by guard cells. The length to width ratio of the stoma is 1:1. The separation between the upper woody lamella and the lower woody lamella is wide at the lateral sides and the polar ends. The polar stems are narrow.

Ilex vomitoria
yaupon

Plate
241

Juglans cinerea, butternut;

Family: Juglandaceae (Plate 242)

Macroscopic Characteristics: Leaves are compound with 11-17 leaflets per leaf.

Leaflets are 5-10 cm long and 3-5 cm wide. Hairs are scattered on the adaxial surface and abundant on the abaxial surface.

Microscopic Characteristics: Epidermal cells are irregular-shaped with straight to straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Calcium oxalate druses are abundant and randomly arranged in the epidermal cell matrix. Two types of trichomes consist of stellate trichomes and segmented fibers. Stellate fibers have smooth margins with multiple fibers on wide base. Segmented fibers are short with 3-6 segments per fiber.

Stomata are randomly arranged in the epidermal matrix. Stomata consist of an oval to fusiform-shaped pore surrounded by crescent-shaped guard cells. The length to width ratio of the stoma is 1.5:1.

Juglans cinerea
butternut

Plate
242

***Juglans nigra*, black walnut;**

Family: Juglandaceae (Plate 243)

Macroscopic Characteristics: Leaves are compound with 15-23 leaflets per leaf. Leaflets are 7-10 cm long and 2-3 cm wide.

Microscopic Characteristics: Epidermal cells are irregular-shaped with straight to straight-curved anticlinal walls. Calcium oxalate druses are abundant and randomly arranged in the epidermal cell matrix. Two types of trichomes consist of stellate trichomes and segmented fibers. Stellate fibers have smooth margins with multiple fibers on a wide base. Segmented fibers are short with 3-6 segments per fiber.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of an oval to fusiform pore surrounded by crescent-shaped guard cells. The length to width ratio of the stoma is 1.6:1. The separation between the upper woody lamella and the lower woody lamella is wide at the lateral sides and narrow at the polar ends. The polar stems are wide.

Juglans nigra
black walnut

Plate
243

***Juniperus communis*, common juniper;**

Family: Cupressaceae (Plate 244)

Macroscopic Characteristics: Needles are awl-shaped with a glaucous concave abaxial surface. Needles are approximately 1.3 cm in length with a pointed apex length (Kershner, Nelson and Spellenberg 2008). The adaxial surface is convex and glossy; the abaxial surface is concave with numerous stomatal lines.

Microscopic Characteristics: Epidermal cells are rectangular with some parallelogram shaped cells. Ends are square to angular with rounded corners. Cells are oriented in a brick-like arrangement with the long axis of cells parallel to each other. Cell length to width ratio ranges from approximately 1.5:1 to 5:1. Anticlinal walls are straight-curved.

The abaxial surface consists of a high density of stomata with pores aligned axially to the epidermal cell long axis. Stomata patterning is ordered into parallel rows with a pair of crescent-shaped guard cells surrounding a fusiform-shaped stoma pore. The stoma is roughly rectangular with rounded polar ends. The stoma is slightly elongated with an approximate length to width aspect ratio of 1.3:1. The separation between the lower and upper woody lamellae is approximately 2 microns. The polar stem is narrow, approximately 2 microns, with a bifurcated extension at each end.

Juniperus communis
common juniper

Plate
244

Legend

Top Image: Abundant stomata in parallel rows are located in a field of parallelogram to rectangular shaped epidermal cells with straight anticlinal walls. (PLM, single polar)

Bottom Image: Detail image of stomata in parallel rows, crescent shaped guard cells surround a fusiform shaped stoma pore. Polar stems are narrow and extend beyond the rounded polar ends; stems are bowtie shaped. (PLM, single polar)

***Juniperus scopulorum*, Rocky Mountain juniper;**

Family: Cupressaceae (Plate 245)

Macroscopic Characteristics: Needles are scale-like with a length of approximately 0.16-0.9 cm (Kershner, Nelson and Spellenberg 2008). Resin glands are conspicuous; stomatal lines are evident in the hidden areas where scale-like needles overlap.

Microscopic Characteristics: Epidermal cells are rectangular shaped cells oriented in a brick-like arrangement with the long axis of cells parallel to each other. Ends are square to angular with rounded corners. Cell length to width ratio ranges from approximately 3:1 to 10:1. Anticlinal walls are straight-curved.

The abaxial surface consists of a high density of stomata with pores axially aligned to epidermal cell long axis. Stomata patterning is ordered into parallel rows; a pair of crescent-shaped guard cells surround a stoma pore. The stoma is roughly rectangular with rounded polar ends. The stoma is slightly elongated with an approximate length to width aspect ratio of 1.7:1. The separation between the lower and upper woody lamellae is approximately 2 microns. The polar stem is narrow, approximately 2 microns, with a bifurcated extension at each end.

Juniperus scopulorum
Rocky Mountain juniper

Plate
245

***Juniperus virginiana*, eastern redcedar;**

Family: Cupressaceae (Plate 246)

Macroscopic Characteristics: Immature leaves are needle-like approximately 1 cm in length; mature leaves are scale-like, approximately 0.16-0.9 cm in length (Kershner, Nelson and Spellenberg 2008). Resin glands are conspicuous; stomatal lines are evident in the hidden areas where scale-like needles overlap. No hairs, scales or trichomes were observed on the leaves.

Microscopic Characteristics: Epidermal cells are rectangular to parallelogram shaped cells. Cells are oriented in a brick-like arrangement with the long axis of cells parallel to each other. Cell length to width ratio ranges from approximately 2:1 to greater than 5:1. Anticlinal walls are straight-curved.

Stomata patterning is ordered into parallel rows with a pair of crescent-shaped guard cells surrounding a stoma pore. The stoma is roughly rectangular with rounded polar ends. Pores are aligned parallel to the epidermal cell long axis. The thickened inner wall extends from the stoma pore to the ends of the guard cells, ends of inner wall are bifurcated at end of guard cells. The separation between the lower and upper woody lamellae is approximately 2 microns. The polar stem is narrow, approximately 2 microns, with a bifurcated extension.

Juniperus virginiana
eastern redcedar

Plate
246

Legend

Epidermal cells are rectangular to parallelogram shaped with straight-curved anticlinal walls. Most epidermal cells are aligned end-to-end but some are arranged in a flagstone pattern. Stomata are arranged in parallel rows. Stomata consist of a pair of crescent shaped guard cells with an oblong pore. Polar ends are bifurcated. Four subsidiary cells surround the stoma, two at the polar ends and one on each side of the guard cells.
(PLM, single polar)

***Kalmia latifolia*, mountain laurel;**

Family: Ericaceae (Plate 247)

Macroscopic Characteristics: Leaves are segmented with a length of 3-12 cm and width of 1-4 cm.

Microscopic Characteristics: Epidermal cells are polygonal to parallelogram-shaped with straight-curved anticlinal walls. Cells are randomly arranged in a flagstone pattern. Trichomes are straight-sided fibers with pointed apices. Calcium oxalate druses are randomly arranged in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells with a fusiform-shaped pore. Stomata are slightly elongated with an approximate length to width aspect ratio of 1.2:1. The separation between the upper woody lamella and the lower woody lamella is wide at the lateral sides and the polar ends. The polar stems are wide.

Kalmia latifolia
mountain laurel

Plate
247

Legend

Top Image: Epidermal cells are polygonal to parallelogram-shaped with straight-angled anticlinal walls. Cells are randomly arranged in a flagstone pattern. Stomata consist of a pair of crescent-shaped guard cells with a fusiform-shaped pore.

Bottom Image: Trichomes are straight-sided fibers with pointed apices. Calcium oxalate druses are randomly arranged in the epidermal cell matrix.
(PLM, single polar)

***Larix laricina*, eastern larch;**

Family: Pinaceae (Plate 248)

Macroscopic Characteristics: Leaves are deciduous, grooved, short, and needle-like. Leaves are produced spirally on shoots; needle length is approximately 1.9-3.2 cm (Kershner, Nelson and Spellenberg 2008). The adaxial surface of the leaf is glossy whereas the abaxial surface consist of a pair of stomatal lines on either side of the central rib.

Microscopic Characteristics: Epidermal cells are rectangular; cells are aligned end-to-end in a brick-like pattern; with length to width ratio that is greater than 5:1. End walls are square to slightly angled. Anticlinal walls are straight. Abundant fine-grained and circular phytoliths are randomly arranged in the epidermal cell matrix.

Stomata patterning is ordered into parallel rows; stoma pores are aligned axially to the long axis of epidermal cells. Guard cells are crescent-shaped cells surrounding an elongated to fusiform pore. The stoma has an approximately length to width ratio of 1.5-1.8:1. Spacing between the lower woody lamellae and upper woody lamella is greater than 5 microns. The polar stem is 2-3 microns wide. Adjacent stomata are typically separated by a single oblong cell between polar ends. The polar end cell has an aspect ratio of approximately 2:1 to 5:1.

Larix laricina
eastern larch

Plate
248

Legend

Epidermal cells are rectangular shaped with end walls that are straight to angular. Anticlinal walls are straight-curved. Cells are aligned end-to-end and stacked in a brick-like pattern. The length to width ratio that is greater than 5:1. Phytoliths are randomly arranged in the epidermal cell matrix.
(PLM, single polar)

***Larix occidentalis*, western larch;**

Family: Pinaceae (Plate 249)

Macroscopic Characteristics: Leaves are deciduous, grooved, short, and needle-like. Leaves are produced spirally on shoots; needle length is approximately 2.5-4.4 cm (Kershner, Nelson and Spellenberg 2008). The adaxial surface of the leaf is glossy whereas the abaxial surface consist of multiple stomatal lines on either side of the central rib.

Microscopic Characteristics: Epidermal cells are rectangular; cells are aligned end-to-end in a brick-like pattern; with length to width ratio that is greater than 5:1. End walls are square to slightly angled. Anticlinal walls are straight.

Stomata patterning is ordered into parallel rows; stoma pores are aligned axially to the long axis of epidermal cells. Crescent-shaped guard cells surround an elongated to fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.5-1.8:1. Spacing between the lower woody lamellae and upper woody lamella is greater than 5 microns. The polar stem is 2-3 microns wide. Adjacent stomata are typically separated by a single oblong cell between polar ends. The polar end cell has an aspect ratio of approximately 5:1.

Larix occidentalis
western larch

Plate
249

Legend

Epidermal cells are rectangular shaped with straight-curved anticlinal walls. Cells are aligned end-to-end and stacked in a brick-like pattern. Cells ends are square to slightly angled. Stomata are arranged in parallel rows. Stomata consist of crescent guard cells with a fusiform shaped pore. Spacing between the lower woody lamellae and upper woody lamella is greater than 5 microns.
(PLM, single polar)

***Linnaea borealis*, twinflower;**

Family: Caprifoliaceae (Plate 250)

Macroscopic Characteristics: Leaves are opposite, evergreen and oval with a length of 0.3-1 cm and width of 0.2-0.7 cm.

Microscopic Characteristics: Epidermal cells are polygonal to irregular-shaped with verrucate anticlinal walls. Cells are arranged in a flagstone or jigsaw puzzle pattern. No phytoliths were observed in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of crescent-shaped guard cells with a fusiform-shaped pore. The stoma has an approximate length to width ratio of 1:1. The separation between the upper woody lamella and the lower woody lamella is wide at the lateral sides and the polar ends. The polar stems are wide.

Linnaea borealis
twinflower

Plate
250

Legend

Epidermal cells are polygonal to irregular-shaped with verrucate anticlinal walls. Cells are arranged in a flagstone pattern. Stomata consist of crescent-shaped guard cells with a fusiform-shaped pore. The stoma has an approximate length to width ratio of 1:1. The separation between the upper and lower woody lamella is wide at the lateral sides and the polar ends. The polar stems are wide. (PLM, single polar)

Liquidambar styraciflua, sweetgum;

Family: Altingiaceae (Plate 251)

Macroscopic Characteristics: Leaves are star-shaped with five pointed palmate lobes. Leaf length is approximately 7.5-12 cm.

Microscopic Characteristics: Epidermal cells are rectangular to polygonal with straight-curved anticlinal walls. Rectangular cells are aligned with leaf veins and polygonal cells are randomly arranged like flagstones in the epidermal cell matrix. Calcium oxalate druses are randomly arranged in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata are oblong and consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The stoma has an approximately length to width ratio of 2.1:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and the polar ends. The polar stems are wide.

Liquidambar styraciflua
sweetgum

Plate
251

***Liriodendron tulipifera*, tuliptree;**

Family: Magnoliaceae (Plate 252)

Macroscopic Characteristics: Leaves are pinnately veined and shaped like a tulip flower. Length is approximately 12.5-15 cm. The adaxial and abaxial surfaces are glabrous however occasional tufts of hairs are on the abaxial central vein.

Microscopic Characteristics: Epidermal cells are polygonal to irregular-shaped with straight-curved anticlinal walls. Cells are randomly arranged like flagstone or jigsaw puzzle pattern in the epidermal cell matrix. Phytoliths are randomly arranged in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata are oblong and consist of a pair of crescent-shaped guard cells surrounding a fat fusiform-shaped pore. The pore is not bilaterally symmetric. The stoma has an approximately length to width ratio of 1.2:1. The separation between the upper woody lamella and the lower woody lamella is wide at the lateral sides and the polar ends. The polar stems are narrow.

Liriodendron tulipifera
tuliptree

Plate
252

Legend

Top Image: Stomata are oblong and consist of a pair of crescent-shaped guard cells surrounding a fat fusiform-shaped pore.
(PLM, single polar)

Bottom Image: Epidermal cells are polygonal to irregular-shaped with straight-curved anticlinal walls. Cells are randomly arranged like flagstones. Phytoliths are randomly arranged in the epidermal cell matrix.
(PLM, single polar)

***Lonicera canadensis*, American honeysuckle;**

Family: Caprifoliaceae (Plate 253)

Macroscopic Characteristics: Leaves have a smooth margin with a length of 3-12 cm and width of 1.5-4 cm. The adaxial surface is glabrous whereas the abaxial surface and veins have occasional hairs.

Microscopic Characteristics: Epidermal cells are polygonal-shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Trichomes are hollow spears with pointed apices. Bases are hexangle with a rosette of epidermal cells surrounding the base. Globular calcium oxalate druses are randomly scattered in the epidermal cell matrix.

Brachyparacytic stomata are randomly arranged. Stomata consist of a pair of crescent-shaped guard cells surrounding an oval to fusiform pore. The stoma has an approximately length to width ratio of 1.6:1. Stomata are not bilaterally symmetric. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and the polar ends. The polar stems are narrow.

Lonicera canadensis
American honeysuckle

Plate
253

***Lonicera involucrata*, twinberry honeysuckle;**

Family: Caprifoliaceae (Plate 254)

Macroscopic Characteristics: Leaves are elliptic with pointed apices. Leaf length is approximately 3–16 cm with a width of 2–8 cm. Margins and the abaxial surface are punctuated with hairs.

Microscopic Characteristics: Epidermal cells are polygonal-shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Trichomes are heavily textured spears with pointed apices. Bases are reinforced. Calcium oxalate druses are randomly arranged in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells and an elongated pore on an elevated reinforced base. The stoma has an approximately length to width ratio of 1.1:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are relatively wide.

Lonicera involucrata
twinberry honeysuckle

Plate
254

Legend

Top Image: Epidermal cells are polygonal-shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Calcium oxalate druses are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells and an elongated pore. (PLM, single polar)

Bottom Image: Trichomes are textured with reinforced bases. (PLM, single polar)

***Lonicera morrowii*, Morrow honeysuckle;**

Family: Caprifoliaceae (Plate 255)

Macroscopic Characteristics: Leaves are oblong with an approximately length of 4-6 cm. Occasional hairs cover the adaxial and abaxial surfaces and the abaxial veins.

Microscopic Characteristics: Epidermal cells are polygonal-shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Trichomes are textured spears with pointed apexes. Phytoliths are randomly arranged in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells and a fusiform-shaped pore on an elevated reinforced base. The stoma has an approximately length to width ratio of 1.4:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are relatively wide.

Lonicera morrowii
Morrow honeysuckle

Plate
255

Legend

Epidermal cells are polygonal-shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Phytoliths are randomly arranged in the epidermal cell matrix. Trichomes are textured with reinforced bases. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The separation between the upper and lower woody lamella is narrow at the lateral sides and wide at the polar ends. (PLM, single polar)

***Lonicera utahensis*, Utah honeysuckle;**

Family: Caprifoliaceae (Plate 256)

Macroscopic Characteristics: Leaves are oval to oblong with an approximately length of approximately 8 cm and a width of 4 cm. Occasional hairs cover the adaxial and abaxial surfaces.

Microscopic Characteristics: Epidermal cells are polygonal-shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Phytoliths are randomly arranged in the epidermal cell matrix. Abundant calcium carbonate rhombohedral druses are aligned with leaf veins. Trichomes are straight-sided with hemi-circular bases.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore on an elevated reinforced base. The stoma has an approximately length to width ratio of 1.3:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are relatively wide.

Lonicera utahensis
Utah honeysuckle

Plate
256

***Magnolia acuminata*, cucumber tree;**

Family: Magnoliaceae (Plate 257)

Macroscopic Characteristics: Leaves are oval to oblong with entire margins. The length is approximately 12-25 cm and a width of 6-12 cm. Hairs cover the adaxial and abaxial surfaces and veins.

Microscopic Characteristics: Epidermal cells are polygonal and arranged in a flagstone pattern. Anticlinal walls are straight-curved. Phytoliths are randomly arranged in the epidermal cell matrix. Calcium oxalate druses are randomly arranged in the epidermal cell matrix. Trichomes are hollow with smooth sides and pointed apices; typically, the lower third of the trichome is curved to hooked.

Brachyparacytic stomata are randomly arranged and consist of a pair of fat crescent-shaped guard cells with a fusiform-shaped pore. The stoma has an approximately length to width ratio of 1:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are wide.

Magnolia acuminata
cucumber-tree

Plate
257

***Magnolia grandiflora*, southern magnolia;**

Family: Magnoliaceae (Plate 258)

Macroscopic Characteristics: Leaves are oval to dark green with entire margins. The length is approximately 20 cm and the width 12 cm. The adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are polygonal-shaped and arranged in a flagstone pattern. Anticlinal walls are straight-curved. Phytoliths are randomly arranged in the epidermal cell matrix.

Brachyparacytic stomata are randomly arranged and consist of a pair of crescent-shaped guard cells with a fusiform-shaped pore. Some guard cells are partially lignified. The stoma is nearly circular has an approximately length to width ratio of 1.1:1. The separation between the upper woody lamella and the lower woody lamella is relative wide at the lateral sides and wide at the polar ends. The polar stems are wide.

Magnolia grandiflora
southern magnolia

Plate
258

***Magnolia kobus*, *Kobus magnolia*;**

Family: Magnoliaceae (Plate 259)

Macroscopic Characteristics: Leaves are oblong with a pointed tip and entire margins. Leaf length is approximately 8-15 cm. The adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are polygonal-shaped and arranged in a flagstone or jigsaw puzzle pattern. Anticlinal walls are straight-curved. Phytoliths are randomly arranged in the epidermal cell matrix.

Brachyparacytic stomata are randomly arranged and consist of a pair of crescent-shaped guard cells with a fusiform-shaped pore. Some guard cells are partially lignified. The stoma has an approximately length to width ratio of 1.2:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are wide.

Magnolia kobus
Kobus magnolia

Plate
259

Legend

Epidermal cells are polygonal and arranged in a flagstone pattern. Anticlinal walls are straight-curved. Phytoliths are randomly arranged in the epidermal cell matrix. Abundant brachyparacytic stomata are randomly arranged and consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The separation between the upper and lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are wide. (PLM, single polar)

***Magnolia loebneri*, Loebner magnolia;**

Family: Magnoliaceae (Plate 260)

Macroscopic Characteristics: Leaves are simple and obovate with a length of 10-15 cm. Leaf margins are entire and both adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are polygonal-shaped and arranged in a flagstone pattern. Anticlinal walls are straight-curved. Phytoliths are randomly arranged in the epidermal cell matrix.

Brachyparacytic stomata are randomly arranged and consist of a pair of crescent-shaped guard cells with a thin pore. Some guard cells are partially lignified. The stoma is an oblong with an approximately length to width ratio of 1.7:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and very wide at the polar ends. The polar stems are wide.

Magnolia loebneri
Loebner magnolia

Plate
260

Legend

Epidermal cells are polygonal and arranged in a flagstone pattern. Anticlinal walls are straight-curved. Phytoliths are randomly arranged in the epidermal cell matrix.

Abundant brachyparacytic stomata are randomly arranged and consist of a pair of crescent-shaped guard cells surrounding a thin pore. The separation between the upper and lower woody lamella is narrow at the lateral sides and very wide at the polar ends. The polar stems are wide. (PLM, single polar)

***Magnolia stellata*, star magnolia;**

Family: Magnoliaceae (Plate 261)

Macroscopic Characteristics: Leaves are oblong with a length of 10 cm and width 4 cm. Leaf margins are entire and both adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are polygonal and arranged in a flagstone pattern. Anticlinal walls are straight-curved. Phytoliths and calcium oxalate druses are randomly arranged in the epidermal cell matrix.

Brachyparacytic stomata are randomly arranged and consist of a pair of crescent-shaped guard cells with a thin pore. Some guard cells are partially lignified. The stoma has an approximately length to width ratio of 1.6:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and very wide at the polar ends. The polar stems are wide.

Magnolia stellata
star magnolia

Plate
261

Legend

Epidermal cells are polygonal and arranged in a flagstone pattern. Anticlinal walls are straight-curved. Phytoliths and calcium oxalate druses are randomly arranged in the epidermal cell matrix. Abundant brachyparacytic stomata are randomly arranged and consists of crescent-shaped guard cells surrounding a thin pore. Polar ends are wide. The separation between the upper and lower woody lamella is narrow at the lateral sides and very wide at the polar ends. (PLM, single polar)

***Magnolia virginiana*, sweetbay;**

Family: Magnoliaceae (Plate 262)

Macroscopic Characteristics: Leaves are oblong with a length of 6-12 cm and a width 3-5 cm.

Microscopic Characteristics: Epidermal cells are polygonal-shaped and arranged in a flagstone pattern. Anticlinal walls are straight-curved. Phytoliths and calcium oxalate druses are randomly arranged in the epidermal cell matrix. Abundant stellate trichomes are arranged randomly in the epidermal cell matrix.

Stomata are randomly arranged and consist of crescent-shaped guard cells surrounding a round to fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.4:1 to 2.2:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are wide.

Magnolia virginiana
sweetbay

Plate
262

***Mahonia repens*, creeping barberry;**

Family: Berberidaceae (Plate 263)

Macroscopic Characteristics: Holly-shaped leaves are glossy with 5-7 spines along the margins. The adaxial surface is glabrous however hairs randomly cover the abaxial surface.

Microscopic Characteristics: Epidermal cells are rectangular to polygonal-shaped with straight to straight-curved anticlinal walls. Trichomes are stellate-shaped with straight sides and an oval base.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a round to fusiform-shaped pore. The length to width ratio of the stoma is approximately 1:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are wide.

Mahonia repens
creeping barberry

Plate
263

Legend

Top Image: Epidermal cells include polygonal and rectangular cells arranged in a flagstone pattern. Anticlinal walls are straight-curved. Trichomes are stellate-shaped fibers with an oval base. Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of fat crescent-shaped guard cells surrounding a round to fusiform-shaped pore.

(PLM, single polar)

***Malus pumila*, common apple;**

Family: Rosaceae (Plate 264)

Macroscopic Characteristics: Leaves are simple, oval and serrate with a length of 7.5-10 cm and a width of 4-5 cm.

Microscopic Characteristics: Epidermal cells are polygonal-shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone or jigsaw puzzle pattern. Calcium carbonate rhombohedral druses are aligned with leaf veins; calcium oxalate druses are randomly arranged. Trichomes have slightly textured margins and rounded apexes.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of crescent-shaped guard cells surrounding an oval to fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.3:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are wide.

Malus pumila
common apple

Plate
264

***Menziesia ferruginea*, rusty menziesia;**

Family: Ericaceae (Plate 265)

Macroscopic Characteristics: Leaves are oval with pointed apexes with a length of 4-6 cm. Hairs were observed on the adaxial surface and margin, occasional hairs were observed on the abaxial surface. Leaf margin is serrate.

Microscopic Characteristics: Epidermal cells are polygonal-shaped with straight-curved anticlinal walls. Phytoliths, calcium oxalate and occasional calcium carbonate rhombohedral druses are randomly arranged in the epidermal cell matrix. Trichomes are distinctly striated spears with pointed apexes.

Menziesia ferruginea
rusty menziesia

Plate
265

***Morus alba*, white mulberry;**

Family: Moraceae (Plate 266)

Macroscopic Characteristics: Leaves are cordate with rounded to acuminate tip. Leaf margins are serrate and length is approximately 5-15 cm. The adaxial and abaxial surfaces are mostly glabrous however hairs are on the veins.

.

Microscopic Characteristics: Epidermal cells are polygonal-shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Trichomes are straight-sided spears with pointed apexes. Trichome bases are elevated and circular to hexangle. Phytoliths and calcium oxalate druses are randomly arranged in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells with a fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.5:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and the polar ends. The polar stems are narrow.

Morus alba
white mulberry

Plate
266

Legend

Top Image: Epidermal cells are polygonal with straight-curved anticlinal walls. Trichome bases elevated and circular to hexangle. Phytoliths and calcium oxalate druses are randomly arranged in the epidermal cell matrix. (PLM, single polar)

Bottom Image: Trichomes are straight-sided spears with pointed apices. (PLM, single polar)

***Morus rubra*, red mulberry;**

Family: Moraceae (Plate 267)

Macroscopic Characteristics: Leaves are broadly cordate with a notched base; length is approximately 7-14 cm and 6-12 cm wide. Leaf margins are serrate. The adaxial and abaxial surfaces are mostly glabrous however a few hairs are on the abaxial veins.

Microscopic Characteristics: Epidermal cells are polygonal-shaped and arranged in a flagstone pattern. Anticlinal walls are straight-curved. Phytoliths and calcium oxalate druses are randomly arranged in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of slightly oblong crescent-shaped guard cells with a fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.6:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and the polar ends. The polar stems are narrow.

Morus rubra
red mulberry

Plate
267

Legend

Epidermal cells are polygonal-shaped and arranged in a flagstone pattern. Anticlinal walls are straight-curved. Phytoliths and calcium oxalate druses are randomly arranged in the epidermal cell matrix. Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells with a fusiform-shaped pore (PLM, single polar)

***Myrica cerifera*, southern bayberry;**

Family: Myricaceae (Plate 268)

Macroscopic Characteristics: Leaves are narrowly ovate with untoothed lower margins, toothed upper margins and pointed apices. Length is approximately 2-8 cm.

Microscopic Characteristics: Epidermal cells are polygonal-shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone or jigsaw puzzle pattern. Calcium oxalate druses are aligned with leaf veins with some druses in the epidermal cell matrix. Trichomes are slightly curved with hollow interiors. Trichome margins are slightly textured.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.1:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are wide.

Myrica cerifera
southern bayberry

Plate
268

Legend

Top Image: Epidermal cells are polygonal with straight-angled anticlinal walls. Cells are arranged in a flagstone pattern. Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore.
(PLM, single polar)

Bottom Image: Calcium oxalate druses are aligned with leaf veins with druses some in the epidermal cell matrix.
(PLM, single polar)

Myrica gale, sweetgale;

Family: Myricaceae (Plate 269)

Macroscopic Characteristics: Leaves are oblanceolate with broad tip and a tapered base, margins are finely toothed or crinkled. Length is approximately 2-5 cm.

Microscopic Characteristics: Epidermal cells are polygonal-shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Calcium oxalate druses are randomly arranged.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The stoma has an approximately length to width ratio of 1:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are wide.

Myrica gale
sweetgale

Plate
269

Legend

Top Image: Epidermal cells are polygonal with straight-angled anticlinal walls. Calcium oxalate druses are randomly arranged. Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. (PLM, single polar)

Bottom Image: Trichomes are straight sided with pointed apices. (PLM, single polar)

***Myriophyllum* spp., watermilfoil;**

Family: Haloragaceae (Plate 270)

Macroscopic Characteristics: Leaves are thread-like with a length of approximately 0.4-1.3 cm.

Microscopic Characteristics: Epidermal cells are square to polygonal-shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Calcium oxalate druses are randomly arranged. Trichomes are short, straight-sided spears with a slight hook.

Stomata are randomly arranged in the epidermal cell matrix. Stomata are circular to oval with a pair of crescent-shaped guard cells surrounding a thin pore. The stoma has an approximately length to width ratio of 1.3-1.7:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and the polar ends. The polar stems are narrow.

***Myriophyllum* spp.**
watermilfoil

Plate
270

Nymphaea advena, yellow waterlily;

Family: Nymphaeaceae (Plate 271)

Macroscopic Characteristics: Leaves are large and circular with notched centers.

Microscopic Characteristics: Epidermal cells are polygonal-shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone or jigsaw puzzle pattern.

Stomata are randomly arranged in the epidermal cell matrix. Stomata are circular-shaped and consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.1:1. The stoma is generally not bilaterally symmetric. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and the polar ends. The polar stems are narrow.

Nymphaea advena
yellow waterlily

Plate
271

Nyssa aquatica, water tupelo;

Family: Cornaceae (Plate 272)

Macroscopic Characteristics: Leaves are glossy, obovate to oblong with smooth margins. Leaf length is approximately 10-20 cm.

Microscopic Characteristics: Epidermal cells are polygonal-shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Trichomes have hollow interiors with textured margins. Trichome bases are hexangle with a rosette pattern of epidermal cells.

Brachyparacytic stomata are randomly arranged in the epidermal cell matrix. Stomata are oblong and consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.8:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are wide.

Nyssa aquatica
water tupelo

Plate
272

Legend

Top Image: Epidermal cells are polygonal with straight-angled anticlinal walls. Trichomes have hollow interiors with textured margins. Stomata are randomly arranged in the epidermal cell matrix. Stomata are oblong and consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. (PLM, single polar)

Bottom Image: Trichome bases are a rosette pattern of epidermal cells. (PLM, single polar)

Nyssa sylvatica, black tupelo;

Family: Cornaceae (Plate 273)

Macroscopic Characteristics: Leaves are elliptic to obovate with entire to toothed margins. Leaf length is approximately 13 cm.

Microscopic Characteristics: Epidermal cells are polygonal-shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Calcium oxalate druses and phytoliths are randomly arranged in the epidermal cell matrix whereas calcium carbonate rhombohedrals are aligned with veins.

Brachyparacytic stomata are randomly arranged in the epidermal cell matrix. Stomata are oblong and consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The stoma has an approximately length to width ratio of 2.1:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and the polar ends. The polar stems are relatively wide.

Nyssa sylvatica
black tupelo

Plate
273

Legend

Epidermal cells are polygonal with straight-angled anticlinal walls. Calcium oxalate druses and phytoliths are randomly arranged in the epidermal cell matrix whereas calcium carbonate rhombohedrals are aligned with veins. Brachyparacytic stomata are randomly arranged in the epidermal cell matrix. Stomata are oblong and consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore.
(PLM, single polar)

***Ostrya virginiana*, hophornbean;**

Family: Betulaceae (Plate 274)

Macroscopic Characteristics: Leaves are ovoid, pinnately veined with doubly serrated margins. Leaf length is approximately 5-13 cm long and 4-6 cm wide.

Microscopic Characteristics: Epidermal cells are polygonal-shaped with straight-curved anticlinal walls. Cells are arranged in a jigsaw puzzle pattern. Trichomes are smooth-sided spears with pointed apices. Trichomes bases are polygonal to hexangle. Fibers are primarily located on leaf veins.

Stomata are randomly arranged in the epidermal cell matrix. Stomata are oblong and consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.5-1.8:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are relatively wide.

Ostrya virginiana
hophornbean

Plate
274

***Parthenocissus vitacea*, Virginia creeper;**

Family: Vitaceae (Plate 275)

Macroscopic Characteristics: Palmate leaves are divided into five leaflets. Leaflets have a width of 3-20 cm and serrated margins. The adaxial and abaxial surfaces are glabrous.

.

Microscopic Characteristics: Epidermal images are polygonal-shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Raphide calcium oxalate druses are randomly arranged in the epidermal cell matrix, a few in bundles.

Stomata are randomly arranged in the epidermal cell matrix. Stomata are oblong and consist of a pair of crescent-shaped guard cells surrounding a fusiform to oval-shaped pore. The stoma has an approximately length to width ratio of 2:1. The separation between the upper woody lamella and the lower woody lamella is wide at the lateral sides and narrow at the polar ends. The polar stems are relatively narrow.

Parthenocissus vitacea
Virginia creeper

Plate
275

***Philadelphus lewisii*, Lewis' mock orange;**

Family: Hydrangeaceae (Plate 275)

Macroscopic Characteristics: Leaves are oval with smooth to serrated margins. Leaf length is approximately 3-5 cm.

Microscopic Characteristics: Epidermal cells are polygonal-shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Calcium oxalate druses are randomly arranged in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.3:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are relatively wide.

Philadelphus lewisii
Lewis' mock orange

Plate
275

***Physocarpus opulifolius*, ninebark;**

Family: Rosaceae (Plate 277)

Macroscopic Characteristics: Leaves are broadly ovate, palmate with 3 lobes. Leaves have double-serrate margins and with a length of approximately 5-15 cm. Veins are prominent and hairs cover the adaxial and abaxial surface.

Microscopic Characteristics: Epidermal cells are polygonal-shaped with straight-curved anticlinal walls. Cells are arranged in a flagstone pattern. Calcium oxalate druses and calcium carbonate rhombohedrals are randomly arranged. Trichomes are curved fibers with smooth straight margins. Trichomes are joined at the base into clumps.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.7:1. The separation between the upper woody lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are relatively narrow.

Physocarpus opulifolius
ninebark

Plate
277

Legend

Top Image: Epidermal cells are polygonal-shaped with straight-curved anticlinal walls. Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore.
(PLM, single polar)

Bottom Image: Calcium oxalate and calcium carbonates are randomly arranged. Tri-chomes are curved fibers with straight margins.
(PLM, single polar)

***Picea abies*, Norway spruce;**

Family: Pinaceae (Plate 278)

Macroscopic Characteristics: Immature needles are four-sided with mature needles become more flattened, stiff and sharp-pointed; needles are 1.3-2.5 cm long (Kershner, Nelson and Spellenberg 2008). Stomatal lines were observed on all four surfaces but more prominent on the abaxial surfaces.

Microscopic Characteristics: Epidermal cells are rectangular to parallelogram shaped with a length to width ratio from 1:1 to greater than 3:1. Cells are oriented in a brick-like arrangement with the long axis of cells parallel to each other. Anticlinal walls are sinuous to verrucate. No phytoliths or trichomes were observed.

Stomata patterning is ordered into parallel rows; stoma pores are aligned axially to the long axis of epidermal cells. Stomata are oval in outline with rounded lateral sides and rounded polar ends. A pair of crescent-shaped guard cells surround a flattened oval shaped stomata pore. Spacing between the lower woody lamellae and upper woody lamella is less than 2 microns. The polar stems are wide.

Picea abies
Norway spruce

Plate
278

***Picea engelmannii*, Engelmann's spruce;**

Family: Pinaceae (Plate 279)

Macroscopic Characteristics: Needles are four-sided, approximately 2-3 cm long, with sharp tips (Kershaw, MacKinnon and Pojar 1998). Stomatal lines were observed on all four surfaces but more prominent on the abaxial surfaces.

Microscopic Characteristics: Epidermal cells are rectangular to parallelogram shaped with a length to width ratio from 1:1 to greater than 3:1. Cells are oriented in a brick-like arrangement with the long axis of cells parallel to each other. Anticlinal walls are sinuous to verrucate. No phytoliths or trichomes were observed.

Stomata patterning is ordered into parallel rows. A pair of crescent-shaped guard cells surround a circular to rectangular pore. Guard cells have rounded sides and ends. The lower woody lamella is narrowly separated from the upper woody lamella however the polar stems are wide. The angle of attachment between polar stem and guard cell is narrow.

Picea engelmannii
Engelmann spruce

Plate
279

Legend

Top Image: Oval stomata are axially aligned to epidermal cells in parallel rows; stoma pores are rectangular with wide polar stems. Separation of lower and upper woody lamellae is narrow. Four subsidiary cells surround the stoma.
(PLM, single polar)

Bottom Image: Rectangular epidermal cells have sinuous to verrucate anticlinal walls.
(PLM, single polar)

***Picea glauca*, white spruce;**

Family: Pinaceae (Plate 280)

Macroscopic Characteristics: Needles are four-sided with sharp tips; length is 1.3-1.9 cm (Kershner, Nelson and Spellenberg 2008). Stomatal lines were observed prominently on all four surfaces.

Microscopic Characteristics: Epidermal cells are rectangular shaped with a length to width ratio of greater than 5:1. Cells are oriented in a brick-like arrangement with the long axis of cells parallel to each other. Anticlinal walls are straight to slightly sinuous. No phytoliths or trichomes were observed.

Stomata patterning is ordered into parallel rows with pores that are fusiform-shaped. Guard cells have rounded sides and ends with the stoma forming an oval outline. Stomata pores are parallel to the linear axis of the epidermal cells. Circular chloroplast inclusions, typically 1-2 inclusions, were observed in some guard cells. The lower woody lamella is narrowly separated from the upper woody lamella however the polar stems are wide. The angle of attachment between polar stem and guard cell is narrow.

Picea glauca
white spruce

Plate
280

***Picea mariana*, black spruce;**

Family: Pinaceae (Plate 281)

Macroscopic Characteristics: Needles are four-sided, stiff and blunt-tipped with a length of 0.6-1.9 cm (Kershner, Nelson and Spellenberg 2008). Stomatal lines were observed prominently on all four surfaces.

Microscopic Characteristics: Epidermal cells are rectangular to parallelogram shaped with a length to width ratio of 1:1 to greater than 5:1. Anticlinal walls are wavy to sinuous with cells stacked in a brick-like patterns. No phytoliths or trichomes were observed.

Stomata patterning is ordered into parallel rows. Stomata are roughly circular with a length to width ratio of approximately 1.3:1. Fusiform-shaped stomata pores are parallel to the linear axis of the epidermal cells. The lower woody lamella is narrowly separated from the upper woody lamella however the polar stems are wide. The angle of attachment between polar stem and guard cell is narrow.

Picea mariana
black spruce

Plate
281

***Picea pungens*, blue spruce;**

Family: Pinaceae (Plate 282)

Macroscopic Characteristics: Needles are four-sided, rigid, with sharp pointed tips; length is 2.1-3.2 cm (Kershner, Nelson and Spellenberg 2008). Stomatal lines were observed prominently on all four surfaces.

Microscopic Characteristics: Epidermal cells are rectangular to parallelogram shaped with a length to width ratios of 1:1 to greater than 5:1. Anticlinal walls are straight-curved to wavy. Cells are stacked end-to-end and in a brick-like patterns. No phytoliths or trichomes were observed.

Stomata patterning is ordered into parallel rows. Fusiform-shaped stomata pores are parallel to the linear axis of the epidermal cells and occasionally lignified. Guard cells are crescent-shaped with rounded sides and ends, the shape of the stoma is oval. Occasional chloroplast cells are within the guard cells. The lower woody lamella is narrowly separated from the upper woody lamella however the polar stems are wide. The angle of attachment between polar stem and guard cell is narrow.

Picea pungens
blue spruce

Plate
282

Legend

Top Image: Stomata are in parallel rows that are axially aligned with rectangular to parallelogram shaped epidermal cells. Stoma pores are fusiform shaped; some pores are lignified. Four subsidiary cells surround the stoma, two at the polar ends and one on each side of the guard cells.
(PLM, single polar)

Bottom Image: The anticlinal walls are wavy.
(PLM, single polar)

***Picea rubens*, red spruce;**

Family: Pinaceae (Plate 283)

Macroscopic Characteristics: Needles are four-sided, slender and stiff with sharp pointed tips; length is 0.6-1.9 cm (Kershner, Nelson and Spellenberg 2008). Stomatal lines were observed on all four surfaces.

Microscopic Characteristics: Epidermal cells are rectangular shaped with a length to width ratio of 1:1 to greater than 5:1. Anticlinal walls are straight to verrucate with cells aligned end-to-end and stacked in a brick-like patterns. No phytoliths or trichomes were observed.

Stomata patterning is ordered into parallel rows. Stomata consist of a pair of crescent-shaped guard cells. Fusiform-shaped stomata pores are parallel to the linear axis of the epidermal cells. Stomata are oval with a length to width ratio of approximately 1.4:1. The lower woody lamella is narrowly separated from the upper woody lamella however the polar stems are wide. The angle of attachment between polar stem and guard cell is narrow.

Picea rubens
red spruce

Plate
283

Legend

Epidermal cells are rectangular shaped with a length to width ratio of 1:1 to greater than 5:1. Anticlinal walls are straight to verrucate with cells stacked in a brick-like patterns. Stomata patterning is ordered into parallel rows. Stomata are oval with a length to width ratio of approximately 1.4:1. Cigar-shaped stomata pores are aligned parallel to the linear axis of the epidermal cells.
(PLM, single polar)

***Picea sitchensis*, sitka spruce;**

Family: Pinaceae (Plate 284)

Macroscopic Characteristics: Needles are four-sided but with a flattened cross-section. Needles are rigid with sharp pointed tips; length is 1.3-2.5 cm (Kershner, Nelson and Spellenberg 2008). Stomatal lines are prominent on the abaxial surface, no stomatal lines were observed on the adaxial surface.

Microscopic Characteristics: Epidermal cells are rectangular shaped with a length to width ratio of 1:1 to greater than 5:1. Anticlinal walls are straight to verrucate with cells aligned end-to-end and stacked in a brick-like patterns. No phytoliths or trichomes were observed.

Stomata patterning is ordered into parallel rows. Stomata consist of a pair of crescent-shaped guard cells. Stomata are oval with a length to width ratio of approximately 1.3:1. Fusiform-shaped stomata pores are parallel to the linear axis of the epidermal cells. The lower woody lamella is narrowly separated from the upper woody lamella however the polar stems are wide. The angle of attachment between polar stem and guard cell is narrow.

Picea sitchensis
sitka spruce

Plate
284

***Pinus albicaulis*, whitebark pine**

Family: Pinaceae (Plate 285)

Macroscopic Characteristics: Five stiff triangle shaped needles, approximately 2.5-7.5 cm in length, are enclosed with a fascicle (Kershner, Nelson and Spellenberg 2008). The adaxial surface is smooth and glossy; faint stomatal lines are arranged in linear rows on the two abaxial surfaces.

Microscopic Characteristics: Epidermal cells are rectangular to parallelogram shaped with a length to width ratio greater than 5:1. Anticlinal walls are sinuous; epidermal cells are stacked end-to-end and arranged in a brick-like pattern. No phytoliths or trichomes were observed.

Stomata patterning is ordered into parallel rows. Stomata, rectangular in outline, have fusiform-shaped pores that are occasionally lignified. Guard cells are crescent-shaped and stomata pores are aligned parallel to the linear axis of the epidermal cells and stomata rows. Spacing between the lower woody lamellae and upper woody lamella is greater than 5 microns. The polar stem width is approximately 5 microns.

Pinus albicaulis
whitebark pine

Plate
285

Legend

Top Image: Epidermal cells are rectangular to parallelogram shaped with sinuous to verrucate anticlinal walls. Stomata are axially aligned in parallel rows.
(PLM, single polar)

Bottom Image: Stoma consists of a pair of crescent shaped guard cells surrounding an oblong fusiform shaped pore. Spacing between lower and upper woody lamellae is greater than 5 microns. Polar stems are also relatively wide.
(PLM, single polar)

***Pinus banksiana*, Jack pine**

Family: Pinaceae (Plate 286)

Macroscopic Characteristics: Two slightly twisted, stiff, triangle shaped needles, approximately 1.9-7.5 cm in length, are enclosed with a fascicle (Kershner, Nelson and Spellenberg 2008).

Microscopic Characteristics: Epidermal cells are rectangular to parallelogram shaped with a length to width ratio greater than 5:1. Anticlinal walls are sinuous to verrucate and epidermal cells are arranged end-to-end and stacked in a brick-like pattern. No phytoliths or trichomes were observed.

Stomata patterning is ordered into parallel rows. Stomata, rectangular in outline, have fusiform-shaped pores. Stomata pores are parallel to the linear axis of the epidermal cells and stomata rows. Guard cells are crescent-shaped. The polar ends of guard cells, adjacent to the polar stems, are thickened. The spacing between the lower and upper woody lamellae is greater than 5 microns. The polar stem width is approximately 5 microns.

Pinus banksiana
Jack pine

Plate
286

***Pinus contorta*, lodgepole pine**

Family: Pinaceae (Plate 287)

Macroscopic Characteristics: Two stiff, twisted, triangle shaped needles, approximately 2.5-7.5 cm in length, are enclosed with a fascicle. (Kershner, Nelson and Spellenberg 2008). Needles are more curved than triangular; stomatal lines are prominent on the concave abaxial surface and near the margins of the convex adaxial surface.

Microscopic Characteristics: Epidermal cells are rectangular and oriented in a brick-like arrangement with the long axis of cells parallel to each other. Cell length to width ratio ranges from approximately 1:1 to greater than 5:1. Anticlinal walls are sinuous to wavy. No trichomes were observed.

The abaxial surface consists of parallel rows of stomata. Stomata are axially aligned with the epidermal cell long axis. A pair of crescent-shaped guard cells surround an oblong stoma pore; some pores are lignified. The polar ends of guard cells, adjacent to the polar stems, are thickened. Stomata are slightly elongated with an approximate length to width aspect ratio of 2.5:1. The polar stem width is wide and the spacing between the lower and upper woody lamellae is greater than 5 microns.

Pinus contorta
lodgepole pine

Plate
287

Legend

Epidermal cells are rectangular and oriented in a brick-like arrangement with the long axis of cells parallel to each other. Stomata are in closely spaced rows, rows are axially aligned with epidermal cells. Stoma are nearly rectangular shaped with an oblong stoma pore. Spacing between lower and upper woody lamella is greater than 5 microns. Polar stems are wide.

(PLM, single polar)

***Pinus echinata*, shortleaf pine**

Family: Pinaceae (Plate 288)

Macroscopic Characteristics: Two slender, flexible, triangle shaped needles, approximately 7-11.4 cm in length, are enclosed with a fascicle (Kershner, Nelson and Spellenberg 2008). Needles are more curved than triangular; stomatal lines are prominent on the concave abaxial surface and near the margins of the convex adaxial surface.

Microscopic Characteristics: Epidermal cells are rectangular and oriented in a brick-like arrangement with the long axis of cells parallel to each other. Cell length to width ratio ranges from approximately 1:1 to greater than 5:1. Anticlinal walls are sinuous to wavy. Cells have square ends. No trichomes were observed.

Stomata are axially aligned in parallel rows. Stomata consist of a pair of crescent-shaped guard cells with nearly circular-shaped pore. The polar ends of guard cells, adjacent to the polar stems, are thickened. Stomata are relatively flat with an approximate length to width aspect ratio of 1.3:1. Spacing between lower and upper woody lamellae is greater than 5 microns. Polar stems are wide.

Pinus echinata
shortleaf pine

Plate
288

Legend

Epidermal cells are rectangular to parallelogram shaped with sinuous to wavy anticlinal walls. Cells have square ends. Stomata are axially aligned in parallel rows. Stomata consist of a pair of crescent shaped guard cells with nearly circular shaped pore. Spacing between lower and upper woody lamellae is greater than 5 microns. Polar stems are wide.
(PLM, single polar)

***Pinus edulis*, pinyon pine**

Family: Pinaceae (Plate 289)

Macroscopic Characteristics: Two stiff, sharp, triangle shaped needles, approximately 1.9-5 cm in length, are enclosed with a fascicle (Kershner, Nelson and Spellenberg 2008). Needles are more curved than triangular; stomatal lines are prominent on the concave abaxial surface and along veins on the convex adaxial surface.

Microscopic Characteristics: Rectangular to parallelogram shaped epidermal cells have crenate to verrucate anticlinal walls. Cells have square ends. Cell length to width ratio ranges from approximately 1:1 to greater than 5:1. Cells are aligned end-to-end and stacked in a brick-like pattern. No trichomes were observed.

Stomata are axially aligned in parallel rows. Stomata consist of a pair of crescent-shaped guard cells with nearly circular pore; many pores are lignified. Stomata are relatively flat with an approximate length to width aspect ratio of 1.1-1.3:1. Spacing between lower and upper woody lamellae is greater than 5 microns. Polar stems are wide; stems project dome-like beyond the margins of guard cells.

Pinus edulis
pinyon pine

Plate
289

***Pinus elliottii*, shortleaf pine**

Family: Pinaceae (Plate 290)

Macroscopic Characteristics: Two or three glossy, stiff, triangle shaped needles, approximately 20-30.5 cm in length, are enclosed with a fascicle (Kershner, Nelson and Spellenberg 2008). The adaxial surface is strongly convex with faint stomatal lines. The concave to V-shaped abaxial surface has prominent stomatal lines.

Microscopic Characteristics: Rectangular to parallelogram shaped epidermal cells have straight anticlinal walls. Cells have square ends. Cell length to width ratio ranges from approximately 3:1 to greater than 5:1. Cells are aligned end-to-end and stacked in a brick-like pattern. No trichomes were observed.

Stomata are axially aligned in parallel rows. Stomata consist of a pair of crescent-shaped guard cells with rectangular pores; many pores are lignified. Stomata are relatively flat with an approximate length to width aspect ratio of 1.2-1.3:1. Spacing between lower and upper woody lamellae is greater than 5 microns. Polar stems are wide.

Pinus elliottii
slash pine

Plate
290

***Pinus flexilis*, limber pine**

Family: Pinaceae (Plate 291)

Macroscopic Characteristics: Five rigid curved triangle shaped needles, approximately 3.8-10.2 cm in length, are enclosed with a fascicle (Kershner, Nelson and Spellenberg 2008). The adaxial surface is slightly convex and glossy. The concave abaxial surfaces are slightly concave with faint stomatal lines.

Microscopic Characteristics: Rectangular to parallelogram shaped epidermal cells have straight anticlinal walls. Cells have square ends. Cell length to width ratio ranges from approximately 3:1 to greater than 5:1. Cells are aligned end-to-end and stacked in a brick-like pattern. No trichomes were observed.

The abaxial surfaces consist of an ordered patterning of stomata in linear rows with pores axially aligned to the epidermal cell long axis. A pair of crescent-shaped guard cells surround a cigar-shaped stoma pore, some pores are lignified. Stomata are slightly elongated with a length to width aspect ratio of approximately 1.9:1. The polar stem width and the spacing between the lower and upper woody lamellae is greater than 5 microns.

Pinus flexilis
limber pine

Plate
291

Legend

Top Image: Rectangular to parallelogram shaped epidermal cells have straight anticlinal walls. Cells have square ends. Stomata are arranged in a linear row; the stomata are axially oriented with epidermal cells.

(PLM, single polar)

Bottom Image: A pair of crescent shaped guard cells surround a cigar-shaped stoma pore, some pores are lignified.

(PLM, single polar)

***Pinus jeffreyi*, Jeffrery pine**

Family: Pinaceae (Plate 292)

Macroscopic Characteristics: Three stout triangle shaped needles, approximately 12.7-25 cm in length, are enclosed with a fascicle (Kershner, Nelson and Spellenberg 2008). The adaxial surface is slightly convex and glossy. The concave abaxial surfaces are slightly concave with faint stomatal lines.

Microscopic Characteristics: Epidermal cells are rectangular with square ends. Cells are arranged end-to-end in a brick-like matrix. Anticlinal walls are wavy to sinuous. Cell length to width ratio exceeds 5:1. No trichomes were observed.

Stomata consist of an ordered patterning of stomata in linear rows with pores axially aligned to the epidermal cell long axis. A pair of crescent-shaped guard cells surround an oval to fusiform-shaped stoma pore, some pores are lignified. Stomata are short with a length to width aspect ratio of approximately 1.3:1. Spacing between lower and upper woody lamella is greater than 5 microns. Polar stems are wide.

Pinus jeffreyi
Jeffrey pine

Plate
292

Legend

Epidermal cells are rectangular with square ends. Cells are arranged end-to-end in a brick-like matrix. Anticlinal walls are wavy to sinuous. Stomata are arranged in parallel rows and consist of a pair of crescent shaped guard cells with an oval to fusiform shaped pore. Spacing between lower and upper woody lamellae is greater than 5 microns. Polar stems are wide.
(PLM, single polar)

***Pinus lambertiana*, sugar pine**

Family: Pinaceae (Plate 293)

Macroscopic Characteristics: Five stout, twisted triangle shaped needles, approximately 6.4-10 cm in length, are enclosed with a fascicle (Kershner, Nelson and Spellenberg 2008). The adaxial surface is slightly convex and glossy. The concave abaxial surfaces are slightly concave with faint stomatal lines.

Microscopic Characteristics: Epidermal cells are rectangular to parallelogram with square to angled ends. Cells are arranged end-to-end in a brick-like matrix. Anticlinal walls are wavy. Cell length to width ratio exceeds 5:1. No trichomes were observed.

Stomata consist of an ordered patterning of stomata in linear rows with pores axially aligned to the epidermal cell long axis. A pair of crescent-shaped guard cells surround an oval to fusiform-shaped stoma pore, some pores are lignified. Stomata are short with a length to width aspect ratio of approximately 1.3:1. Spacing between lower and upper woody lamella is greater than 5 microns. Polar stems are wide.

Pinus lambertiana
sugar pine

Plate
293

Legend

Epidermal cells are rectangular to parallelogram with square to angled ends. Cells are arranged end-to-end in a brick-like matrix. Anticlinal walls are wavy. Stomata are arranged in parallel rows and consist of a pair of crescent shaped guard cells with fusi-form shaped pore. Spacing between lower and upper woody lamellae is greater than 5 microns. Polar stems are wide.
(PLM, single polar)

***Pinus monticola*, western white pine**

Family: Pinaceae (Plate 294)

Macroscopic Characteristics: Five thin, twisted, triangle shaped needles, approximately 5-10 cm in length, are enclosed with a fascicle (Kershner, Nelson and Spellenberg 2008). The adaxial surface is slightly glossy with no stomatal lines; stomatal lines are on the abaxial surfaces.

Microscopic Characteristics: Epidermal cells are rectangular to parallelogram with square to angled ends. Cells are arranged end-to-end and stacked in a brick-like pattern. Anticlinal walls are wavy. Cell length to width ratio exceeds 5:1. No phytoliths or trichomes were observed.

Stomata consist of an ordered patterning of stomata in linear rows with pores axially aligned to the epidermal cell long axis. A pair of crescent-shaped guard cells surround an oval to fusiform-shaped stoma pore. Stomata are elongated with a length to width aspect ratio of approximately 1.7:1. Spacing between lower and upper woody lamellae is greater than 5 microns. Polar stems are wide.

Pinus monticola
western white pine

Plate
294

Legend

Epidermal cells are rectangular to parallelogram with square to angled ends. Cells are arranged end-to-end in a brick-like matrix. Anticlinal walls are wavy. Stomata are arranged in parallel rows and consist of a pair of crescent shaped guard cells with fusiform shaped pore. Spacing between lower and upper woody lamellae is greater than 5 microns. Polar stems are wide.
(PLM, single polar)

***Pinus palustris*, longleaf pine**

Family: Pinaceae (Plate 295)

Macroscopic Characteristics: Three flexible triangle shaped needles, approximately 20-46 cm in length, are enclosed with a fascicle (Kershner, Nelson and Spellenberg 2008). The adaxial surface is convex and glossy; the abaxial surface consist of a central prominent vein bordered by two concave surfaces with very faint stomatal lines.

Microscopic Characteristics: Epidermal cells are rectangular to parallelogram shaped. Cell ends are square. Cells are aligned end-to-end and stacked in a brick-like pattern. Anticlinal walls are straight to slightly verrucate. Cell length to width ratio exceeds 5:1. No phytoliths or trichomes were observed.

Stomata consist of an ordered patterning of stomata in linear rows with pores axially aligned to the epidermal cell long axis. Stomatal rows occur singularly and are separated by multiple rows of epidermal cells. A pair of crescent-shaped guard cells surround an oval to fusiform-shaped stoma pore. Stomata are short with a length to width aspect ratio of approximately 1.3:1. Spacing between lower and upper woody lamellae is greater than 5 microns. Polar stems are wide.

Pinus palustris
longleaf pine

Plate
295

Legend

Epidermal cells are rectangular to parallelogram shaped. Cell ends are square. Cells are stacked end-to-end in a brick-like pattern. Anticlinal walls are straight to verrucate. Stomata are arranged in parallel rows and consist of a pair of crescent shaped guard cells with fusiform shaped pore. Spacing between lower and upper woody lamellae is greater than 5 microns. Polar stems are wide.
(PLM, single polar)

***Pinus ponderosa*, Ponderosa pine**

Family: Pinaceae (Plate 296)

Macroscopic Characteristics: Three stout, stiff, and sharp triangle shaped needles, approximately 12.7-28 cm in length, are enclosed with a fascicle (Kershner, Nelson and Spellenberg 2008). The adaxial surface is convex and glossy with faint stomatal lines; the abaxial surface consist of a central prominent vein bordered by two concave surfaces and faint stomatal lines.

Microscopic Characteristics: Epidermal cells are rectangular to parallelogram shaped. Cell ends are square or angled. Cells are aligned end-to-end and stacked in a brick-like pattern. Anticlinal walls are sinuate to wavy. Cell length to width ratio ranges from 3:1 to greater than 5:1. Anisotropic phytoliths are scattered along epidermal cells. No trichomes were observed.

Stomata consist of an ordered patterning of stomata in linear rows with pores axially aligned to the epidermal cell long axis. Stomatal rows occur singularly and are separated by multiple rows of epidermal cells. A pair of crescent-shaped guard cells surround an oval to fusiform-shaped stoma pore. Stomata are short with a length to width aspect ratio of approximately 1.2:1. Spacing between lower and upper woody lamellae is greater than 5 microns. Polar stems are wide.

Pinus ponderosa
Ponderosa pine

Plate
296

Legend

Epidermal cells are rectangular to parallelogram shaped. Cell ends are square or angled. Cells are stacked end-to-end in a brick-like pattern. Anticlinal walls are sinuate to wavy. Stomata are arranged in parallel rows and consist of a pair of crescent shaped guard cells with a fusiform shaped pore. Spacing between lower and upper woody lamellae is greater than 5 microns. Polar stems are wide.
(PLM, single polar)

***Pinus resinosa*, red pine**

Family: Pinaceae (Plate 297)

Macroscopic Characteristics: Two brittle triangle shaped needles, approximately 10-16.5 cm in length, are enclosed with a fascicle (Kershner, Nelson and Spellenberg 2008). Needles are more curved than triangular; stomatal lines are faint on the concave abaxial surface and convex adaxial surface.

Microscopic Characteristics: Epidermal cells are rectangular to parallelogram shaped. Cell ends are square or angled. Cells are aligned end-to-end and stacked in a brick-like pattern. Anticlinal walls are sinuate to verrucate. Cell length to width ratio ranges from 1:1 to greater than 5:1. No trichomes were observed.

Stomata consist of an ordered patterning of stomata in linear rows with pores axially aligned to the epidermal cell long axis. Stomatal rows occur singularly and are separated by multiple rows of epidermal cells. A pair of crescent-shaped guard cells surround an oval to fusiform-shaped stoma pore; some pores are lignified. Stomata are short with a length to width aspect ratio of approximately 1.2:1. Spacing between lower and upper woody lamellae is greater than 5 microns. Polar stems are wide.

Pinus resinosa
red pine

Plate
297

Legend

Epidermal cells are rectangular to parallelogram shaped. Cell ends are square or angled. Cells are stacked end-to-end in a brick-like pattern. Anticlinal walls are sinuate to verrucate. Stomata are arranged in parallel rows and consist of a pair of crescent shaped guard cells with fusiform shaped pore. Spacing between lower and upper woody lamellae is greater than 5 microns. Polar stems are wide.
(PLM, single polar)

***Pinus rigida*, pitch pine**

Family: Pinaceae (Plate 298)

Macroscopic Characteristics: Three stout, slightly twisted, triangle shaped needles, approximately 7.5-10 cm in length, are enclosed with a fascicle (Kershner, Nelson and Spellenberg 2008). The adaxial surface is convex and glossy with faint stomatal lines; the abaxial surface consist of a central prominent vein bordered by two concave surfaces and faint stomatal lines.

Microscopic Characteristics: Epidermal cells are rectangular to parallelogram shaped. Cell ends are square or angled. Cells are aligned end-to-end and stacked in a brick-like pattern. Anticlinal walls are wavy to verrucate. Cell length to width ratio is greater than 5:1. No trichomes were observed.

Stomata consist of an ordered patterning of stomata in linear rows with pores axially aligned to the epidermal cell long axis. Stomatal rows occur singularly and are separated by multiple rows of epidermal cells. A pair of crescent-shaped guard cells surround an oval to fusiform-shaped stoma pore. Stomata are slightly oblong with a length to width aspect ratio of approximately 1.4-1.6:1. Spacing between lower and upper woody lamellae is greater than 5 microns. Polar stems are wide.

Pinus rigida
pitch pine

Plate
298

***Pinus sabiniana*, gray pine**

Family: Pinaceae (Plate 299)

Macroscopic Characteristics: Three slender, flexible triangle shaped needles, approximately 20-30 cm in length, are enclosed with a fascicle (Kershner, Nelson and Spellenberg 2008). The adaxial surface is convex and glossy with faint stomatal lines; the abaxial surface consist of a central prominent vein bordered by two concave surfaces and faint stomatal lines.

Microscopic Characteristics: Epidermal cells are rectangular to parallelogram shaped. Cell ends are square or angled. Cells are stacked end-to-end in a brick-like pattern. Anticlinal walls are wavy to verrucate. Cell length to width ratio is greater than 5:1. No trichomes were observed.

Stomata consist of an ordered patterning of stomata in linear rows with pores axially aligned to the epidermal cell long axis. Stomatal rows occur singularly and are separated by multiple rows of epidermal cells. A pair of crescent-shaped guard cells surround an oval to fusiform-shaped stoma pore. Stomata are short with a length to width aspect ratio of approximately 1.2-1.4:1. Spacing between lower and upper woody lamellae is greater than 5 microns. Polar stems are wide.

Pinus sabiniana
gray pine

Plate
299

Legend

Epidermal cells are rectangular to parallelogram shaped. Cell ends are square or angled. Cells are stacked end-to-end in a brick-like pattern. Anticlinal walls are sinuate to verrucate. Stomata are arranged in parallel rows and consist of a pair of crescent shaped guard cells with fusi-form shaped pore. Spacing between lower and upper woody lamellae is greater than 5 microns. Polar stems are wide.
(PLM, single polar)

***Pinus strobus*, eastern white pine**

Family: Pinaceae (Plate 300)

Macroscopic Characteristics: Five soft, flexible, triangle shaped needles, approximately 5-12.7 cm in length, are enclosed with a fascicle (Kershner, Nelson and Spellenberg 2008). The adaxial surface is smooth and glossy with serrate margins; stomatal lines are arranged in linear rows on the two abaxial surfaces.

Microscopic Characteristics: Epidermal cells are rectangular to parallelogram with square to angled ends. Cells are aligned end-to-end and stacked in a brick-like pattern. Anticlinal walls are wavy to verrucate. No phytoliths or trichomes were observed.

Stomata patterning is ordered into parallel rows. Stomata, rectangular in outline, have oval to fusiform-shaped pores. Guard cells are crescent-shaped and stomata pores are aligned parallel to the linear axis of the epidermal cells and stomata rows. Stomata are short with a length to width aspect ratio of approximately 1.3:1. Spacing between lower and upper woody lamellae is greater than 5 microns. Polar stems are wide.

Pinus strobus
eastern white pine

Plate
300

Pinus sylvestris, Scots pine

Family: Pinaceae (Plate 301)

Macroscopic Characteristics: Two twisted triangle shaped needles, approximately 3.8-7.5 cm in length, are enclosed with a fascicle (Kershner, Nelson and Spellenberg 2008). The adaxial surface is smooth and glossy with faint stomatal lines near the margins. The abaxial surface consist of a central vein separating two concave surfaces with faint stomatal lines.

Microscopic Characteristics: Epidermal cells are rectangular to parallelogram shaped. Cell ends are square or angled. Cells are aligned end-to-end and stacked in a brick-like pattern. Anticlinal walls are sinuate to verrucate. Cell length to width ratio is greater than 5:1. No phytoliths or trichomes were observed.

Oblong stomata are arranged in parallel rows, most stomata are rectangular in outline. Stomatal rows occur singularly or in pairs and are separated by multiple rows of epidermal cells. Stomata consist of a pair of crescent-shaped guard cells with fusiform-shaped pore. Stomata are slightly oblong with a length to width aspect ratio of approximately 1.5:1. Spacing between the lower woody lamellae and upper woody lamella is greater than 5 microns. Polar stems are wide.

Pinus sylvestris
Scots pine

Plate
301

***Pinus taeda*, loblolly pine**

Family: Pinaceae (Plate 302)

Macroscopic Characteristics: Three thin and twisted triangle shaped needles, approximately 15-23 cm in length, are enclosed with a fascicle (Kershner, Nelson and Spellenberg 2008). The adaxial surface is smooth and glossy with evenly spaced stomatal lines. The abaxial surface consist of a central vein separating two concave surfaces with stomatal lines.

Microscopic Characteristics: Epidermal cells are rectangular to parallelogram shaped. Cell ends are square or angled. Cells are stacked end-to-end in a brick-like pattern. Cell length to width ratio is greater than 5:1. Anticlinal walls are wavy to verrucate. No phytoliths or trichomes were observed.

Stomata patterning is ordered into parallel rows. Stomatal rows occur singularly and are separated by multiple rows of epidermal cells. Stomata, rectangular in outline, have oval to fusiform-shaped pores. Guard cells are crescent-shaped and stomata pores are aligned parallel to the linear axis of the epidermal cells and stomata rows. Stomata are short with a length to width aspect ratio of approximately 1.7:1. Spacing between lower and upper woody lamellae is greater than 5 microns. Polar stems are wide.

Pinus taeda
loblolly pine

Plate
302

Legend

Epidermal cells are rectangular to parallelogram shaped. Cell ends are square or angled. Cells are stacked end-to-end in a brick-like pattern. Anticlinal walls are sinuate to verrucate. Stomata are arranged in parallel rows and consist of a pair of crescent shaped guard cells with fusiform shaped pore. Spacing between lower and upper woody lamellae is greater than 5 microns. Polar stems are wide.
(PLM, single polar)

***Pinus virginiana*, Virginia pine**

Family: Pinaceae (Plate 303)

Macroscopic Characteristics: Two stiff and twisted triangle shaped needles, approximately 2.5-7.5 cm in length, are enclosed with a fascicle (Kershner, Nelson and Spellenberg 2008). Needles are more curved than triangular; stomatal lines are evenly spaced on the convex adaxial and concave abaxial surface.

Microscopic Characteristics: Epidermal cells are rectangular to parallelogram shaped. Cell ends are square or angled. Cells are aligned end-to-end and stacked in a brick-like pattern. Anticlinal walls are wavy to verrucate. Cell length to width ratio is greater than 5:1. No phytoliths or trichomes were observed.

Stomata patterning is ordered into parallel rows. Stomatal rows occur singularly and are separated by multiple rows of epidermal cells. Stomata, rectangular in outline, have oval to fusiform-shaped pores. Guard cells are crescent-shaped and stomata pores are aligned parallel to the linear axis of the epidermal cells and stomata rows. Stomata are short with a length to width aspect ratio of approximately 1.3:1. Spacing between lower and upper woody lamellae is greater than 5 microns. Polar stems are wide.

Pinus virginiana
Virginia pine

Plate
303

***Platanus occidentalis*, American sycamore**

Family: Platanaceae (Plate 304)

Macroscopic Characteristics: Leaves are alternate with three to five lobes. Leaves are ovate to orbicular with a length of approximately 10-23 cm. Occasional hairs are on the adaxial veins; the abaxial and adaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are polygonal-shaped and arranged in a flagstone pattern. Anticlinal walls are straight-curved. Calcium carbonate rhombohedrals druses are aligned with leaf veins. Calcium oxalate druses are less common and are randomly scattered in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix. A pair of crescent-shaped guard cells surround a fusiform-shaped pore. Stomata are nearly circular. The stoma has an approximately length to width ratio of 1.1:1. The separation between the upper woody lamella and the lower woody lamella is wide at the lateral sides and the polar ends. The polar stems are narrow.

Platanus occidentalis
American sycamore

Plate
304

Legend

Epidermal cells are polygonal-shaped. Anticlinal walls are straight-curved. Calcium carbonate rhombohedrals are aligned with leaf veins. Calcium oxalate druses are randomly scattered in the epidermal cell matrix. Stomata are randomly arranged in the epidermal cell matrix. A pair of crescent-shaped guard cells surround a fusiform pore; stomata are nearly circular. The separation between the upper and lower woody lamella is wide at the lateral sides and the polar ends.
(PLM, single polar)

***Platanus racemosa*, California sycamore**

Family: Platanaceae (Plate 305)

Macroscopic Characteristics: Leaves are alternate, ovate to orbicular with three to five lobes. Leaf length is approximately 25 cm. Light hairs coat the adaxial and abaxial surfaces.

Microscopic Characteristics: Epidermal cells are polygonal-shaped and arranged in a flagstone pattern. Anticlinal walls are straight-curved. Calcium oxalate druses are randomly scattered in the epidermal cell matrix. Trichomes are wide with parallel sides.

Stomata are randomly arranged in the epidermal cell matrix. A pair of crescent-shaped guard cells surround a fusiform-shaped pore; stomata are nearly circular. Stomata are attached to the epidermal cell matrix with reinforced fibers. The stoma has an approximately length to width ratio of 1:1. The separation between the upper woody lamella and the lower woody lamella is wide at the lateral sides and the polar ends. The polar stems are wide.

Plantanus racemosa
California sycamore

Plate
305

***Populus alba*, white poplar**

Family: Salicaceae (Plate 306)

Macroscopic Characteristics: Leaves are five-lobed with an approximate length of 4-15 cm. The adaxial surface is glabrous. The abaxial surface is glaucous and pubescent.

Microscopic Characteristics: Epidermal cells are polygonal-shaped with aspect ratio of approximately 1:1. Epidermal cells under leaf veins are rectangular. Anticlinal walls are straight-curved. Calcium carbonate rhombohedral crystals are aligned with the leaf veins. Calcium oxalate druses are randomly scattered in the epidermal cell matrix. Trichomes are long sinuous fibers with smooth margins and occasional non-parallel sides.

Stomata are randomly arranged in the epidermal cell matrix. A pair of oblong crescent-shaped guard cells surround a fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.8:1. The separation between the upper wood lamella and the lower woody lamella is wide at the lateral sides and relatively wide at the polar ends. The polar stems are narrow.

Populus alba
white poplar

Plate
306

***Populus angustifolia*, narrowleaf cottonwood**

Family: Salicaceae (Plate 307)

Macroscopic Characteristics: Leaves are lanceolate to ovate with an approximately length of 5-13 cm. Leaf margins are serrate

Microscopic Characteristics: Epidermal cells are polygonal-shaped with aspect ratio of approximately 1:1. Anticlinal walls are straight-curved. Calcium carbonate rhombohedral crystals are aligned with the leaf veins. Calcium oxalate druses are randomly scattered in the epidermal cell matrix.

Brachyparacytic stomata are randomly arranged in the epidermal cell matrix. A pair of oblong crescent-shaped guard cells surround a fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.8:1. The separation between the upper wood lamella and the lower woody lamella is wide at the lateral sides and relatively wide at the polar ends. The polar stems are narrow.

Populus angustifolia
narrowleaf poplar

Plate
307

***Populus balsamifera*, balsam poplar;**

Family: Salicaceae (Plate 308)

Macroscopic Characteristics: Leaves margins are notched with pointed apexes, length is approximately 12 cm.

Microscopic Characteristics: Epidermal cells are polygonal-shaped and cells are arranged in a flagstone pattern. Anticlinal walls are straight-curved. Calcium oxalate druses are randomly scattered in the epidermal cell matrix. Trichomes are straight to slightly curved spears with pointed apexes. Bases are reinforced.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells with fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.2:1. The separation between the upper wood lamella and the lower woody lamella is wide at the lateral sides and relatively wide at the polar ends. The polar stems are narrow.

Populus balsamifera
balsam poplar

Plate
308

Legend

Epidermal cells are polygonal-shaped. Cells are arranged in a flagstone pattern. Anticlinal walls are straight-curved. Calcium oxalate druses are randomly scattered in the epidermal cell matrix. Trichomes are straight to slightly curved spears with pointed apices. Bases are reinforced. Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells with fusiform-shaped pore.
(PLM, single polar)

***Populus deltoides*, eastern cottonwood;**

Family: Salicaceae (Plate 309)

Macroscopic Characteristics: Leaves margins are deltoid shaped with coarse, curved teeth, length is approximately 4-10 cm and 4-11 cm wide. The adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are polygonal shaped. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight- curved. Calcium oxalate druses are randomly scattered in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of oblong crescent-shaped guard cells with fusiform-shaped pore. The stoma has an approximately length to width ratio of 2.2:1. The separation between the upper wood lamella and the lower woody lamella is wide at the lateral sides and relatively wide at the polar ends. The polar stems are narrow.

Populus deltoides
eastern cottonwood

Plate
309

Legend

Epidermal cells are polygonal-shaped. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Calcium oxalate druses are randomly scattered in the epidermal cell matrix. Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of oblong crescent-shaped guard cells with fusiform-shaped pore. The stoma has an approximately length to width ratio of 2.2:1.
(PLM, single polar)

***Populus grandidentata*, bigtooth aspen;**

Family: Salicaceae (Plate 310)

Macroscopic Characteristics: Leaves are orbicular to ovate with a length of approximately 7.5-10 cm. Leaves margins are bluntly serrate and pinnately veined. The adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are polygonal-shaped. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Calcium carbonate rhombohedral druses are primarily aligned with the leaf veins.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells with fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.4:1. The separation between the upper wood lamella and the lower woody lamella is wide at the lateral sides and relatively wide at the polar ends. The polar stems are narrow.

Populus grandidentata
bigtooth aspen

Plate
310

***Populus nigra 'Italica'*, Lombardy poplar;**

Family: Salicaceae (Plate 311)

Macroscopic Characteristics: Leaves are triangular to diamond-shaped with a length of 5-8 cm and width of 6-8 cm. The margins are bluntly serrate; the adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are polygonal shaped. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Calcium carbonates rhombohedral druses are randomly scattered in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells with fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.4:1. The separation between the upper wood lamella and the lower woody lamella is wide at the lateral sides and relatively wide at the polar ends. The polar stems are narrow.

Populus nigra 'Italica'
Lombardy poplar

Plate
311

***Populus tremuloides*, quaking aspen;**

Family: Salicaceae (Plate 312)

Macroscopic Characteristics: Leaves are oval with a length of 3-7 cm. The margins are bluntly serrate; the adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are polygonal-shaped. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Calcium carbonate rhombohedral druses are aligned with the leaf veins.

Stomata are oblong and randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells with fusiform-shaped pore. The stoma has an approximately length to width ratio of 2.1:1. The separation between the upper wood lamella and the lower woody lamella is wide at the lateral sides and relatively wide at the polar ends. The polar stems are narrow.

Populus tremuloides
quaking aspen

Plate
312

***Potamogeton gramineus*, variable leaf pondweed;**

Family: Potamogetonaceae (Plate 313)

Macroscopic Characteristics: Leaves are ovate with wide serrations. The length is approximately 4-9 cm and the width of 0.5-1.2 cm. Hairs are scattered on the adaxial surface and more abundant on the abaxial surface.

Microscopic Characteristics: Epidermal cells are rectangular to polygonal-shaped. Cells near veins are rectangular and stacked brick-like. Cells in the open matrix are polygonal and arranged in flagstone pattern. Anticlinal walls are straight to straight-curved. Calcium oxalate druses are randomly arranged in the epidermal cell matrix. Trichomes are hollow with vertical striations and pointed apices.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells with fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.8:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are narrow.

Potamogeton gramineus
variable leaf pondweed

Plate
313

Legend

Epidermal cells are rectangular to polygonal-shaped. Cells near veins are rectangular and stacked brick-like. Cells in the open matrix are polygonal and arranged in flagstone pattern. Anticlinal walls are straight to straight-curved. Calcium oxalate druses are randomly arranged in the epidermal cell matrix. Trichomes are hollow with vertical striations and pointed apices. Stomata consist of a pair of crescent-shaped guard cells with fusiform-shaped pore. (PLM, single polar)

***Prosopis juliflora*, mesquite;**

Family: Fabaceae (Plate 314)

Macroscopic Characteristics: Leaves are bipinnately compound of 12-25 leaflets. Leaflets are 0.6-1.6 cm long and -.15-0.3 cm wide. The margins are entire with glabrous adaxial and abaxial surfaces.

Microscopic Characteristics: Epidermal cells are polygonal-shaped. Cells are arranged in a flagstone pattern. Anticlinal walls are straight-curved. Phytoliths are randomly arranged in the epidermal cell matrix. No trichomes were observed.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells with fusiform-shaped pore. Typically, stomata are centered within an epidermal cell. The stoma has an approximately length to width ratio of 1.1:1. The separation between the upper wood lamella and the lower woody lamella is wide at the lateral sides and the polar ends. The polar stems are narrow.

Prosopis juliflora
mesquite

Plate
314

Legend

Epidermal cells are polygonal-shaped. Cells are arranged in a flagstone pattern. Anticlinal walls are straight-curved. Phytoliths are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells with fusiform-shaped pore. Stomata are randomly arranged in the epidermal cell matrix. Typically, stomata are centered within an epidermal cell. The separation between the upper and lower woody lamella is wide at the lateral sides and the polar ends. (PLM, single polar)

***Prunus americana*, apricot;**

Family: Rosaceae (Plate 315)

Macroscopic Characteristics: Leaves are oval with a length of 5-10 cm. Margins are bluntly serrate. The adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are polygonal-shaped. Cells are arranged in a flagstone pattern. Anticlinal walls are straight-curved. Calcium oxalate druses are aligned with leaf veins and scattered randomly in the epidermal cell matrix.

Stomata consist of a pair of crescent-shaped guard cells with fusiform-shaped pore. Stomata are randomly arranged in the epidermal cell matrix. The stoma has an approximately length to width ratio of 1.6:1. The separation between the upper wood lamella and the lower woody lamella is wide at the lateral sides and the polar ends. The polar stems are narrow.

Prunus americana
apricot

Plate
315

***Prunus caroliniana*, Carolina laurelcherry;**

Family: Rosaceae (Plate 316)

Macroscopic Characteristics: Leaves are oblanceolate to elliptic with a length of 5-12 cm. Leaves are leathery and margins are entire. The adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are polygonal-shaped. Cells are arranged in a flagstone pattern. Cells are more elongated near leaf veins. Anticlinal walls are straight-curved. Calcium oxalate druses are randomly in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells with fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.2:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are wide.

Prunus caroliniana
Carolina laurelcherry

Plate
316

***Prunus domestica*, European plum;**

Family: Rosaceae (Plate 317)

Macroscopic Characteristics: Leaves are oval to oblong with a length of approximately 10 cm. Leaf have wavy to serrate margins. The adaxial surface is glabrous however the veins of the abaxial surface has tufts of hair.

Microscopic Characteristics: Epidermal cells are polygonal-shaped. Cells are arranged in a flagstone pattern. Anticlinal walls are straight-curved. Calcium oxalate druses are randomly in the epidermal cell matrix. Calcium carbonate rhombohedral druses are aligned with leaf veins. Trichomes have parallel sides with pointed apexes.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells with fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.4:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are wide.

Prunus domestica
European plum

Plate
317

***Prunus pensylvanica*, pin cherry;**

Family: Rosaceae (Plate 318)

Macroscopic Characteristics: Leaves are thin and oblong with recurved teeth. Leaf length is approximately 4-11 cm and 1-5 cm wide. The adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are polygonal-shaped. Cells in the epidermal cell matrix have an aspect ratio of near 1:1 whereas cells over leaf veins have an elongated ratio of 1.5:1 and greater. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Calcium oxalate druses are mostly aligned with leaf veins.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells with fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.5:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are wide.

Prunus pensylvanica
pin cherry

Plate
318

Legend

Epidermal cells are polygonal-shaped. Cells in the epidermal cell matrix have an aspect ratio of near 1:1 whereas cells over leaf veins have an elongated ratio of 1.5:1 and greater. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Globular calcium oxalate druses are mostly aligned with leaf veins.
(PLM, single polar)

***Prunus persica*, peach;**

Family: Rosaceae (Plate 319)

Macroscopic Characteristics: Leaves are lanceolate and pinnately veined with a length of 7-16 cm and width of 2.3 cm.

Microscopic Characteristics: Epidermal cells are polygonal-shaped. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Calcium oxalate druses are mostly aligned with leaf veins. Trichomes have smooth sides with pointed apexes. Fibers are mostly flat.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. Occasionally the pore is lignified. The stoma has an approximately length to width ratio of 1.6:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are wide.

Prunus persica
peach

Plate
319

***Prunus serotina*, black cherry;**

Family: Rosaceae (Plate 320)

Macroscopic Characteristics: Leaves are ovate to lanceolate with toothed margins. Leaf length is approximately 5-13 cm. The adaxial surface is glabrous however the veins of the abaxial surface has tufts of hair.

Microscopic Characteristics: Epidermal cells are polygonal-shaped. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Calcium carbonate rhombohedral druses are aligned with leaf veins. Calcium oxalate druses are randomly arranged. Trichomes are flat and hollow with smooth margins.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. Occasionally the pore is lignified. The stoma has an approximately length to width ratio of 1.5:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are wide.

Prunus serotina
black cherry

Plate
320

***Prunus virginiana*, chokecherry;**

Family: Rosaceae (Plate 321)

Macroscopic Characteristics: Leaves are oval with a length of approximately 3-10 cm. Margins are serrate.

Microscopic Characteristics: Epidermal cells are polygonal-shaped. Cells are arranged in a jigsaw puzzle pattern. Anticlinal walls are straight to straight-curved. Calcium oxalate druses are mostly aligned with leaf veins.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an oblong to fusiform-shaped pore. Stomata are attached to epidermal cells with reinforced fibers. The stoma has an approximately length to width ratio of 1.2-1.4:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are wide.

Prunus virginiana
chokecherry

Plate
321

***Pseudotsuga menziesii* var. *glauca*, Douglas-fir**

Family: Pinaceae (Plate 322)

Macroscopic Characteristics: Needles are flattened and linear, approximately 1.9-3.2 cm in length (Kershner, Nelson and Spellenberg 2008). A pair of stomatal lines occur on each side of the central rib of the abaxial surface.

Microscopic Characteristics: Epidermal cells are long rectangular cellular structures with rounded ends. Cells are aligned end-to-end in a brick-like pattern; length to width ratio ranges from 3:1 to greater than 5:1. Anticlinal walls are straight to straight-curved. No phytoliths or trichomes were observed.

The abaxial surface consists of an ordered patterning of parallel rows of stomata with pores aligned axially to epidermal cell long axis. A pair of crescent-shaped guard cells surround an oval to short fusiform-shaped pore. Stomata are nearly circular with an approximate length to width aspect ratio of 1.3:1. The width of the polar stem is approximately 5 microns however the spacing between the lower and upper woody lamellae is approximately 4 microns.

Pseudotsuga menziesii var. *glauca*
Douglas-fir

Plate
322

Legend

Epidermal cells are long rectangular cellular structures with rounded ends. Cells are aligned end-to-end in a brick-like pattern; length to width ratio ranges from 3:1 to greater than 5:1. Anticlinal walls are straight to straight-curved. The abaxial surface consists of an ordered patterning of parallel rows of stomata with pores aligned axially to epidermal cell long axis. A pair of crescent guard cells surround an oval to short fusiform shaped pore.
(PLM, single polar)

***Pteridium aquilinum*, western brackenfern;**

Family: Dennstaedtiaceae (Plate 323)

Macroscopic Characteristics: Fronds are triangular with a length of approximately 1 meter.

Microscopic Characteristics: Epidermal cells are irregular-shaped. Cells are arranged in a jigsaw puzzle pattern. Anticlinal walls are straight-curved to wavy. Veins are in parallel rows and vein epidermal cells are elongated with wavy margins.

Stomata are aligned with leaf veins; the long axis of the guard cells are aligned with the veins. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.7:1. The separation between the upper wood lamella and the lower woody lamella is wide at the lateral sides and the polar ends. The polar stems are wide.

Pteridium aquilinum
western brackenfield

Plate
323

***Purshia tridentata*, antelope bitterbrush;**

Family: Rosaceae (Plate 324)

Macroscopic Characteristics: Leaves are three to five lobes with a length of 0.5-2 cm. Both the adaxial and abaxial surfaces are hairy.

Microscopic Characteristics: Epidermal cells are polygonal-shaped. Cells are arranged in a flagstone pattern. Anticlinal walls are straight-curved. Cells over veins are rectangular with straight anticlinal walls. Two varieties of trichomes were observed, one is long fibers with smooth parallel walls. The second variety is short spears with pointed apexes. Calcium oxalate druses are scattered randomly in the epidermal cell matrix.

Stomata are randomly arranged and consist of a pair of crescent-shaped guard cells surrounding a narrow pore. The stoma has an approximately length to width ratio that ranges from 1:1 to 1.4:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and the polar ends. The polar stems are wide.

Purshia tridentata
antelope bitterbrush

Plate
324

Legend

Epidermal cells are polygonal-shaped. Anticlinal walls are straight-curved. Calcium oxalate druses are scattered randomly in the epidermal cell matrix. Two varieties of trichomes were observed, one is long fibers with smooth parallel walls. The second variety is short spars with pointed apices. Stomata are randomly arranged and consist of a pair of crescent-shaped guard cells surrounding a narrow pore.
(PLM, single polar)

***Pyrola secunda*, checkerboard wintergreen;**

Family: Rosaceae (Plate 325)

Macroscopic Characteristics: Leaves are elliptic to round with serrated margins. Leaf length is approximately 1.5-4 cm.

Microscopic Characteristics: Epidermal cells are polygonal-shaped. Cells are arranged in a jigsaw puzzle pattern. Cells are elongated near leaf veins. Anticlinal walls are straight-curved. Calcium oxalate druses are randomly arranged in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells with fusiform-shaped pore. Guard cells have striations from outer margin to inner margin. The stoma has an approximately length to width ratio of 1.2:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are wide.

Pyrola secunda
checkerberry wintergreen

Plate
325

***Quercus agrifolia*, coast live oak;**

Family: Fagaceae (Plate 326)

Macroscopic Characteristics: Leaves are oval to convex with a length of 2-7 cm and width of 1-4 cm. Leaf margins are spinose margins. The adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are polygonal and arranged in a flagstone pattern. Anticlinal walls are straight-curved. Calcium carbonate rhombohedral and calcium oxalate druses are randomly arranged in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The stoma has an approximately length to width ratio of 1:1. The separation between the upper wood lamella and the lower woody lamella is relatively wide at the lateral sides and wide at the polar ends. The polar stems are wide.

Quercus agrifolia
coast live oak

Plate
326

***Quercus alba*, white oak;**

Family: Fagaceae (Plate 327)

Macroscopic Characteristics: Leaves are shallow lobed with a length of 13-22 cm and a width of 7-11 cm. The abaxial veins are prominent. The adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are polygonal and arranged in a flagstone or jigsaw puzzle pattern. Cells over veins are rectangular with square to angular ends. Anticlinal walls are straight to straight-curved. Calcium carbonate rhombohedral druses are aligned with leaf veins. Calcium oxalate druses are randomly arranged in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The stoma has an approximately length to width ratio of 2.3:1. The separation between the upper wood lamella and the lower woody lamella is relatively wide at the lateral sides and wide at the polar ends. The polar stems are wide.

Quercus alba
white oak

Plate
327

***Quercus bicolor*, swamp white oak;**

Family: Fagaceae (Plate 328)

Macroscopic Characteristics: Leaves are shallow lobed and broadly ovoid with a length of 12-18 cm and a width of 7-11 cm. The adaxial surface is glabrous whereas the abaxial surface is pubescent and veins are prominent.

Microscopic Characteristics: Epidermal cells are polygonal-shaped and arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Calcium carbonate rhombohedral druses are aligned with leaf veins. Calcium oxalate druses are randomly arranged in the epidermal cell matrix. Trichomes are stellate.

Stomata consist of a pair of crescent-shaped guard cells surrounding a wide fusiform-shaped pore. Stomata are randomly arranged in the epidermal cell matrix. The stoma has an approximately length to width ratio of 1.2:1. The separation between the upper wood lamella and the lower woody lamella is relatively wide at the lateral sides and wide at the polar ends. The polar stems are wide.

Quercus bicolor
swamp white oak

Plate
328

***Quercus chrysolepis*, canyon live oak;**

Family: Fagaceae (Plate 329)

Macroscopic Characteristics: Leaves are oblong to elliptical with a turned under edge margin and spiny teeth. Leaf length is 2.5-8 cm and 1.2-4 cm. The adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are polygonal-shaped and arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Calcium carbonate rhombohedral druses are aligned with leaf veins. Calcium oxalate druses are randomly arranged in the epidermal cell matrix.

Abundant stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an oval to fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.3:1. The separation between the upper wood lamella and the lower woody lamella is relatively wide at the lateral sides and wide at the polar ends. The polar stems are wide.

Quercus chrysolepis
canyon live oak

Plate
329

***Quercus coccinea*, scarlet oak;**

Family: Fagaceae (Plate 330)

Macroscopic Characteristics: Leaves are seven lobed with deep sinuses; each lobe has 3-7 teeth. Leaf length is approximately 7-17 cm and 8-13 cm in width. The adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are polygonal-shaped. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved.

Abundant stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.3:1. The separation between the upper wood lamella and the lower woody lamella is relatively wide at the lateral sides and wide at the polar ends. The polar stems are wide.

Quercus coccinea
scarlet oak

Plate
330

***Quercus gambelii*, gambel oak;**

Family: Fagaceae (Plate 331)

Macroscopic Characteristics: Leaves are deeply lobed with a length of 7-12 cm and a width of 4-6 cm. The adaxial and abaxial surfaces are glabrous whereas hairs cover the abaxial veins.

Microscopic Characteristics: Epidermal cells are polygonal-shaped and arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Trichomes are slightly curved spears with smooth margins. Some trichomes are jointed into multiple fibers. Calcium carbonate rhombohedral druses are aligned with leaf veins.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.1:1. The separation between the upper wood lamella and the lower woody lamella is relatively wide at the lateral sides and wide at the polar ends. The polar stems are wide.

Quercus gambelii
gambel oak

Plate
331

***Quercus laurifolia*, laurel oak;**

Family: Fagaceae (Plate 332)

Macroscopic Characteristics: Leaves are broadly lanceolate and unlobed with a length of 2.5-13 cm and a width of 0.5-2 cm. The margins are entire and the adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are polygonal-shaped and arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Calcium oxalate druses are randomly arranged in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of fat crescent-shaped guard cells surrounding a fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.1:1. The separation between the upper wood lamella and the lower woody lamella is wide at the lateral sides and the polar ends. The polar stems are wide.

Quercus laurifolia
laurel oak

Plate
332

***Quercus macrocarpa*, burr oak;**

Family: Fagaceae (Plate 333)

Macroscopic Characteristics: Leaves are broad with lobed margin; the length is approximately 7-15 cm and 5-13 cm wide. The adaxial surface is glabrous whereas tufts of hairs cover the abaxial veins.

Microscopic Characteristics: Epidermal cells are polygonal-shaped and arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Calcium oxalate druses are randomly arranged in the epidermal cell matrix. Calcium carbonate rhombohedral druses are aligned with leaf veins. Trichomes are slightly curved spears with smooth margins. Some trichomes are jointed into multiple fibers.

Stomata are randomly arranged in the epidermal cell matrix. Elongated stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The stoma has an approximately length to width ratio of 2.5:1. The separation between the upper wood lamella and the lower woody lamella is wide at the lateral sides and the polar ends. The polar stems are wide.

Quercus macrocarpa
burr oak

Plate
333

***Quercus nigra*, water oak;**

Family: Fagaceae (Plate 334)

Macroscopic Characteristics: Leaves are spatula shaped with rounded tip and a wedge base; the length is approximately 3-12 cm and 2-6 cm wide. The margins are entire and the adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are polygonal-shaped and arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Calcium oxalate druses are randomly arranged in the epidermal cell matrix. Calcium carbonate rhombohedral druses are aligned with leaf veins.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. Polar ends are bifurcated. The stoma has an approximately length to width ratio of 1.4:1. The separation between the upper wood lamella and the lower woody lamella is wide at the lateral sides and the polar ends. The polar stems are wide.

Quercus nigra
water oak

Plate
334

Legend

Top Image: Epidermal cells are polygonal and arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore.
(PLM, single polar)

Bottom Image: Calcium oxalate druses are randomly arranged in the epidermal cell matrix. Calcium carbonate rhombohedral druses are aligned with leaf veins.
(PLM, single polar)

***Quercus palustris*, pin oak;**

Family: Fagaceae (Plate 335)

Macroscopic Characteristics: Leaves are broad with five to seven lobes; each lobe is bristle-tipped. Leaf length is approximately 5-16 cm and width is 5-12 cm. The adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are rectangular to polygonal-shaped. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Calcium oxalate druses are randomly arranged in the epidermal cell matrix. Calcium carbonate rhombohedral druses are aligned with leaf veins.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. Polar ends are bifurcated. The stoma has an approximately length to width ratio of 1.1:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and the polar ends. The polar stems are wide.

Quercus palustris
pin oak

Plate
335

***Quercus rubra*, northern red oak;**

Family: Fagaceae (Plate 336)

Macroscopic Characteristics: Leaves are oblong to ovate with seven to nine lobes. Leaf length is approximately 13-25 cm and width is 10-15 cm. The adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are polygonal to rectangular-shaped. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Calcium oxalate druses are randomly arranged in the epidermal cell matrix. Calcium carbonate rhombohedral druses are aligned with veins.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.3:1. The separation between the upper wood lamella and the lower woody lamella is wide at the lateral sides and the polar ends. The polar stems are wide.

Quercus rubra
northern red oak

Plate
336

***Quercus stellata*, post oak;**

Family: Fagaceae (Plate 337)

Macroscopic Characteristics: Leathery tomentose leaves have three perpendicular lobes shaped like a Maltese cross. The adaxial and abaxial surfaces are glabrous whereas tufts of hair are attached to abaxial veins.

Microscopic Characteristics: Epidermal cells are polygonal to rectangular-shaped. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Calcium carbonate rhombohedral druses are aligned with veins. Trichomes are stellate with pointed apexes.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The stoma has an approximately length to width ratio of 2:1. The separation between the upper wood lamella and the lower woody lamella is wide at the lateral sides and the polar ends. The polar stems are wide.

Quercus stellata
post oak

Plate
337

Legend

Top Image: Epidermal cells are polygonal to rectangular-shaped. Anticlinal walls are straight to straight-curved. Calcium carbonate rhombohedral druses are aligned with veins. Stomata are randomly arranged. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore.
(PLM, single polar)

Trichomes are stellate with pointed apices.
(PLM, single polar)

***Quercus velutina*, black oak;**

Family: Fagaceae (Plate 338)

Macroscopic Characteristics: Leaves have deep U-shaped notches with bristle tips; length is approximately 10-20 cm. The adaxial surface is glabrous whereas tufts of hair are attached to abaxial veins.

Microscopic Characteristics: Epidermal cells are polygonal to rectangular-shaped. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Calcium carbonate rhombohedral druses are aligned with veins. Globular calcium oxalate druses are randomly arranged. Trichomes are stellate.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. Polar ends are bifurcated. The stoma has an approximately length to width ratio of 1.6:1. The separation between the upper wood lamella and the lower woody lamella is wide at the lateral sides and the polar ends. The polar stems are wide.

Quercus velutina
black oak

Plate
338

Legend

Top Image: Epidermal cells are polygonal to rectangular-shaped. Anticlinal walls are straight to straight-curved. Calcium carbonate rhombohedral druses are aligned with veins. Calcium oxalate druses are randomly arranged. Stomata are randomly arranged and consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore.

Bottom Image: Trichomes are stellate.
(PLM, single polar)

***Quercus virginiana*, live oak;**

Family: Fagaceae (Plate 339)

Macroscopic Characteristics: Leaves are leathery, stiff and tomentose with a length of 2-15 cm and width of 1-5 cm.

Microscopic Characteristics: Epidermal cells are polygonal-shaped. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Calcium carbonate rhombohedral druses are aligned with veins; calcium oxalate druses are randomly arranged. Trichomes are stellate.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.2:1. The separation between the upper wood lamella and the lower woody lamella is wide at the lateral sides and the polar ends. The polar stems are wide.

Quercus virginiana
live oak

Plate
339

***Rhamnus cathartica*, European buckthorn;**

Family: Rhamnaceae (Plate 340)

Macroscopic Characteristics: Leaves are oval to elliptic with a length of 2.5-9 cm and a width of 1-3.5 cm. Margins are coarsely serrate; the adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are polygonal-shaped and arranged in a flagstone pattern. Anticlinal walls are straight-curved to sinuous. No phytoliths or trichomes were observed.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an elongated fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.4:1. The separation between the upper wood lamella and the lower woody lamella is relatively wide at the lateral sides and the polar ends. The polar stems are wide.

Rhamnus cathartica
European buckthorn

Plate
340

Legend

Epidermal cells are polygonal-shaped. Anticlinal walls are straight-curved to sinuous. Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an elongated fusiform-shaped pore. The separation between the upper and lower woody lamella is relatively wide at the lateral sides and narrow at the polar ends. Polar stems are wide. (PLM, single polar)

***Rhamnus frangula*, glossy buckthorn;**

Family: Rhamnaceae (Plate 341)

Macroscopic Characteristics: Leaves are ovate with 6-10 pairs of grooves. The margins are bluntly serrate with a length of 3-7 cm and a width of 2.5-4 cm. The adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are polygonal-shaped and arranged in a flagstone pattern. Anticlinal walls are straight-curved. Calcium oxalate and calcium carbonate rhombohedral druses are randomly arranged.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.5:1. The separation between the upper wood lamella and the lower woody lamella is relatively wide at the lateral sides and the polar ends. The polar stems are wide.

Rhamnus frangula
glossy buckthorn

Plate
341

***Rhododendron macrophyllum*, Pacific rhododendron;**

Family: Ericaceae (Plate 342)

Macroscopic Characteristics: Leaves are evergreen, thick, leathery and oblong to elliptic. Length is 8-20 cm and width is 3-7 cm. The margins are entire and the adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are polygonal shaped. Cells are arranged in a flagstone pattern. Anticlinal walls are straight-curved. No trichomes or phytoliths were observed.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an oval to fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.3:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and relatively wide at the polar ends. The polar stems are wide.

Rhododendron macrophyllum
Pacific rhodoendron

Plate
342

***Rhododendron maximum*, great laurel;**

Family: Ericaceae (Plate 343)

Macroscopic Characteristics: Leaves are evergreen, thick, leathery and oblong. Length is 9-19 cm and width is 2-4.7 cm. The margins are entire and the adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are polygonal-shaped. Cells are arranged in a flagstone pattern. Anticlinal walls are straight-curved. Calcium oxalate druses are randomly arranged in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an oval to fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.2:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and relatively wide at the polar ends. The polar stems are wide.

Rhododendron maximum
giant laurel

Plate
343

***Rhus aromatica*, fragrant sumac;**

Family: Anacardiaceae (Plate 344)

Macroscopic Characteristics: Leaves are trifoliate and dentate to crenate. Leaf length is approximately 7.5 cm and width is approximately 2 cm.

Microscopic Characteristics: Epidermal cells are polygonal-shaped. Cells are arranged in a jigsaw puzzle pattern. Anticlinal walls are straight-curved. Trichomes are straight to slightly curved spears. The adaxial and abaxial surfaces are glabrous.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an oval to fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.9:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are relatively narrow.

Rhus aromatica
fragrant sumac

Plate
344

Legend

Top Image: Epidermal cells are polygonal-shaped. Cells are arranged in a flagstone pattern. Anticlinal walls are straight-curved. Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an oval to fusiform-shaped pore.
(PLMd, single polar)

Bottom Image: Trichomes are straight to slightly curved spars.
(PLM, single polar)

***Rhus copallinum*, winged sumac;**

Family: Anacardiaceae (Plate 345)

Macroscopic Characteristics: Leaves are pinnately compound with the length of 30 cm and 7-15 leaflets per leaf. Leaflets are lance-shaped with entire margins. The adaxial and abaxial surfaces are glabrous whereas tufts of hairs cover the abaxial veins.

Microscopic Characteristics: Epidermal cells are polygonal-shaped. Cells are arranged in a flagstone pattern. Anticlinal walls are straight-curved. Trichomes are straight to slightly curved spears with pointed apexes. Bases are hexangle. Calcium oxalate druses are randomly arranged in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. At times, stomata are deformed. The stoma has an approximately length to width ratio of 1.7:1. The separation between the upper wood lamella and the lower woody lamella is wide at the lateral sides and narrow at the polar ends. The polar stems are relatively narrow.

Rhus copallinum
winged sumac

Plate
345

***Ribes aureum*, golden currant;**

Family: Grossulariaceae (Plate 346)

Macroscopic Characteristics: Leaves are circular with rounded lobes. Leaves are approximately 5 cm in diameter. The adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are polygonal-shaped. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Calcium oxalate druses are randomly arranged in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of elongated crescent-shaped guard cells surrounding a fusiform-shaped pore. The stoma has an approximately length to width ratio of 2:1. The separation between the upper wood lamella and the lower woody lamella is wide at the lateral sides and wide at the polar ends. The polar stems are relatively wide.

Ribes aureum
golden currant

Plate
346

Legend

Epidermal cells are polygonal-shaped. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Calcium oxalate druses are randomly arranged. Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of elongated crescent-shaped guard cells surrounding a fusiform-shaped pore. The separation between the upper and lower woody lamella is wide at the lateral sides and wide at the polar ends. (PLM, single polar)

***Ribes inerme*, whitestem gooseberry;**

Family: Grossulariaceae (Plate 347)

Macroscopic Characteristics: Leaves are small and deeply divided into 3-5 toothed lobes. The adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are polygonal-shaped. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Calcium oxalate druses are randomly arranged.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. Some pores are lignified. The stoma has an approximately length to width ratio of 1.1:1. The separation between the upper wood lamella and the lower woody lamella is wide at the lateral sides and wide at the polar ends. The polar stems are relatively wide.

Ribes inerme
whitestem gooseberry

Plate
347

***Ribes lacustre*, prickly currant;**

Family: Grossulariaceae (Plate 348)

Macroscopic Characteristics: Leaves are maple-like with 3-7 deep lobes. Width of the leaves is approximately 2-5 cm.

Microscopic Characteristics: Epidermal cells are polygonal-shaped. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Calcium oxalate druses are randomly arranged. Trichomes are straight to curved spears with smooth margins.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an oval to fusiform-shaped pore. Stomata are attached to epidermal cells with reinforced fibers. The stoma has an approximately length to width ratio of 1.2:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are relatively wide.

Ribes lacustre
prickly currant

Plate
348

Legend

Epidermal cells are polygonal-shaped. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Calcium oxalate druses are randomly arranged. Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. Stomata are attached to epidermal cells with reinforced fibers. (PLM, single polar)

***Ribes oxyacanthoides* spp. *cognatum*, stream currant;**

Family: Grossulariaceae (Plate 349)

Macroscopic Characteristics: Leaves are maple-like with 3-5 deeply cut lobes. Width of the leaves is approximately 3-4 cm.

Microscopic Characteristics: Epidermal cells are polygonal-shaped. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Calcium oxalate druses are randomly arranged. Trichomes are straight to curved with pointed apices.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. Some pores are lignified. The stoma has an approximately length to width ratio of 1.4:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are relatively wide.

Ribes oxycanthoides spp. *cognatum*
stream currant

Plate
349

***Ribes viscosissimum*, sticky currant;**

Family: Grossulariaceae (Plate 350)

Macroscopic Characteristics: Leaves are maple-like with 3-5 rounded, blunt-toothed lobes. The adaxial surface is glabrous whereas the abaxial veins are cover with coarse bristles.

Microscopic Characteristics: Epidermal cells are polygonal-shaped. Cells are arranged in a flagstone pattern. Cells under veins are rectangular to elongated polygons. Anticlinal walls are straight to straight-curved. Calcium oxalate druses are randomly arranged. Trichomes have straight sides and pointed apexes.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.2:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are relatively wide.

Ribes viscosissimum
sticky currant

Plate
350

***Robinia pseudoacacia*, black locust;**

Family: Fabaceae (Plate 351)

Macroscopic Characteristics: Leaves are compound with 9-19 leaflets. Leaflets are 2.5-5 cm long and 0.3-0.8 cm wide. The adaxial surface is glabrous whereas the abaxial veins are covered with hairs.

Microscopic Characteristics: Epidermal cells are polygonal-shaped. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight- curved. Rectangular phytoliths with curved margins and rhombohedral phytoliths are randomly arranged in the epidermal matrix. Trichomes are straight to curved spears with smooth margins and pointed apices.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-pore. The stoma has an approximately length to width ratio of 1.4:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and the polar ends. The polar stems are relatively narrow.

Robinia pseudoacacia
black locust

Plate
351

***Rosa woodsii*, Woods' rose;**

Family: Rosaceae (Plate 352)

Macroscopic Characteristics: Leaves are pinnately compound with 5-7 oval leaflets; leaflets are 3-4 cm long. The margins are coarsely serrate. The adaxial surface is glabrous whereas hairs are present on the margins and the abaxial surface.

Microscopic Characteristics Epidermal cells are polygonal-shaped. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Calcium oxalate druses are aligned with veins and randomly arranged. Trichomes are hollow and curved to wavy. Apexes are pointed, and margins are smooth. Trichomes bases are primarily attached to leaf veins.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.4:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are relatively narrow.

Rosa woodsii
Woods' rose

Plate
352

Legend

Epidermal cells are polygonal-shaped. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Calcium oxalate druses are aligned with veins and randomly arranged. Trichomes are hollow and curved to wavy. Apexes are pointed and margins are smooth. Trichomes bases are primarily attached to leaf veins. (PLM, single polar)

***Rubus fruticosus*, shrubby blackberry;**

Family: Rosaceae (Plate 353)

Macroscopic Characteristics: Leaves are palmately compound with 3-5 leaflets on prickly petioles. Leaflets are ovate with serrated margins; leaflet length is approximately 3-9 cm and the width is 2.5-5 cm. Hairs are on the adaxial and abaxial surfaces.

Microscopic Characteristics Epidermal cells are polygonal shaped. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Calcium oxalate druses are randomly arranged. Trichomes are hollow and curved with pointed apices and smooth margins.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.4:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are wide.

Rubus fruticosus
shrubby blackberry

Plate
353

Legend

Epidermal cells are polygonal-shaped. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Calcium oxalate druses are randomly arranged. Trichomes are hollow and curved with pointed apices. Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore.
(PLM, single polar)

***Rubus idaeus ssp. strigosus*, grayleaf red raspberry;**

Family: Rosaceae (Plate 354)

Macroscopic Characteristics: Leaves are pinnately compound with three leaflets on petioles that are stiff bristled; leaflets are serrate with a length of 4-10 cm. The adaxial surface is glabrous whereas the abaxial surface is pubescent.

Microscopic Characteristics Epidermal cells are polygonal to rectangular shaped. Cells under veins are oblong to rectangular whereas cells in the epidermal cell matrix are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Calcium oxalate druses are randomly arranged. Trichomes include straight to curved spears and long sinuous fiber with smooth margins. Spears have bases that have rectangular to hexangle bases with a rosette of epidermal cells.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are wide.

Rubus idaeus ssp. strigosus
grayleaf red raspberry

Plate
354

***Rubus parviflorus*, thimbleberry;**

Family: Rosaceae (Plate 355)

Macroscopic Characteristics: Leaves are palmate (maple-like) with 3-7 lobes and a width of 5-20 cm. Margins are serrated; the adaxial and abaxial surfaces are pubescent.

Microscopic Characteristics Epidermal cells are polygonal to rectangular shaped. Cells under veins are oblong to rectangular whereas cells in the epidermal cell matrix are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Calcium oxalate druses are randomly arranged.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.3:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are wide.

Rubus parviflorus
thimbleberry

Plate
355

***Salix fragilis*, crack willow;**

Family: Salicaceae (Plate 356)

Macroscopic Characteristics: Leaves are lanceolate with finely serrated margins; length is approximately 9-15 cm and the width is 1.5-3 cm. The adaxial surface is glabrous whereas occasional hairs are observed on the abaxial veins.

Microscopic Characteristics: Epidermal cells are rectangular to polygonal shaped. Anticlinal walls are straight to straight-curved. Calcite carbonate rhombohedral druses are aligned with veins. Calcite oxalate druses are randomly arranged in the epidermal cell matrix. Trichomes have straight sides with hollow interiors and pointed apices.

Brachyparacytic stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform pore. The stoma has an approximately length to width ratio of 1.2:1. The separation between the upper wood lamella and the lower woody lamella is wide at the lateral sides and the polar ends. The polar stems are wide.

Salix fragilis
crack willow

Plate
356

***Sambucus racemosa*, red elderberry;**

Family: Caprifoliaceae (Plate 357)

Macroscopic Characteristics: Leaves are pinnately compound with 5-7 leaflets; leaflet length is 15-23 cm. Hairs are lightly scattered on the adaxial surface and margins whereas they are heavier on the abaxial surface.

Microscopic Characteristics: Epidermal cells are irregular shaped. Anticlinal walls are straight to straight-curved. Calcite oxalate druses are randomly arranged in the epidermal cell matrix. Trichomes are straight to curved fibers with pointed apexes and smooth margins.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.4:1. The separation between the upper wood lamella and the lower woody lamella is relatively wide at the lateral sides and the polar ends. The polar stems are wide.

Sambucus racemosa
red elderberry

Plate
357

***Sassafras albidum*sa, sassafras;**

Family: Lauraceae (Plate 358)

Macroscopic Characteristics: Leaves ovate to obovate with a length of 10-16 cm and a width of 5-10 cm. The adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are polygonal-shaped with a few irregular shaped cells. Anticlinal walls are straight to straight-curved. No phytoliths or trichomes were observed.

Stomata are small and randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a thin pore. At times, the inner margins of the guard cells appear as two parallel lines. The stoma has an approximately length to width ratio of 1.2:1. The separation between the upper wood lamella and the lower woody lamella is relatively narrow at the lateral sides and relatively wide the polar ends. The polar stems are wide.

Sassafras albidum
sassafras

Plate
358

Legend

Epidermal cells are polygonal-shape with a few irregular-shaped cells. Anticlinal walls are straight to straight-curved. Stomata are small and randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a thin pore. At times, the inner margins of the guard cells appear as two parallel lines.
(PLM, single polar)

***Shepherdia canadensis*, russet buffaloberry;**

Family: Elaeagnaceae (Plate 359)

Macroscopic Characteristics: Leaves are oval to ovate with entire margins; length is approximately 1-6 cm and width is 1.3 cm. The adaxial and abaxial surfaces are pubescent.

Microscopic Characteristics: Epidermal cells are polygonal to irregular-shaped cells. Anticlinal walls are straight to straight-curved. Trichomes have smooth margins and pointed apices. Trichome bases are round to oval with a rosette of epidermal cells surrounding the base. Calcium oxalate druses are randomly arranged.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform pore. The stoma has an approximately length to width ratio of 1.6:1. The separation between the upper wood lamella and the lower woody lamella is relatively narrow at the lateral sides and wide the polar ends. The polar stems are wide.

Shepherdia canadensis
russet buffaloberry

Plate
359

***Smilax tamnoides*, greenbriers;**

Family: Liliaceae (Plate 360)

Macroscopic Characteristics: Leaves are rounded to cordate with ciliate to finely serrate margins; length is approximately 7.5 to 13 cm. The adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are irregular shaped cells. Anticlinal walls are straight to straight-curved. Phytoliths are anisotropic straight thin spears.

Brachyparacytic stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.2:1. The separation between the upper wood lamella and the lower woody lamella is wide at the lateral sides and narrow at the polar ends. The polar stems are wide.

Smilax tamnoides
bristly greenbrier

Plate
360

Legend

Epidermal cells are irregular shaped cells. Anticlinal walls are straight to straight-curved. Brachyparacytic stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent shaped guard cells surrounding a fusiform pore. The separation between the upper and lower woody lamella is wide at the lateral sides and narrow at the polar ends. The polar stems are wide.
(PLM, single polar)

***Sorbus americana*, American mountain ash;**

Family: Rosaceae (Plate 361)

Macroscopic Characteristics: Leaves are alternate and compound with 13-17 leaflets. Leaflet are lanceolate to long oval with a length of 5-8 cm. Margins are serrate; the adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are rectangular to polygonal-shaped cells. Anticlinal walls are straight to straight-curved. Cells under veins are rectangular whereas other cells are polygonal. Calcium carbonate rhombohedral and calcium oxalate druses are randomly arranged.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an oval to fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.6:1. The separation between the upper wood lamella and the lower woody lamella is wide at the lateral sides and the polar ends. The polar stems are narrow.

Sorbus americana
American mountain ash

Plate
361

***Sorbus torminalis*, checkertree;**

Family: Rosaceae (Plate 362)

Macroscopic Characteristics: Leaves are approximately 6-14 cm long and wide with 5-9 acute finely toothed lobes. Margins are serrate; the adaxial and abaxial surfaces are glabrous whereas hairs are on the abaxial veins.

Microscopic Characteristics: Epidermal cells are irregular shaped cells. Anticlinal walls are straight to straight-curved. Calcium carbonate rhombohedral druses are mostly overlying veins. Trichomes have smooth margins, long and have substantial square to hexangle bases

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an oval to fusiform pore. The stoma has an approximately length to width ratio of 1.8:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and relatively wide at the polar ends. The polar stems are wide.

Sorbus torminalis
checkertree

Plate
362

Legend

Top Image: Epidermal cells are irregular-shaped cells. Anticlinal walls are straight to straight-curved. Calcium carbonate rhombohedral druses are mostly overlying veins. Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an oval to fusiform-shaped pore. (PLM, single polar)

Bottom Image: Trichomes are straight-sided. (PLM, single polar)

***Spiraea betulifolia*, white spirea;**

Family: Rosaceae (Plate 363)

Macroscopic Characteristics: Leaves have round to ovate with serrate margins. The length is approximately 5 cm. The lower half of the leaf margin is entire; the upper half is coarsely serrate. The adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are irregular-shaped cells. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Calcium oxalate druses are randomly arranged.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a narrow pore. The stoma has an approximately length to width ratio of 1.5:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and relatively wide at the polar ends. The polar stems are wide.

Spiraea betulifolia
white spirea

Plate
363

***Symphoricarpos albus*, common snowberry;**

Family: Caprifoliaceae (Plate 364)

Macroscopic Characteristics: Leaves are elliptic to oval with smooth margins; approximate length is 2-5 cm. Hairs are on the margin and the adaxial and abaxial surfaces.

Microscopic Characteristics: Epidermal cells are rectangular to polygonal-shaped cells. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Calcium oxalate druses are mostly aligned with the veins. Trichomes are hooked shaped fibers with pointed apexes.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an oval to fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.1:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are wide.

Symphoricarpos albus
common snowberry

Plate
364

***Symphoricarpos occidentalis*, western snowberry;**

Family: Caprifoliaceae (Plate 365)

Macroscopic Characteristics: Leaves are leathery, elliptic to oval with rounded to blunt apexes. The approximate length is 2.5-8 cm and a width of 2-5 cm. The adaxial surface is glabrous whereas the hairs cover the abaxial veins.

Microscopic Characteristics: Epidermal cells are rectangular to polygonal shaped cells. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Calcium oxalate druses randomly arranged in the epidermal cell matrix. Trichomes are hooked shaped fibers with pointed apexes.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an oval to fusiform-shaped pore. The polar ends are wide. The stoma has an approximately length to width ratio of 1.1:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are relatively narrow.

Symphoricarpos occidentalis
western snowberry

Plate
365

***Symphoricarpos orbiculatus*, coralberry;**

Family: Caprifoliaceae (Plate 366)

Macroscopic Characteristics: Leaves are oval to elliptic with a length of 7 cm. The adaxial surface is glabrous whereas the abaxial veins are covered with hairs.

Microscopic Characteristics: Epidermal cells are rectangular to polygonal-shaped cells. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Trichomes are hooked shaped fibers with pointed apexes. Bases are square to hexangle.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an oblong to fusiform-shaped pore. Some stomata are deformed. The stoma has an approximately length to width ratio of 1.6:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are relatively narrow.

Symphoricarpos orbiculatus
coralberry

Plate
366

Legend

Epidermal cells are rectangular to polygonal-shaped cells. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Trichomes are hooked-shaped fibers with pointed apices. Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an oblong to fusiform-shaped pore. Some guard cells are deformed. (PLM, single polar)

***Taxus brevifolia*, Pacific yew;**

Family: Taxaceae (Plate 367)

Macroscopic Characteristics: Leaves are lanceolate and arranged in two flat rows; the leaf length is 1.2-1.9 cm (Kershner, Nelson and Spellenberg 2008). The adaxial surface is glossy whereas the abaxial surface is dull; stomatal lines were not apparent on either surface.

Microscopic Characteristics: Epidermal cells are parallelogram to rectangular shaped with a length to width that ranges from approximately 1:1 to 3:1. Anticlinal walls are straight to straight-curved. No trichomes or phytoliths were observed.

Stomata are arranged in parallel rows with a single or double cell separating each stoma. Stomata are circular to oval in outline with a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The separation between the lower and upper woody lamellae is approximately 2 microns. The polar stems are with a bifurcated extension at each end.

Taxus brevifolia
Pacific yew

Plate
367

***Taxus canadensis*, Canada yew;**

Family: Taxaceae (Plate 368)

Macroscopic Characteristics: Leaves are lanceolate, flat and arranged in two flat rows. Leaf length is 1-2.5 cm and width is 0.1-0.3 cm. The adaxial surface is glossy whereas the abaxial surface is dull; faint stomatal lines were observed on the abaxial surface.

Microscopic Characteristics: Epidermal cells are parallelogram to rectangular shaped with a length to width ratios from approximately 1:1 to greater than 5:1. Anticlinal walls are straight to straight-curved.

Stomata are arranged in parallel rows with a single or double cell separating each stoma. Stomata are circular to oval in outline with a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The separation between the lower and upper woody lamellae is approximately 2 microns. The polar stems are with a bifurcated extension at each end.

Taxus canadensis
Canada yew

Plate
368

Legend

Epidermal cells are parallelogram to rectangular shaped with a length to width ratio from approximately 1:1 to greater than 5:1. Anticlinal walls are straight to straight-curved. Stomata are arranged in parallel rows with a single or double cell separating each stoma. Stomata are circular to oval in outline with a pair of crescent shaped guard cells surrounding a fusiform shaped pore. Polar ends are wide and bifurcated.
(PLM, single polar)

***Thuja occidentalis*, northern white-cedar**

Family: Cupressaceae (Plate 369)

Macroscopic Characteristics: Scale-like leaves are approximately 0.3-0.6 cm in length with prominent resin glands (Kershner, Nelson and Spellenberg 2008). The adaxial surface is glossy however no stomatal lines were visible.

Microscopic Characteristics: Epidermal cells are parallelogram shaped with a length to width ratios from approximately 1:1 to greater than 5:1. Anticlinal walls are straight-curved. No phytoliths or trichomes were observed.

Stomata are randomly arranged in the epidermal cell matrix. Stomata with fusiform to square shaped pore openings were observed. Stomata are nearly circular with a length to width aspect ratio of approximately 1:1. The thickened inner wall extends from the stoma pore to the ends of the guard cells, ends of inner wall are bifurcated at end of guard cells. Spacing between the lower woody lamellae and upper woody lamella is less than 5 microns. The polar stems are narrow.

Thuja occidentalis
northern white-cedar

Plate
369

Legend

Epidermal cells are parallelogram shaped with a length to width ratios from approximately 1:1 to greater than 5:1. Anticlinal walls are straight-curved. Stomata with fusiform to square shaped pore openings were observed. Stomata are nearly circular with a length to width aspect ratio of approximately 1:1. Spacing between the lower woody lamella and upper woody lamella is less than 5 microns. The polar stems are narrow. (PLM, single polar)

***Thuja plicata*, western redcedar**

Family: Cupressaceae (Plate 370)

Macroscopic Characteristics: Scale-like leaves are approximately 0.3-0.6 cm in length with prominent resin glands (Kershner, Nelson and Spellenberg 2008). The adaxial surface is glossy however no stomatal lines were visible.

Microscopic Characteristics: Two types of epidermal cells were observed, one was circular and the other was rectangular to parallelogram shaped. Rectangular to parallelogram cells have length to width ratios from approximately 1:1 to greater than 5:1. Anticlinal walls of both cell types are straight-curved. No phytoliths or trichomes were observed.

Stomata are randomly arranged in the epidermal cell matrix. Stomata with fusiform to square shaped pore openings were observed. Stomata are nearly circular with a length to width aspect ratio of approximately 1.3:1. The thickened inner wall extends from the stoma pore to the ends of the guard cells, ends of inner wall are bifurcated at end of guard cells. Spacing between the lower woody lamellae and upper woody lamella is less than 5 microns. The polar stems are narrow.

Thuja plicata
western redcedar

Plate
370

***Tilia americana*, American basswood;**

Family: Tiliaceae (Plate 371)

Macroscopic Characteristics: Leaves are cordate to ovate with coarsely serrated margins and an asymmetrical base. Leaf length is 10-15 cm. The adaxial surface is glabrous whereas tufts of hair are present on the abaxial veins.

Microscopic Characteristics: Epidermal cells are rectangular to parallelogram-shaped with a length to width ratio of 1:1 to 3:1. Anticlinal walls are straight to straight-curved. Calcium carbonate rhombohedral druses are aligned with leaf veins. Trichomes have smooth sides with non-parallel margins.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.3:1.

Tilia americana
American basswood

Plate
371

***Tilia cordata*, littleleaf linden;**

Family: Tiliaceae (Plate 372)

Macroscopic Characteristics: Leaves are triangular-ovate with a distinctively heart-shape; length is approximately 3-8 cm.

Microscopic Characteristics: Epidermal cells are rectangular to polygonal shaped; some cells are hexangle. Anticlinal walls are straight to straight-curved. Calcium carbonate rhombohedral druses are aligned with leaf veins.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.3:1. The separation between the upper wood lamella and the lower woody lamella is wide at the lateral sides and polar ends. The polar stems are wide.

Tilia cordata
littleleaf linden

Plate
372

Legend

Epidermal cells are rectangular to polygonal-shaped; some cells are hexangle. Anticlinal walls of are straight to straight-curved. Calcium carbonate rhombohedral druses are aligned with leaf veins. Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells with a fusiform-shaped pore.
(PLM, single polar)

***Toxicodendron radicans*, eastern poison ivy;**

Family: Anacardiaceae (Plate 373)

Macroscopic Characteristics: Leaves are trifoliate with ovate leaflets; leaflets are 3-12 cm in length.

Microscopic Characteristics: Epidermal cells are irregular-shaped. Anticlinal walls are straight to straight-curved. Calcium oxalate and calcium carbonate rhombohedral druses are randomly arranged in the epidermal cell matrix. Trichomes are straight to curved fibers with pointed apices. Internal sections are wavy.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells with a fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.4-1.7:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are wide.

Toxicodendron radicans
eastern poison ivy

Plate
373

Legend

Epidermal cells are irregular-shaped. Anticlinal walls of are straight to straight-curved. Calcium oxalate and calcium carbonate rhombohedral druses are randomly arranged in the epidermal cell matrix. Trichomes are straight to curved fibers with pointed apexes. Internal sections are wavy. Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells with a fusiform-shaped pore.
(PLM, single polar)

***Tsuga canadensis*, eastern hemlock**

Family: Pinaceae (Plate 374)

Macroscopic Characteristics: Leaves are needle-like, flattened and two-ranked with a length is approximately 0.6-1.3 cm apex (Kershner, Nelson and Spellenberg 2008). The adaxial surface is glossy with no visible stomatal lines. The abaxial surface is dull with multiple prominent stomatal lines on each side of the central rib.

Microscopic Characteristics: Epidermal cells are rectangular with square to angled ends. Length to width ratio is greater 5:1 with straight to straight-curved anticlinal walls. No phytoliths or trichomes were observed.

Stomata are arranged in parallel rows; each stoma are separate by a single or double epidermal cell. Stomata are rectangular to oval with straight lateral sides and rounded polar ends. Guard cells are crescent-shaped and surround a fusiform-shaped pore. The lower woody and upper woody lamella are narrow and the polar ends are relatively narrow. Four subsidiary cells surround the stoma, two parallel to the guard cells and two at polar ends.

Tsuga canadensis
eastern hemlock

Plate
374

Legend

Epidermal cells are rectangular with square to angled ends. Length to width ratio is greater 5:1 with straight to straight-curved anticlinal walls. Stomata are arranged in parallel rows. Stomata are rectangular to oval with crescent shaped guard cells and an oblong to fusiform shaped pore. The lower woody and upper woody lamella are narrow and the polar ends are relatively narrow..
(PLM, single polar)

***Tsuga mertensiana*, mountain hemlock**

Family: Pinaceae (Plate 375)

Macroscopic Characteristics: Leaves are needle-like, flattened and four-angled in cross-section with a length is approximately 1.3-2.5 cm apex (Kershner, Nelson and Spellenberg 2008). Both adaxial and abaxial surfaces are slightly glossy with multiple parallel stomatal lines.

Microscopic Characteristics: Epidermal cells are rectangular with square to angled ends. Length to width ratio is ranges from 1:1 to greater 5:1 with straight to straight-curved anticlinal walls. No phytoliths or trichomes were observed.

Stomata are arranged in parallel rows; each stoma are separate by a single or double epidermal cell. Stomata are rectangular to oval with crescent-shaped guard cells and oblong to fusiform-shaped pore. The lower woody and upper woody lamella are narrow and the polar ends are relatively narrow. Four subsidiary cells surround the stoma, two parallel to the guard cells and two at polar ends.

Tsuga mertensiana
mountain hemlock

Plate
375

***Ulmus alata*, winged elm;**

Family: Ulmaceae (Plate 376)

Macroscopic Characteristics: Leaves are oblong to elliptic with a length of 6.5 cm and width of 2 cm. The adaxial surface is glabrous whereas hairs cover the abaxial veins and part of the leaf.

Microscopic Characteristics: Epidermal cells are rectangular to polygonal. Cells are arranged in a flagstone pattern. Anticlinal walls are straight-curved. Calcium carbonate rhombohedral druses are aligned with leaf veins. Trichomes are straight sided with hollow interiors and pointed apexes.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.5:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and the polar ends. The polar stems are wide.

Ulmus alata
winged elm

Plate
376

***Ulmus americana*, American elm;**

Family: Ulmaceae (Plate 377)

Macroscopic Characteristics: Leaves are oblong to elliptic with double-serrated margins; length is approximately 7-20 cm. The adaxial surface is glabrous whereas the abaxial surface and veins have stiff hairs.

Microscopic Characteristics: Epidermal cells are rectangular to polygonal. Cells are arranged in a flagstone pattern. Anticlinal walls are straight-curved. Calcium carbonate rhombohedral druses are aligned with leaf veins. Trichomes are striated with smooth margins and hollow interiors.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform pore. The stoma has an approximately length to width ratio of 1.4:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and the polar ends. The polar stems are relatively narrow.

Ulmus americana
American elm

Plate
377

Legend

Top Image: Epidermal cells are rectangular to polygonal. Cells are aligned in a flagstone pattern. Calcium carbonate rhombohebral druses are aligned with leaf veins. Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform pore. (PLM, single polar)

Bottom Image: Trichomes are striated with smooth margins and hollow interiors. (PLM, single polar)

***Ulmus glabra*, Wych elm;**

Family: Ulmaceae (Plate 378)

Macroscopic Characteristics: Leaves are obovate with length of 6-17 cm and width of 3-12 cm. The adaxial surface is glabrous whereas hairs cover the abaxial surface.

Microscopic Characteristics: Epidermal cells are rectangular to polygonal. Anticlinal walls are straight to straight-curved. Cells are arranged in a flagstone pattern. Calcium oxalate druses are randomly arranged in the epidermal cell matrix. Trichomes are short hooked spears with striations. Trichome bases are round to hexangle with a rosette of epidermal cells.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform pore. The stoma has an approximately length to width ratio of 2.2:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are relatively narrow.

Ulmus glabra
Wych elm

Plate
378

Legend

Top Image: Epidermal cells are rectangular to polygonal. Cells are arranged in a flagstone pattern. Calcium oxalate druses are randomly arranged in the epidermal cell matrix. Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore.
(PLM, single polar)

Bottom Image: Trichomes are short, hooked spines.
(PLM, single polar)

***Ulmus pumila*, Siberian elm;**

Family: Ulmaceae (Plate 379)

Macroscopic Characteristics: Leaves are obovate with coarsely serrated margins. Leaf length is less than 7 cm and width less than 3 cm.

Microscopic Characteristics: Epidermal cells are rectangular to polygonal. Anticlinal walls are straight to straight-curved. Cells are arranged in a flagstone pattern. Calcium oxalate druses are randomly arranged in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform pore. The stoma has an approximately length to width ratio of 1.6:1. The separation between the upper wood lamella and the lower woody lamella is wide at the lateral sides and relatively narrow at the polar ends. The polar stems are relatively narrow.

Ulmus pumila
Siberian elm

Plate
379

Legend

Epidermal cells are rectangular to polygonal. Cells are arranged in a flagstone pattern. Calcium oxalate druses are randomly arranged in the epidermal cell matrix. Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. The separation between the upper and lower woody lamella is wide at the lateral sides and relatively narrow at the polar ends.

***Ulmus rubra*, slippery elm;**

Family: Ulmaceae (Plate 380)

Macroscopic Characteristics: Leaves are oblong to obovate with double-serrate margins; length is approximately 10-20 cm.

Microscopic Characteristics: Epidermal cells are rectangular to polygonal. Anticlinal walls are straight to straight-curved. Cells are arranged in a flagstone pattern. Calcium carbonate rhombohedrals are aligned with veins whereas calcium oxalate druses are randomly arranged in the epidermal cell matrix. Trichomes are straight fibers with vertical striations and hollow interiors. Bases are round to polygonal and surrounded by a rosette of epidermal cells.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a narrow pore. The stoma has an approximately length to width ratio of 2.1:1. The separation between the upper wood lamella and the lower woody lamella is wide at the lateral sides and relatively narrow at the polar ends. The polar stems are relatively narrow.

Ulmus rubra
slippery elm

Plate
380

Legend

Top Image: Epidermal cells are rectangular to polygonal. Cells are arranged in a flagstone pattern. Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore. (PLM, single polar)

Bottom Image: Calcium oxalate druses are randomly arranged, trichomes are hooked fibers. (PLM, single polar)

***Ulmus thomasii*, rock elm;**

Family: Ulmaceae (Plate 381)

Macroscopic Characteristics: Leaves are oval to obovate with serrated margins; length is approximately 5-10 cm and 2-5 cm wide.

Microscopic Characteristics: Epidermal cells are polygonal to irregular-shaped. Anticlinal walls are straight to straight-curved. Cells are arranged in a flagstone pattern. Calcium carbonate rhombohedrals are aligned with veins whereas calcium oxalate druses are randomly arranged in the epidermal cell matrix. Trichomes are straight fibers with vertical striations and hollow interiors. Bases are round to polygonal and surrounded by a rosette of epidermal cells.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a narrow pore. The stoma has an approximately length to width ratio of 2.3:1. The separation between the upper wood lamella and the lower woody lamella is wide at the lateral sides and relatively narrow at the polar ends. The polar stems are relatively narrow.

Ulmus thomasii
rock elm

Plate
381

Legend

Top Image: Epidermal cells are polygonal to irregular. Calcium carbonate rhomboidal druses are aligned with the veins. Calcium oxalate druses are randomly arranged. Stomata are randomly arranged. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform-shaped pore.
(PLM, single polar)

Bottom Image: Trichomes are straight to curved fibers with vertical striations.
(PLM, single polar)

***Vaccinium angustifolium*, lowbush blueberry;**

Family: Ericaceae (Plate 382)

Macroscopic Characteristics: Leaves are elliptic with finely serrated margins; length is approximately 2-4 cm and width is 0.6-2 cm.

Microscopic Characteristics: Epidermal cells are irregular-shaped cells. Cells are arranged in a jigsaw puzzle pattern. Anticlinal walls are straight to straight-curved. Calcium oxalate druses are randomly arranged in the epidermal cell matrix.

Brachyparacytic stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an oval to fusiform-shaped pore. The stoma has an approximately length to width ratio of 2.3:1. The separation between the upper wood lamella and the lower woody lamella is wide at the lateral sides and the polar ends. The polar stems are relatively wide.

Vaccinium angustifolium
lowbush blueberry

Plate
382

***Vaccinium membranaceum*, thinleaf huckleberry;**

Family: Ericaceae (Plate 383)

Macroscopic Characteristics: Leaves are membranous, serrated and oval with a length of 5 cm.

Microscopic Characteristics: Epidermal cells are rectangular to polygonal-shaped cells. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Calcium carbonates and calcium oxalate druses are randomly arranged in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an oval to fusiform-shaped pore. The stoma has an approximately length to width ratio of 2:1. The separation between the upper wood lamella and the lower woody lamella is wide at the lateral sides and the polar ends. The polar stems are wide.

Vaccinium membranaceum
thinleaf huckleberry

Plate
383

***Viburnum opulus*, European cranberrybush;**

Family: Caprifoliaceae (Plate 384)

Macroscopic Characteristics: Leaves are tri-lobed with serrated margins; length is approximately 5-10 cm. Hairs are present on the adaxial and abaxial surfaces.

Microscopic Characteristics: Epidermal cells are rectangular to polygonal-shaped cells. Cells are arranged in a jigsaw puzzle pattern. Anticlinal walls are straight to straight-curved. Calcium carbonate and calcium oxalate druses are randomly arranged in the epidermal cell matrix. Trichomes are curved fibers with striations on the surface. The apex is pointed and the bases are circular to hexangle. The interior is mostly hollow.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an oval to fusiform-shaped pore. The stoma has an approximately length to width ratio of 2:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and the polar ends. The polar stems are narrow.

Viburnum opulus
European cranberrybush

Plate
384

***Viburnum prunifolium*, blackhaw;**

Family: Caprifoliaceae (Plate 385)

Macroscopic Characteristics: Leaves are ovate to orbicular with a length of 9 cm and width of 6 cm. Leaf margins are serrate.

Microscopic Characteristics: Epidermal cells are polygonal to irregular shaped cells. Cells are arranged in a flagstone or jigsaw puzzle pattern. Anticlinal walls are straight to straight-curved. Calcium oxalate druses are randomly arranged in the epidermal cell matrix.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding an oval to fusiform-shaped pore. The stoma has an approximately length to width ratio of 1.7:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are relatively narrow.

Viburnum prunifolium
blackhaw

Plate
385

***Viburnum rufidulum*, rusty blackhaw;**

Family: Caprifoliaceae (Plate 386)

Macroscopic Characteristics: Leaves are leathery, glossy and ovate to obovate. Leaf length is approximately 10 cm. The adaxial and abaxial surfaces are glabrous.

Microscopic Characteristics: Epidermal cells are polygonal to irregular shaped cells. Cells are arranged in a flagstone or jigsaw puzzle pattern. Anticlinal walls are straight to straight-curved.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform pore. The stoma has an approximately length to width ratio of 1.7:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and wide at the polar ends. The polar stems are relatively narrow.

Viburnum rufidulum
rusty blackhaw

Plate
386

***Vitis riparia*, riverbank grape;**

Family: Vitaceae (Plate 387)

Macroscopic Characteristics: Leaves are lobed with serrate margins; length is 5-25 cm and width is 5-20 cm. Hairs are present on the margins, adaxial and abaxial surfaces.

Microscopic Characteristics: Epidermal cells are rectangular to polygonal-shaped. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Phytoliths, raphides, and calcium oxalate globular druses are randomly arranged in the epidermal cell matrix. Trichomes are hooked and segmented with pointed apexes.

Stomata are randomly arranged in the epidermal cell matrix. Stomata consist of a pair of crescent-shaped guard cells surrounding a fusiform pore. The stoma has an approximately length to width ratio of 1.6:1. The separation between the upper wood lamella and the lower woody lamella is narrow at the lateral sides and the polar ends. The polar stems are narrow.

Vitis riparia
riverbank grape

Plate
387

Legend

Top Image: Phytoliths, raphides, and calcium oxalate globular druses are randomly arranged in the epidermal cell matrix.
(PLM, crossed polars)

Bottom Image: Epidermal cells are rectangular to polygonal-shaped cells. Cells are arranged in a flagstone pattern. Anticlinal walls are straight to straight-curved. Trichomes are segmented with pointed apices.
(PLM, single polar)

5 Microhistology of Plant Fragments in Herbivore Diets

Published: Henderson, J. J. and Vucetich, J. A. (2016). Microhistology of Plant Fragments in Herbivore Diets. *The Microscope* 64 (2), pp 61 – 68.

John J. Henderson and John A. Vucetich

Authors: School of Forest Resources and Environmental Science, Michigan
Technological University, Houghton, MI 49931, USA.

Mention of a proprietary product does not constitute a guarantee or warranty of the product by the author and does not imply its approval to the exclusion of the other products that also may be suitable.

Abstract

Microhistologically-based studies of diet focus on the identification of fragments of food items that appear in samples of scat. When the subject is an herbivore, the fragments of interest are plant, grass, and woody stem. Diagnostic fragment features include cellular features (cell shapes, stomata, tracheae, etc.), inclusions (silica, calcium carbonate and oxalate, starch, etc.) and epidermal surface growths (trichomes, scales, glands, etc.). Rough botanical groupings can generally be determined with one or two characteristics whereas many botanical fragments can be identified to species using multiple characteristics. Despite some challenges such as differential digestibility and identification of single small fragments, microhistological studies of diets have resulted in some fascinating insight into the foraging behavior of domesticated and wild herbivores.

Keywords

Microhistology, scat, fecal, pellet, diet, forage, herbivore

5.1 Introduction

Microhistology is the microscopic examination of fecal pellets that provides for close examination of diet (Holechek 1982, Henderson 2012). Microhistologically-based studies of diet are non-intrusive and allow for sampling without disturbing or sacrificing the animal (Anthony and Smith 1974, Holechek et al. 1982a), which can be important when studying endangered species, for example. Microhistologically-based studies of diet can also readily produce larger sample sizes than other methods such as direct observations of consumers (e.g., Belovsky 1978). Compared to another alternative, i.e., detecting and tallying browsed plants in the field (e.g., Shipley et al. 1998, Skarpe and Hester 2008, Shipley 2010), microhistologically-based studies are not vulnerable to detection errors. Finally, microhistologically-based studies are less expensive and require less equipment and skills than other laboratory techniques such as DNA sequencing (e.g., Murphree 2012).

Microhistologically-based studies of diet focus on the identification of fragments of food items that appear in samples of scat. When the research subject is a carnivore the fragments include insect fragments, feathers, hairs or chemical analysis of digested tissues (e.g., Ralph et al. 1985, Chame 2003). In particular, the pattern of cuticular scales on the hairs of many mammalian prey are diagnostic (e.g., Day 1966, Teerink 2003). When the subject is an herbivore, then the fragments of interest are plant, grass, and woody stem fragments (Holechek et al. 1982a, Springer and Smith 1981). In this paper, we will restrict our discussion to botanical materials. Unlike traditional tissue histology, feces are not sectioned with a microtome (Bancroft and Gamble 2008). Dried feces are either mounted unaltered, washed and sorted prior to mounting, or ground in a Wiley mill with a 1.0 mm screen and the resulting fragments mounted on microscope slides (Holechek 1982). A brightfield microscope (BM), phase contrast microscope (PCM) or polarized light microscope (PLM) is used for the identification of cellular fragments (Howard and Samual 1979, Holechek 1982, Hurst and Beck 1988, Carriere 2000, Henderson et al. 2014).

Preparation of a reference collection is necessary for comparison and training. Two approaches are utilized in the preparation of reference plant material for microscopic work. One approach is to grind up the plant material in a Wiley mill similar to the procedure used for fecal samples (Sparks and Malechek 1968). The second approach is to peel and mount a square or rectangular epidermal section of the representative plant specimens (Carriere 2002). The second approach provides better microscopic views of key diagnostics. A 100x magnification is the standard magnification used for fecal microhistological examinations (Carriere 2002). Nevertheless, microscopic examination and photomicrography at 200-400x permits more detailed examination of most diagnostic features. Diagnostic features include cellular features (cell shapes, stomata, tracheae, etc.), inclusions (silica, calcium carbonate and oxalate, starch, etc.) and epidermal surface growths (trichomes, scales, glands, etc.). Higher powers, including 200x and 400x, should be available for detailed examination of finer features. Many of these diagnostic features are family or genera specific.

5.2 Cellular Structures

Epidermal or undifferentiated general cells are described in relation to their cellular shape. Common shapes include square and rectangular, polygonal, and irregular. Anticlinal walls are described as straight, straight-curved, sinuous or wavy (Figs. 1 & 2). Stomata (sites of gas exchange for plants) consist of elliptical openings surrounded by two kidney-shaped guard cells. Additional specialized cells are frequently seen associated with stomata in addition to structural modifications to the adjacent epidermal cells. Three stomata types are most commonly observed in microhistology and include anomocytic, brachyparacytic and tetracytic (Figs. 3 & 4). Anomocytic have no specialized cells supporting the stomata; the cell shapes around the stomata are the same as the other areas of the epidermis. Brachyparacytic stomata have two support cells aligned parallel with the guard cells whereas tetracytic stomata have four support cells; two are aligned with the guard cells and two are at the distal and proximal ends of the guard cells.

5.3 Inclusions

The morphology of various inclusions is often diagnostic. Common inclusions include minerals, crystals, and starch grains. Minerals and crystals, also called druses, include phytoliths (non-crystalline silicon dioxide) and various calcium compounds. Phytoliths are common in graminoids (grasses) and some dicotyledons. Calcium compounds include calcium oxalate and calcium carbonate. Calcium druses are found in a variety of plant groups including algae, angiosperms and gymnosperms. Taxonomists categorize druses into multiple morphological classifications (Metcalf and Chalk 1960, Madella, et al. 2005). Druse shapes are divided into three categories: rhombohedral (square and rectangular), raphides (needle-like) and globular (dog-bone, butterfly, and other shapes). Orientation of mineral inclusions ranges from random to ordered. Phytoliths are typically random however calcium compounds are frequently aligned with leaf veins and cellular structures. Depending on stomach retention times, some calcium compounds are dissolved and not visible in microhistological samples.

Starch is occasionally encountered; starch grains are polymers of stored energy that are visible under BM as spherical or ellipsoidal shapes. Using PLM, starch grains show a distinctive Maltese-cross (Fig. 5).

5.4 Surface Growths

Trichomes are hair or bristle epidermal outgrowths. They take a variety of morphologic forms including unbranched, multi-armed, stellate, and scales. In addition, unbranched trichome morphologies are described as solid, hollow, pitted, and/or ridged. The unbranched trichome apex is described as pointed or rounded (Figs. 6 & 7). During the mastication and digestion process, trichomes can be subdivided; however sufficient morphological features are usually present to permit identification. Support cells are groups of basal cells arranged to support trichomes to other epidermal cells. Support cells are described as single or segmented.

5.5 Plant Identification

An identification guide can greatly aid in the identification of botanical specimens. Few identification guides related to microhistology are available. There is a photographic key for Arctic plants (Carriere 2000), an identification key for central Argentinian grasses (Lindstrom et al. 1998), a grazer's atlas of grasses and shrubs (Howard and Samuel 1979), a microhistological guide of aquatic plants of Florida (Hurst and Beck 1988) and a microhistological guide of Yellowstone moose browse (Henderson et al. 2013). It would aid any microscopist to make a set of reference samples. Microscopical identification is facilitated by observation of many characteristics.

Rough botanical groupings can generally be determined with one or two characteristics. Conifers and graminoids (grasses) typically have “brick-like” geometric cell shapes and elongated stomata in parallel rows (Figs. 2a & 2b). In addition, graminoids typically have silica inclusions that are easily identified with PLM. Typically, deciduous leaves are characterized by a random assortment of stomata and non-geometric cell shapes (Figs. 8 through 10). Many botanical fragments can be identified to species using multiple characteristics. The following examples illustrate how studying a set of reference examples can lead to the development of diagnostic descriptions:

Abies lasiocarpa (subalpine fir): Subalpine fir is winter browse for moose near the upper tree line (high elevation) of the Rocky Mountains. Square to parallelogram epidermal cell shapes—roughly 30-50 microns long and 15-20 micron wide with wavy to sinuous anticlinal walls – are stacked in a linear pattern of blocks. Parallel rows of tetracytic stomata are found on the abaxial (underside) surface, frequently with calcium oxalate inclusions within the stomata opening (Fig. 8, Table 1).

Potamogeton natans (floating pondweed): Pondweed is frequently consumed by waterfowl and moose; and commonly carpets shallow areas of ponds. The cell shape of the epidermis appears like a “jigsaw puzzle” with thick sinuous anticlinal walls. Multiple polygonal cell shapes anchor the unbranched textured hollow trichomes. Random

anomocytic oval stomata are randomly scattered in the cellular matrix and the opening pore was “cigar-like” in shape (Fig. 9).

Populus angustifolia (narrowleaf cottonwood): Narrowleaf cottonwood is consumed by deer, moose and other browsers; and is common near streams in the foothill to montane regions of the Rocky Mountains. The epidermal surface consists of polygonal cell shapes with straight to slightly curved anticlinal walls. Anomocytic stomata are randomly arranged and stomata consists of ellipse shaped guard cells and a vesica piscis shaped pore slit. Unbranched hollow trichomes with hexangle to circular bases are scattered about the epidermis and calcium oxalate druses are aligned with major and minor leaf veins (Fig. 10).

Table 1 further illustrates the microhistological basis for distinguishing even closely related species. Again, diagnostic tables such as Table 1 can be developed by studying a reference collection.

5.6 Discussion

Microhistology is not without its challenges. Herbaceous forage is much easier to identify than woody winter browse. The internal structure and inclusions of leaves benefits the microscopist with many characteristics for rapid identification. Woody material consists of less identifying characteristics; making it difficult to determine plant species based on a single fiber or bundle. In a research or forensic laboratory, additional time and techniques can be applied to identify most botanical materials, however when analyzing hundreds of samples, botanical fragments with few identifiable characteristics are listed as unknown or unidentifiable.

In addition, estimating composition of herbivore diet can be complicated by differential digestibility (Parikh 2015). Some botanical materials, such as twigs and bark, consist of abundant lignin and hemicellulose; the primary constituents that pass the digestive process. Other plant parts consist of constituents that are readily digested. For example, the aquatic algae *Spirogyra* is consumed by manatee and moose but seldom

found in microhistological samples (Franzmann and Schwartz 1997, Hurst and Beck 1988, Morris 2014). Some masticated and digested plant fragments present insufficient identifiable features making speciation difficult. In spite of these challenges, microhistology has demonstrated itself to be a useful tool.

Microhistological studies of diets have resulted in some fascinating insight into the foraging behavior of domesticated herbivores (e.g., Eckerle et al. 2009, Rentfleish and Hansen 2000). For example, Holechek et al. (1982b) determined that diets of free-ranging cattle included a higher percentage of forbs (non-woody herbaceous plants) and shrubs than previously thought; data for this study showed that 23% of cattle diet consisted of forbs and shrubs. Cattle were previously thought to forage primarily on graminoids (grasses). Based on microhistological dietary studies, range management practices were modified to include parcels with a higher percentage of forbs and shrubs (Holechek 1995).

Similarly, interesting insights have been had in applying this method to wild herbivores (e.g., Merrill 1994, Gallardo et al. 2014, Ferretti et al. 2015). For example, Jung et al. (2015) used microhistology to study food resource competition among three native ungulates (caribou (*Rangifer tarandus*), thimhorn sheep (*Ovis dalli*), moose (*Alces alces*)) and two recently introduced ungulates (bison (*Bison bison*) and elk (*Cervus canadensis*)). Three of these ungulates (bison, sheep and caribou) are grazers (feeding primarily on ground cover), one (elk) is an intermediate forager (feeding on both ground cover and shrubs) and one (moose) is a browser (feeding primarily on shrubs and trees). Microhistological studies revealed little dietary overlap between the intermediate feeder and the browser. However, dietary overlap was noted with grazers leading to possible high resource competition. High resource competition increases forage use and leads to degradation of the resource and eventual diminished health of the animals. This knowledge highlights the value of microhistological dietary insight in wildlife management.

Figure B.1: Typical cell shapes and anticlinal walls. Illustration (a) depicts rectangular cell shape and straight-curved anticlinal walls, (b) depicts rectangular cell shape and wavy anticlinal walls, and (c) depicts an irregular cell shape and sinuous anticlinal walls. Drawings by Joanna Rogers, used with permission.

Figure B.2: Photomicrographs of cell shapes and anticlinal walls. Panel (a) shows the rectangular cell shape and straight-angled anticlinal walls of *Carduus nutans* (musk thistle). Panel (b) shows the wavy anticlinal walls of *Carex aquatilis* (water sedge). Panel (c) illustrates the irregular cell shape with sinuous anticlinal walls of *Potamogeton natans* (floating pondweed). All images were taken with polarized light microscope and single polar.

Figure B.3: The cellular structures that surround stomata can also be diagnostic. Three common structures include anomocytic (a), brachyparacytic (b), and tetracytic (c). Anomocytic has five or more cells randomly surrounding the guard cells, brachyparacytic includes two cells flanking the guard cells, and tetracytic has two cells aligned with the guard cells and two cells at either end of the guard cells. Drawing by Joanna Rogers, used with permission.

Figure B.4: Photomicrograph of three stomata types, anomocytic stomata of *Potamogeton natans* (floating pondweed) (a), brachyparacytic stomata of *Salix eastwoodiae* (mountain willow) (b), and four cells surrounding the guard cells of tetracytic stomata of *Picea engelmannii* (Engelmann's spruce) (c). All images were taken with a polarized light microscope and single polar.

Figure B.5: Photomicrograph of starch grains showing Maltese-cross shape with polarized light microscope and crossed-polars. The cross remains aligned with the analyzer and polarizer upon stage rotation of the microscope.

Figure B.6: Trichomes are surface inclusions frequently encountered in microhistological samples. These shapes include unbranched (solid, textured, curved, fluted and hollow) (a), multi-branched (b), stellate (c), and scales (d). Drawing by Joanna Rogers, used with permission.

Figure B.7: Photomicrographs of trichome surface inclusions found on plant material. A solid unbranched trichome from *Lonicera involucrata* (twinberry honeysuckle) (a), textured unbranched trichome from *Symphoricarpos albus* (common snowberry) (b), hollow unbranched curved trichome from *Physocarpus malvaceus* (mallow ninebark) (c), multi-branched trichomes from *Nuphar lutea* (yellow pond-lily) (d), stellate trichome from *Shepherdia argenta* (silver buffaloberry) (e), and a scale trichome from *Elaeagnus commutata* (silverberry) (f). Images (a), (e), and (f) were taken with a polarized light microscope, crossed-polars and first-order red compensator. Images (b) through (d) were taken with polarized light microscope and single polar.

Figure B.8: Photomicrographs of *Abies lasiocarpa* (subalpine fir); left image shows tetracytic stomata filled with calcium oxalate. Right image illustrates parallelogram cellular structure with wavy anticlinal walls. Both images were taken with a polarized light microscope and single polar.

Figure B.9: Photomicrographs of *Potamogeton natans* (floating pondweed); the left images shows an unbranched hollow trichome with circular base. The right image depicts an anomocytic stomata and sinuous anticlinal walls with “jigsaw puzzle” cell shapes. Both images were taken with a polarized light microscope and single polar.

Figure B.10: Photomicrographs of *Populus angustifolia* (narrowleaf cottonwood); the left image has a hollow unbranched trichome that is attached to the epidermal surface with a hexangle base. The right image has anomocytic stomata and “flagstone” cell shapes with straight to curved anticlinal walls. Both images were taken with a polarized light microscope and single polar.

Table B.1: Summary of four microhistological characteristics capable of distinguishing a set of closely related forage species. Cell shapes are shown in Figures 1 and 2 and may be square-rectangular (s-r), parallelogram (par), irregular (irr), or polygonal (pol). Anticlinal walls, also shown in Figures 1 and 2, and may be wavy (wav), sinuous (sin), straight (str), or straight-curved (s-c). Stomata are shown in Figures 3 and 4 and may be anomocytic (ano), brachyparacytic (bra), or tetracytic (tet). Inclusions are shown in Figures 5 and 8, and may be druses (dru), glands (gla), or starch (str). While none of these species are characterized by trichomes (see Fig. 6 and 7), many species are.

Table of plant fragment characteristics														
Species	Cell Shapes				Anticlinal Walls				Stomata			Inclusions		
	s-r	par	irr	pol	wav	sin	str	s-c	ano	bra	tet	dru	gla	str
<i>Abies lasiocarpa</i> (subalpine fir)		X			X						X	X		
<i>Juniperus communis</i> (common juniper)		X					X	X			X	X		
<i>Juniperus scopulorum</i> (Rocky Mt. juniper)	X	X		X				X	X					
<i>Picea engelmannii</i> (Engelman spruce)	X	X		X		X					X	X		
<i>Picea pungens</i> (Colorado blue spruce)	X	X						X	X			X		
<i>Pinus albicaulis</i> (whitebark pine)	X	X				X			X					
<i>Pinus contorta</i> (lodgepole pine)	X	X			X				X					
<i>Pinus flexilis</i> (limber pine)	X	X			X				X			X		
<i>Pseudotsuga menziesii</i> (Douglas fir)	X							X	X			X		

Reference List

Alipayo, D., Valdez, R., Holechek, J. L., and Cardenas, M. (1992). Evaluation of microhistological analysis for determining ruminant diet botanical composition. *Journal of Range Management*, 148-152.

Anthony, R. G., and Smith, N. S. (1974). Comparison of rumen and fecal analysis to describe deer diets. *Journal of Wildlife Management*, **38**:535-540.

Bancroft, J. D., and Gamble, M. (2008). *Theory and practice of histological techniques*. Elsevier Health Sciences.

Baumgartner, L. T., and Martin, A. C. (1939). Plant histology as an aid in squirrel food-habit studies. *Journal of Wildlife Management*, **3**:62-68.

Belovsky, G. E. (1978). Diet optimization in a generalist herbivore: the moose. *Theoretical population biology*, **14**(1):105-134.

Belovsky, G. E. (1981). Food plant selection by a generalist herbivore: the moose. *Ecology*, **62**:1020-1030.

Bergvall, U. A., and O. Leimar. 2005. Plant secondary compounds and the frequency of food types affect food choice by mammalian herbivores. *Ecology* **86**:2450-2460.

Bjugstad, A. J., Crawford, H. S., and Neal, D. L. (1970). *Determining forage consumption by direct observation of domestic animals*. In: Range and Wildlife Habitat Evaluation-A Research Symposium, U.S. Department of Agriculture Forest Service Miscellaneous Publication No. 1147. 220 p.

Brandner, T. A., Peterson, R. O., and Risenhoover, K. L. 1990. Balsam fir on Isle Royale: effects of moose herbivory and population density. *Ecology* **71**:155-164.

- Carrière, S. (2002). Photographic key for the microhistological identification of some Arctic vascular plants. *Arctic*, 247-268.
- Carson, R. T., Louviere, J. J., Anderson, D. A., Arabie, P., Bunch, D. S., Hensher, D. A., Johnson, R. M., Kuhfeld, W. F., Steinberg, D., Swait, J., and Timmermans, H. (1994). Experimental analysis of choice. *Marketing Letters* **5**:351-367.
- Chame, M. (2003). Terrestrial mammal feces: a morphometric summary and description. *Memórias do Instituto Oswaldo Cruz*, **98**:71-94.
- Chesson, J. 1978. Measuring preference in selective predation. *Ecology* **59**:211-215.
- Chesson, J. 1983. The estimation and analysis of preference and its relationship to foraging models. *Ecology*, **64**:1297-1304.
- Chevallier-Redor, Verheyden-Tixier, N., H., Verdier, M., and Dumont, B. (2001). Foraging behaviour of red deer *Cervus elaphus* as a function of the relative availability of two tree species. *Animal Research* **50**:57–65.
- Clay, R. S., and Court, T. H. (1932). *The history of the microscope*. Charles Griffin.
- Clements H. S., Tambling, C. J., Hayward, M. W., and Kerley, G. I. H. (2014). An objective approach to determining the weight ranges of prey preferred by and accessible to the five large African carnivores. *PLoS ONE*, **9**:e101054
- Cohen, Y., J. Pastor, and Moen, R. (1999). Bite, chew, and swallow. *Ecological Modelling*, **116**:1-14.
- Clements H. S., Tambling, C. J., Hayward, M. W., and Kerley, G. I. H. (2014). An objective approach to determining the weight ranges of prey preferred by and accessible to the five large African carnivores. *PLoS ONE* **9**:e101054

- Davis, R. B. (1951). *The food habits of white tailed deer on the cattle stocked, liveoak-mesquite ranges of the King Ranch, as determined by analyses of deer rumen contents*. M.S. Thesis. Texas A and M University.
- Day, M. G. (1966). Identification of hair and feather remains in the gut and faeces of stoats and weasels. *Journal of Zoology*, **148**(2):201-217.
- De Jager, N. R. D., Pastor, J., and Hodgson, A. L. (2009). Scaling the effects of moose browsing on forage distribution, from the geometry of plant canopies to landscapes. *Ecological Monographs*, **79**:281-297.
- Denton, John A. (1990). *Society and the official world: a reintroduction to sociology*. Dix Hills, N.Y: General Hall
- Di Stefano, J., and Newell, G. R. (2008). Diet selection by the swamp wallaby (*Wallabia bicolor*): feeding strategies under conditions of changed food availability. *Journal of Mammalogy*, **89**:1540-1549.
- Dirschl, H. J. (1962). Sieve mesh size related to analysis of antelope rumen contents. *Journal of Wildlife Management*, **26**:327-328.
- Dusi, Julian L. (1947). Methods for the determination of food habits by plant microtechniques and histology of their application to cottontail rabbit food habits. *Journal of Wildlife Management*, **13**:295-298.
- Dussault, C., Courtois, R., Ouellet, J. P. and Girard, I. (2005). Space use of moose in relation to food availability. *Canadian Journal of Zoology*, **83**:1431-1437.
- Eckerle, G. J., Olson, K. C., Jaeger, J. R., Fick, W. H., Pacheco, L. A., and Walburger, K. (2009). Microhistological characterization of the botanical composition of diets grazed by beef cows in the Kansas Flint Hills during winter. In *American Society of Animal Science*.
- Edenius L., Ericsson, G., and Naslund, P. (2002). Selectivity by moose vs the spatial distribution of aspen: a natural experiment. *Ecography*, **25**:289–294.

Fortin, D., Fryxell, J. M., and Pilote, R. (2002). The temporal scale of foraging decisions in bison. *Ecology* **83**:970-982.

Fortin D., Fryxell, J. M., O'Brodovich, L., and Frandsen, D. (2003). Foraging ecology of bison at the landscape and plant community levels: the applicability of energy maximization principles. *Oecologia*, **134**:219–227.

Fortin, D., Boyce, M. S., Merrill, E. H., and Fryxell, J. M. (2004). Foraging costs of vigilance in large mammalian herbivores. *Oikos*, **107**:172-180.

Fortin, D., Beyer, H. L., Boyce, M. S., Smith, D. W., Duchesne, T., and Mao, J. S. (2005). Wolves influence elk movements: behavior shapes a trophic cascade in Yellowstone National Park. *Ecology*, **86**:1320-1330.

Gallardo, M. A., Rivero, M. J., and Faúndez, L. (2014). The grazing behavior and diet selectivity of two lamb breeds on secondary successional pastures in the Chiloé Archipelago. *Livestock Science*, **161**:69-79.

Ferretti, F., Corazza, M., Campana, I., Pietrocini, V., Brunetti, C., Scornavacca, D., and Lovari, S. (2015). Competition between wild herbivores: reintroduced red deer and Apennine chamois. *Behavioral Ecology*, aru226.

Franzmann, A. W., and Schwartz, C. C. (1997). *Ecology and management of the North American moose*. Smithsonian Institution Press.

Fitzgerald, A. E., and Waddington, D. C. (1979). Comparison of two methods of fecal analysis of herbivore diet. *Journal of Wildlife Management*, **43**(2):468-473.

Garrigus, W. P., and Rusk, H. P. (1939). *Some effects of the species and stage of maturity of plants on the forage consumption of grazing steers of various weights*. Agricultural Experiment Station Bulletin 454.

- Garrott R. A., Bruggeman, J. E., Becker, M. S., Kalinowski, S. T., and White, P. J. (2007). Evaluating prey switching in wolf-ungulate systems. *Ecological Applications*, **17**:1588–1597.
- Hansen, R. M., Foppe, T. M., Gilbert, M. B., Clark, R. C., and Reynolds, H. W. (1976). The microhistological analyses of feces as an estimator of herbivore diet. *Unpublished report available from the Department of Range Science, Colorado State University, Ft. Collins, CO, USA*.
- Harpole, W. S., and Suding, K. N. (2007). Frequency-dependence stabilizes competitive interactions among four annual plants. *Ecology Letters*, **10**:1164-1169.
- Hassell, M. P. (2000). *The spatial and temporal dynamics of host parasitoid interactions*. Oxford University Press, Oxford, UK.
- Henderson, J. J. (2012). *Microhistology of moose browse using polarized light microscopy and age and sex-determination using moose scat*. (Master's thesis, University of Nebraska at Kearney).
- Henderson, J. J. and Vucetich, J. A. (2016). Microhistology of Plant Fragments in Herbivore Diets. *The Microscope*, **64**(2):61 – 68.
- Henderson, J. J., Granger, J., and Phillips, G. J. (2013). *Microhistological atlas of Greater Yellowstone moose browse*. Castaway Press.
- Henderson, J. J., Phillips, G., and Springer, J. T. (2014). Microhistology and Plant Material Using Low-Cost Materials for Polarized Light Microscopy. *The Microscope*, **62**(3):117-121.
- Holechek, J. L. (1982). Sample preparation techniques for microhistological analysis. *Journal of Range Management Archives*, **35**(2):267-268.
- Holechek, J. L., and Gross, B D. (1982a). Training needed for quantifying simulated diets from fragmented range plants. *Journal of Range Management*, **35**:644-647.

- Holechek, J. L., and Gross, B. D. (1982b). Evaluation of different calculation procedures for microhistological analysis. *Journal of Range Management*, 721-723.
- Holechek, J. L., Gross, B., Dabo, S. M., and Stephenson, T. (1982a). Effects of sample preparation, growth stage, and observer on microhistological analysis of herbivore diets. *Journal of Wildlife Management*, **46**:502–504.
- Holechek, J. L., and Vavra, M. (1981). The effect of slide and frequency observation numbers on the precision of microhistological analysis. *Journal of Range Management*, **34**:337-338.
- Holechek, J. L., Vavra, M., and Pieper, R. D. (1982b). Botanical composition determination of range herbivore diets: A review. *Journal of Range Management*, **35**:309-315.
- Holechek, J. L., Vavra, M., Skovlin, J., and Krueger, W. C. (1982c). Cattle diets in the Blue Mountains of Oregon II. Forests. *Journal of Range Management*, 239-242.
- Holechek, J. L., Pieper, R. D., and Herbel, C. H. (1995). *Range management: principles and practices* (No. Ed. 2). Prentice-Hall.
- Howard, G. S., and Samuel, M. J. (1979). *Atlas of epidermal plant fragments ingested by grazing animals* (No. 1582). Department of Agriculture, Science and Education Administration.
- Hurst, L. A., and Beck, C. A. (1988). *Microhistological Characteristics of Selected Aquatic Plants of Florida, With Techniques for the Study of Manatee Food Habits* (No. FWS-88 (18)). Florida cooperative fish and wildlife research unit, Gainesville.
- Illius A. W., and Fitzgibbon, C. (1994). Costs of vigilance in foraging ungulates. *Animal Behavior* **47**:481–484.

- Jędrzejewski, W., Jędrzejewska, B., Okarm, H., and Ruprecht, A. L. (1992). Wolf predation and snow cover as mortality factors in the ungulate community of the Białowieża National Park, Poland. *Oecologia*, **90**:27-36.
- Jingfors, K. T. (1982). Seasonal activity budgets and movements of a reintroduced Alaska muskox herd. *Journal of Wildlife Management*, **46**:344-350.
- Johnson, M. K., Wolford, H., and Pearson, H. A. (1983). *Microhistological techniques for food habits analysis*. U. S. Department of Agriculture. Research Paper SO-1 99. 41 p.
- Jung, T. S., Stotyn, S. A., and Czetwertynski, S. M. (2015). Dietary overlap and potential competition in a dynamic ungulate community in northwestern Canada. *The Journal of Wildlife Management*, **79**(8):1277-1285.
- Kershaw, L. J., MacKinnon, A., and Pojar, J. (1998). *Plants of the Rocky Mountains*. J. Lone Pine Publishing, Edmonton, Alberta.
- Kershner, B., Mathews, D., Nelson, G., and Spellenberg, R. (2008). *Field guide to trees of North America*. National Wildlife Federation, Sterling Publishing Co., New York/London.
- Larter, N. C. (1999). Seasonal changes in arctic hare, *Lepus arcticus*, diet composition and differential digestibility. *Canadian Field-Naturalist*, **113**(3).
- Lindström, L. I., Mújica, M. B., and Bóo, R. M. (1998). A key to identify perennial grasses in central Argentina based on microhistological characteristics. *Canadian journal of botany*, **76**(8):1467-1475.
- Lundberg P., Astrom, M., and Danell, K. (1990). An experimental test of frequency-dependent food selection: winter browsing by moose. *Holarctic Ecology*, **13**:177–182.
- Madella, M., Alexandre, A. and Ball, T. (2005). International code for phytolith nomenclature 1.0. *Annals of Botany*, **96**(2):253-260.

- Manly, B. F., McDonald, L. L., Thomas, D. L., McDonald, T. L., and Erickson, W. P. (2007). *Resource selection by animals: statistical design and analysis for field studies*. Kluwer Academic Publishers, New York, New York, USA.
- Marsh, K. J., Wallis, I. R., Andrew, R. L., and Foley, W. J. (2006). The detoxification limitation hypothesis: where did it come from and where is it going? *Journal of Chemical Ecology*, **32**:1247-1266.
- Mech, L. D., Smith, D. W., Murphy, K. M., and MacNulty, D. R. (2001). Winter severity and wolf predation on a formerly wolf-free elk herd. *The Journal of Wildlife Management*, **65**:998-1003.
- Metcalf, C. R., and Chalk, L. (1979). *Anatomy of the dicotyledons: volume 1. Systematic anatomy of leaf and stem, with a brief history of the subject*. Oxford University Press.
- Moen, A. N. (1976). Energy conservation by white-tailed deer in the winter. *Ecology*, **57**:192-198.
- Moen, R., Pastor, J., and Cohen, Y. (1997). A spatially explicit model of moose foraging and energetics. *Ecology*, **78**:505-521.
- Montgomery, R. A., Vucetich, J. A., Peterson, R. O., Roloff, G. J., and Millenbah, K. F. (2012). The influence of winter severity, predation and senescence on moose habitat use. *Journal of Animal Ecology*, **82**:301-309.
- Morris, D. M. (2014). *Aquatic habitat use by North American moose (Alces alces) and associated richness and biomass of submersed and floating-leaved aquatic vegetation in north-central Minnesota* (Doctoral dissertation, Lakehead University).
- Murdoch, W. W. (1969). Switching in generalist predators: experiments on prey specificity and stability of prey populations. *Ecological Monographs*, **39**:335-354.

- Murdoch, W. W., and Oaten, A. (1975). Predation and population stability. *Advances in Ecological Research*, **9**:1-131.
- Murphree, J. J. (2012). *Evaluation of the Efficacy of DNA Sequencing and Microhistological Analysis for Determining Diet Composition in Ungulates* (Doctoral dissertation, Arizona State University).
- Parikh, G. L. (2015). *The influence of diet composition, plant defense chemicals, and winter severity on the nutritional condition of a free ranging, generalist herbivore*. (Master's Thesis, Michigan Technological University).
- Parikh G. L., Forbey, J. S., Robb, B., Peterson, R. O., Vucetich, L. M., and Vucetich, J. A. (2016). The influence of plant defensive chemicals, diet composition, and winter severity on the nutritional condition of a free-ranging, generalist herbivore. *Oikos*, doi:10.1111/oik.03359.
- Parker, K. L., Robbins, C. T., and Hanley, T. A. (1984). Energy expenditures for locomotion by mule deer and elk. *Journal of Wildlife Management*, **48**:474-488.
- Peterson, R. O. (1995). *The wolves of Isle Royale: a broken balance*. University of Michigan Press.
- Pierce, B. M., Bowyer, R. T., and Bleich, V. C. (2004). Habitat selection by mule deer: forage benefits or risk of predation? *Journal of Wildlife Management*, **68**:533-541.
- Prabhakar, M. (2004). Structure, delimitation, nomenclature and classification of stomata. *ACTA Botanica Sinica-English Edition*, **46**(2):242-252.
- Pyke, G. H., Pulliam, H. R., and Charnov, E. L. (1977). Optimal foraging: a selective review of theory and tests. *The quarterly review of biology*, **52**(2):137-154.
- R Core Team. (2014). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria. URL <http://www.R-project.org/>.

Ralph, C. P., Nagata, S. E., and Ralph, C. J. (1985). Analysis of droppings to describe diets of small birds. *Journal of Field Ornithology*, 165-174.

Renecker L. A. and Schwartz, C. C. (1997). Food habits and feeding behavior. Pages 441-478 in Franzmann, A. W., and C. C. Schwartz, editors. *Ecology and management of the North American moose*. Smithsonian Institution Press, Washington DC, USA.

Rentflesh, J. A., and Hansen, H. H. (2000). Microhistology in the ENRECA Project. In *Proceedings of the Integrated Livestock-Crop Production Systems in the Smallholder Farming Systems in Zimbabwe Workshop*. Harare, Zimbabwe (Vol. 10, No. 13, pp. 201-206).

Rice, R. W. (1970). *Stomach content analysis: a comparison of the rumen vs. esophageal techniques*. International Range and Wildlife Management-Habitat Evolution-A Research Symposium. U.S. Department of Agriculture, Forest Service Miscellaneous Publication No. 1147. 220 p.

Ripple, W. J., and Beschta, R. L. (2003). Wolf reintroduction, predation risk, and cottonwood recovery in Yellowstone National Park. *Forest Ecology and Management*, **184**:299-313.

Risenhoover, K. L. (1987). *Winter foraging strategies of moose in subarctic and boreal forest habitats*. PhD Dissertation. Michigan Technological University, Houghton, Michigan, USA.

Renecker L. A. and Schwartz, C. C. (1997). *Food habits and feeding behavior*. Pages 441-478 in Franzmann, A. W., and C. C. Schwartz, editors. *Ecology and management of the North American moose*. Smithsonian Institution Press, Washington DC, USA.

- Ripple, W. J., and Beschta, R. L. (2003). Wolf reintroduction, predation risk, and cottonwood recovery in Yellowstone National Park. *Forest Ecology and Management*, **184**:299-313.
- Robbins, C. T., Spalinger, D. E., and van Hoven, W. (1995). Adaptation of ruminants to browse and grass diets: are anatomical-based browser-grazer interpretations. *Oecologia*, *103*(2), 208-213.
- Robinson, B. G., and Merrill, E. H. (2012). The influence of snow on the functional response of grazing ungulates. *Oikos*, **121**:28-34.
- Samuel, M. J., and Howard, G. S. (1983). Disappearing forbs in microhistological analysis of diets. *Journal of Range Manage*, **36**:132-133.
- Sanders, S., and Grochowski, J. (2011). *Implementation of a long-term vegetation monitoring program at Isle Royale National Park*. NPS/GLKN/NRTR 2011/387. U.S. Department of the Interior, National Park Service, Fort Collins, Colorado, USA.
- Shipley, L. A. (2007). The influence of bite size on foraging at larger spatial and temporal scales by mammalian herbivores. *Oikos*, **116**:1964-1974.
- Shipley, L. (2010). Fifty years of food and foraging in moose: lessons in ecology from a model herbivore. *Alces: A Journal Devoted to the Biology and Management of Moose*, **46**:1-13.
- Shipley, L. A., Blomquist, S., and Danell, K. (1998). Diet choices made by free-ranging moose in northern Sweden in relation to plant distribution, chemistry, and morphology. *Canadian Journal of Zoology*, **76**(9):1722-1733.
- Skarpe, C., and Hester, A. J. (2008). Plant traits, browsing and grazing herbivores, and vegetation dynamics. In *The ecology of browsing and grazing* (pp. 217-261). Springer Berlin Heidelberg.

Sparks, D. R., and Malechek, J. C. (1968). Estimating percentage dry weight in diets using a microscopic technique. *Journal of Range Management Archives*, **21**(4):264-265.

Springer, J. T., and Smith, J. S. (1981). Summer food habits of coyotes in Central Wyoming. *Western North American Naturalist*, **41**(4):449-456.

Teerink, B. J. (2003). *Hair of West European mammals: atlas and identification key*. Cambridge University Press. Theurer, C. B. (1970). Determination of botanical and chemical composition of the grazing animals diet. In: Proc. National Conference of Forage Quality Evaluation and Utilization. Nebraska Center for Continuing Education, Lincoln. J1-J17 p.

Toweill, D. E., and Thomas, J. W. (Eds.). (2002). *North American elk: ecology and management*. Smithsonian Institution Press.

Tversky, A., and Simonson, I. (1993). Context-dependent preferences. *Management Science*, **39**:1179-1189.

USDA, NRCS. (2018). The PLANTS Database (<http://plants.usda.gov>, 2 January 2018). National Plant Data Team, Greensboro, NC 27401-4901 USA.

Van Dyne, G. M., and Torell, D. T. (1964). Development and use of the esophageal fistula. *Journal of Range Management*, **17**:7-19.

Vavra, M., and Holechek, J. L. (1980). Factors influencing microhistological analysis of herbivore diets. *Journal of Range Management*, **33**:371-374.

Verdolin, J. L. (2006). Meta-analysis of foraging and predation risk trade-offs in terrestrial systems. *Behavioral Ecology and Sociobiology*, **60**:457-464.

Vucetich, J. A., Peterson, R. O., and Schaefer, C. L. (2002). The effect of prey and predator densities on wolf predation. *Ecology*, **83**(11):3003-3013.

Vucetich, J. A., and Peterson, R. O. (2004). The influence of prey consumption and demographic stochasticity on population growth rate of Isle Royale wolves *Canis lupus*. *Oikos*, **107**(2), 309-320.

Vucetich, J. A., and Peterson, R. O. (2004). The influence of prey consumption and demographic stochasticity on population growth rate of Isle Royale wolves *Canis lupus*. *Oikos*, **107**:309-320.

Vucetich, J. A., Hebblewhite, M., Smith, D. W., and Peterson, R. O. (2011). Predicting prey population dynamics from kill rate, predation rate and predator–prey ratios in three wolf-ungulate systems. *Journal of Animal Ecology*, **80**:1236-1245.

Vucetich, J. A., and Peterson, R. O. (2014). *Ecological studies of wolves on Isle Royale: Annual report 2010–11*. School of Forest Resources and Environmental Science, Michigan Technological University, Houghton, Michigan, USA.

Wertham, F. (1933). Are the histological lesions of dementia paralytica specific? *American Journal of Psychiatry*, **89**(4):811-821.

Wirsing, A. J., Heithaus, M. R., and Dill, L. M. (2007). Living on the edge: dugongs prefer to forage in microhabitats that allow escape from rather than avoidance of predators. *Animal Behaviour*, **74**:93-101.

Zuur, A. E., Ieno, N., Walker, N., Saveliev, A. A., and Smith, G. M. (2009). *Mixed effects models and extensions in ecology with R*. Springer, New York, New York, USA.

6 Permissions, permits and related documents.

<p align="center">SCIENTIFIC RESEARCH AND COLLECTING PERMIT</p> <p align="center">Grants permission in accordance with the attached general and special conditions</p> <p align="center">United States Department of the Interior National Park Service Grand Teton</p>	<p>Study#: GRTE-00437</p> <p>Permit#: GRTE-2017-SCI-0078</p> <p>Start Date: Aug 15, 2017</p> <p>Expiration Date: Dec 31, 2017</p> <p>Coop Agreement#:</p> <p>Optional Park Code:</p>
--	--

Name of principal investigator:	Name: Mr John henderson	Phone: 3076903313	Email: moosehenderson@yahoo.com
Name of institution represented: Michigan Technological University			
Co-Investigators:			
	Name: Andrew Storer	Phone: 906-487-3470	Email: storer@mtu.edu
Study Title: Microhistology of Elk Forage in the Greater Yellowstone Ecosystem			
Purpose of study: Collection of elk forage, analysis of plant material under microscope and publication of an microhistological atlas to aid researchers studying elk diet using fecal pellets.			
Subject/Discipline: Mammals Vascular Plants			
Locations authorized: Samples will be collected in areas next to public roads, established trails, and other public access areas.			
Transportation method to research site(s): Personal vehicle and foot travel.			
Collection of the following specimens or materials, quantities, and any limitations on collecting:			
Name of repository for specimens or sample materials if applicable: Repository type: Will be destroyed through analysis or discarded after analysis Objects collected: We will collect approximately 150 specimens of elk forage including stems with leaves of woody plants, a single wildflower or forb, or a single specimen of grass with inflorescence.			
Specific conditions or restrictions (also see attached conditions): We appreciate your interest in advancing science in Grand Teton National Park and/or the John D. Rockefeller, Jr. Memorial Parkway. THIS PERMIT SERVES AS YOUR GATE PASS THROUGH 12/31/2017. You are required to carry your Research Permit with you at all times; it serves as a gate pass for the duration of your fieldwork. Please make copies of this document for each co-investigator and field assistant and have them carry a copy of your Research Permit with them at all times in the park. By signing this permit, you agree that you are responsible for the research-related activities of your staff. Please ensure that field staff adhere to all conditions of your permit. Field staff must possess a copy of your permit at all times while in the field. Your research permit does not authorize you to enter closed or restricted areas (service roads, wildlife closure areas, carcass dumps sites, bear management areas, wolf den sites, fish spawning areas, bird nesting areas, etc.) unless otherwise specified within this permit. Report all emergencies by calling 911.			

Recommended by park staff (name and title):

wildlife biologist

Reviewed by Collections Manager:

Yes ☒ No ☐

Approved by park official:

Date Approved:

8/14/17

Title:

Chief of Science and Resource Mgmt

Conditions And Restrictions Of this Permit As Specified
(less signed and dated by the principal investigator)

(Principal investigator's signature)

(Date)

THIS PERMIT AND ATTACHED CONDITIONS AND RESTRICTIONS MUST BE CARRIED AT ALL TIMES WHILE
CONDUCTING RESEARCH ACTIVITIES IN THE DESIGNATED PARK(S)

Michigan Tech

Moose Henderson <jjhender@mtu.edu>

permission to include journal article as part of dissertation

2 messages

Moose Henderson <jjhender@mtu.edu>
To: themicroscope@mcri.org

Mon, Jan 8, 2018 at 2:13 PM

Dear Managing Editor of The Microscope Journal;

May I have permission to reproduce, as part of my PhD dissertation, the article submitted and published in The Microscope Journal, volume 64(2), pp 61-68 titled "Microhistology of Plant Fragments in Herbivore Diets". I was the primary author. Responding to this email will be sufficient and thank you in advance.

Moose (aka: john j. henderson)
PhD Candidate: Moose Ecology
Michigan Technological University
Houghton, Michigan, USA

Dean Golemis <dgolemis@mcri.org>
To: Moose Henderson <jjhender@mtu.edu>

Mon, Jan 8, 2018 at 4:19 PM

Hi Moose,

Happy New Year!

This email is acknowledgement of permission granted to use *The Microscope* article for the intended use as stated. If it's applicable, please include a reference to the article in your dissertation.

Best wishes,
dean.

Dean Golemis
Managing Editor, Microscope Publications
McCrone Research Institute www.mcri.org
2820 S. Michigan Avenue, Chicago IL 60616-3230
Tel. (312) 842-7100 Fax (312) 842-1078
dgolemis@mcri.org

Subscribe to *The Microscope* journal -- new low price for first-time individual subscribers, \$38.50! >>www.mcri.org

From: Moose Henderson <jjhender@mtu.edu>
Date: Monday, January 8, 2018 at 1:13 PM
To: <themicroscope@mcri.org>
Subject: permission to include journal article as part of dissertation
[Quoted text hidden]

Joanna Rogers
Pelkie, Michigan

January 1, 2016

I was commissioned by John J. Henderson to produce drawings of trichomes, stomata and other cellular components. Permission is granted to John J. Henderson to use these drawings in journals, dissertations or other documents provided attribution is given.

Sincerely;

Joanna Rogers