COMPARATIVE ANATOMY WITHIN THE
GENUS CELASTRUS

by

Helen Sumpter, A. B., 1926
University of Kansas.

Submitted to the Department
of Botany and the Graduate School
of the University of Kansas in
partial fulfillment of the require-
ments for the Degree of Master of
Arts.

Approved:

May, 1926.

Chairman of the Dept of Botany.
ACKNOWLEDGMENT

The writer wishes to express her appreciation to Professor W. C. Stevens, Chairman of the Department of Botany, for his many thoughtful suggestions and for his kind encouragement.
<table>
<thead>
<tr>
<th>TABLE OF CONTENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
</tr>
<tr>
<td>Literature</td>
</tr>
<tr>
<td>Methods</td>
</tr>
<tr>
<td>Discussion</td>
</tr>
<tr>
<td><strong>Leaf</strong></td>
</tr>
<tr>
<td>Description</td>
</tr>
<tr>
<td>Surface View</td>
</tr>
<tr>
<td>Epidermis</td>
</tr>
<tr>
<td>Stomata</td>
</tr>
<tr>
<td><strong>Venation</strong></td>
</tr>
<tr>
<td><strong>Cross Section</strong></td>
</tr>
<tr>
<td>Stomata</td>
</tr>
<tr>
<td>Upper epidermis</td>
</tr>
<tr>
<td>Hypoderm</td>
</tr>
<tr>
<td>Palisade parenchyma</td>
</tr>
<tr>
<td>Veins</td>
</tr>
<tr>
<td>Spongy parenchyma</td>
</tr>
<tr>
<td>Lower epidermis</td>
</tr>
<tr>
<td>Midrib</td>
</tr>
<tr>
<td>Margin</td>
</tr>
<tr>
<td>Petiole</td>
</tr>
<tr>
<td><strong>Stem</strong></td>
</tr>
<tr>
<td>Cross Section</td>
</tr>
<tr>
<td>Section</td>
</tr>
<tr>
<td>---------------------------------</td>
</tr>
<tr>
<td>One-year-old internode</td>
</tr>
<tr>
<td>Two-year-old internode</td>
</tr>
<tr>
<td>Longitudinal Section</td>
</tr>
<tr>
<td>Pith</td>
</tr>
<tr>
<td>Medullary rays</td>
</tr>
<tr>
<td>Macerations</td>
</tr>
<tr>
<td>Keys</td>
</tr>
<tr>
<td>Root</td>
</tr>
<tr>
<td>Conclusion</td>
</tr>
<tr>
<td>Bibliography</td>
</tr>
</tbody>
</table>
INTRODUCTION

We learn from Engler and Prantl ('97) that the Celastraceae are found in all vegetative regions of the earth outside of the Arctic zones. In the Cretaceous, the family was represented in Europe and North America and during the Tertiary it extended into Alaska, Greenland, Spitzbergen, and possibly into Australia and Java. The fossils of leaves would indicate that Euonymus and Celastrus were among the genera represented at that time. Now there are about 33 genera with 375 species, either shrubs, small trees, or vines, widely distributed over the earth, excepting in the Arctic regions.

The genus Celastrus L. or staff-tree is made up of more than thirty species of deciduous, rarely evergreen shrubs, usually twining. They are principally native to the mountains of East India and China, less often to Japan, the Sunday Islands, the Philippines, to Kaiser Wilhelmsland, and Australia, with one species each in the Figi Islands, in North America and perhaps also in Colombia, South America.

The leaves of the plants of this genus are alternate, petioled, and serrate or crenate. The buds have several
imbricate scales, and the flowers are polygamo-dioecious, small, greenish or whitish, five merous, and in axillary cymes or terminal panicles. The ovary is superior and the fruit is a capsule, usually yellow, dehiscent into three valves, each containing one to two seeds, enclosed in a fleshy crimson aril. These shrubs are ornamental and are grown chiefly for their handsome yellow fruit, opening at maturity and disclosing a crimson center.
Some work has been done on the anatomy of the genus Celastrus, mostly before 1900 and is summarized by Solereder ('08) in his book on the anatomy of dicotyledons. He discusses the leaf and its axis, and the cork, and other regions of the bark as well as the wood and pith of the stem.

The detailed descriptions of the genus and the species were obtained from Rehder ('27).

Wehmer ('11) discusses the cell products throughout the family Celastraceae.

Gerhard ('02) studied the leaf of Celastrus and tells of the presence of caoutchouc in acuminatus in such large quantities that in breaking the leaf across, the fragments cling together because of the tough elastic threads. Gerhard found a concentric bundle in the midrib of acuminatus.

H. Schenk ('93) describes very briefly in the wood of the sharp demarkation of the annular rings and the wide tracheal tubes of the spring growth of scandens.

In an undetermined species of Celastrus from Nilgherries an external grooving in the stems occur, according to Jussieu ('43).
Moller ('76) studied the bark. He described the periderm, which is developed from the outermost layer of the cortex, and the bast fibers which are cracked or broken. He also speaks of the sieve tubes as having extremely broad cavities and end walls beset with large perforations. The medullary rays, he found to be one to six rows wide.

According to Plitt ('86) the open bundle form is found in the vascular bundle of the petiole of scandens but this feature does not hold throughout the family. Pierre ('92) also studied the vascular bundle in the petiole and found it to consist of a single strand.

Metz ('08) investigated the structure and cell products of the leaves of the Celastraceae, but his work consisted principally of a summary of the results obtained by Stenzel and Solereder.

Stenzel ('93) did more extensive investigating in the genus Celastrus than any of the authors mentioned above. I will give a brief summary of his work. In the leaf the epidermal cells are broader than high and the outer walls of the upper epidermal cells was thicker than the outer wall of the lower. The side walls of the upper epidermal cells were sometimes wavy, thus giving strength to the leaf. A hypoderm was found in disperma and papnana and Stenzel believed it to have systematic value. The stomata he found to be of the usual type, varying in form from circular to
long-elliptical. The leaves usually have two rows of palisade cells and about an equal amount of spongy parenchyma. However, this proportion varied too much with the amount of illumination under which the leaf developed to be of value in classification.

The vascular system in the petiole and blade was of two types, open and closed, but both were connected by intermediate stages. This as well as the occurrence of simple and compound crystals was considered sufficiently distinctive to be of taxonomic value. In the stem, Stenzel found that the cork began to form very early from the first cell layer, under the epidermis. The cork cells were all thin walled, except the inner edge of the outer cell row.

The sclerenchyma fibers were in bundles or in a ring in a line separating the outer bark from the phloem. Scandens had peculiarly folded bast fibers in the primary bark.

The wood consisted of tracheal tubes, wood parenchyma, wood fibers and tracheids, in all of which transition forms occur making identification doubtful. Prosenchyma was found to be the greater part of the wood mass. Little wood parenchyma was present. The pith was homogenous, that is, made up of living cells only. The medullary rays were quite various in breadth.

The purpose of my study was to determine the anatomical situation in the genus and to discover on what
different sets of characters the species can be distinguished anatomically; to discover what sets of characters have been more stable and so not recognizable specific features; and to see what effect geographical distribution has seemed to make upon these features.
METHODS

All of the species of Celastrus which I obtained in this country, that is, scandens from Lawrence, Kansas; orbiculatus from Gage Park, Topeka, Kansas; flagellaris, hypolencus, rugosus, augulatus, and Loeseneri from "The Arnold Arboretum" in Boston Massachusetts; and paniculatus from the Missouri Botanical Gardens at St. Louis, Missouri, were fresh when they arrived, and the sections of leaf and stem could easily be cut when mounted on the microtome between elder pith and cork. The rest of the species which I investigated were sent from the Royal Botanic Gardens at Kew, England, and when they arrived in Lawrence the leaves were browned and the tissues somewhat distorted. It was necessary to soak them in water until softened and mount them on blocks of wood in the following manner. The air was pumped from the material while submerged in acetone and allowed to stand for an hour. It was then transferred to a five per cent solution of cellulose-acetate in acetone and allowed to stand for another hour. The blocks of pine wood on which the specimens were to be mounted were put through the same process and the sections were mounted by dropping five percent cellulose-acetate over them very slowly and allowing it to become quite firm before transferring to a solution of two-thirds alcohol to one-third glycerine. Here they stood until it was convenient to cut them.
In cutting longitudinal sections of stems it was found to be very satisfactory to use the above method in fixing the stem to a wooden block -- much more satisfactory than enclosures in paraffin.

Instead of using an ordinary microtome knife for cutting sections a Gillette razor blade was paraffined to the microtome blade so that just the bevel of the razor blade extended over the other. This could be removed and sharpened very quickly.

Chloral hydrate in saturated solution was used as a clearing agent, both for individual sections and entire leaves. Hydrogen-peroxide was also used to clear the leaves of the species which came from England.

Many of the sections were mounted in glycerine jelly. This was found to be much better than glycerine as the slide could be photographed, than kept indefinitely for further study without danger of a smeared cover glass or a torn section.

Macerations were made with chromic acid. The photomicrographs illustrating this thesis are negative prints obtained by projecting the image by means of a microscope directly upon photomicrographic paper (Rito Hard), contained in the ordinary dry plate holder. The time of exposure varied with the kind of light used. For the first pictures taken an Edison Pointolite Lamp was used and from three to five minutes exposure was required. For the later pictures a carbon arc light, fed by clockwork, was used and only about twenty
to thirty seconds were required.

The photographs of drawings are negative prints made with a large camera and "Enlarging Mat Cyko" Paper, manufactured by the Ansco Company, Binghamton, New York.
DISCUSSION

The Leaf

Description.

The nature leaves of the species of Celastrus which I studied vary in length from 36 mm. in rosthornianus (Fig.115) to 144 mm. in angulatus (Fig. 102). For the average length of leaf in each species see row 7 in Table II, page 28. Most of the species have acute leaf tips. Flagellaris (Fig. 108) has an obtuse tip and orbiculatus (Fig. 111) usually has an acute tip but occasionally the tip may be obtuse. The tips of Loeseneri (Fig. 110), speciformis (Fig.114) and rosthornianus (Fig.115) are less sharply acute than the other species. Scandens (Fig. 103) shows how the leaf tapers toward the petiole, typically. Angulatus (Fig. 102) flagellaris (Fig.108) and paniculatus (Fig. 112) are broader at the base of the leaf. The leaves of all the species studied have rather fine serrations.

Below are detailed descriptions of the leaves of each species. The first eleven are taken from Rehder ('27) and the last two, which are not listed in Rehder (l.c.) I have described from my own observations.

C. scandens (Fig. 103)--Leaves ovate to oblong ovate, acuminate, broadcuneate at the base, serrulate, glabrous. Canada to South Dakota and New Mexico. Introduced 1736.
C. paniculatus -- Leaves broad elliptic or obovate to elliptic-oblong. Himalayas.

C. angulatus -- Leaves broad-ovate to nearly orbicular abruptly short acuminate, crenate-serrate, glabrous. Remarkable for its large leaves. Introduced in 1900 from China.

C. hypoleucus -- Leaves elliptic, to oblong-elliptic, short acuminate, remotely serrulate, dark green above, bluish white beneath. Introduced from Central China in 1900.

C. speciformis -- Leaves elliptic-oblong to elliptic-lanceolate, crenate-serrulate, slightly glancescent beneath. Introduced in 1908 from West China.

C. rugosus -- Leaves elliptic-ovate or elliptic, to elliptic-oblong, short acuminate, broad cuneate or rounded at the base. Crenate-serrate to crenate-dentate, rugose above, reticulate at maturity beneath, glabrous or puberulous on the veins. Introduced from West China in 1908.

C. orbiculatus -- Leaves suborbicular to obovate, or oblong-oboovate, acute or abruptly acuminate, crenate or crenate-serrate. Introduced in 1880 from Japan-China.

C. Loeseneri -- Leaves broadly elliptic to lance-elliptic, acuminate, rounded or broad cuneate, coarsely crenate-serrate. Introduced in 1907 from central China.
C. rosthornianus -- Leaves narrow-elliptic to elliptic-oblung, broad-acuminate, cuneate, remotely serrate, or serrulate, at maturity thickish, smooth above with obsolete veinlets beneath, yellowish green. Introduced in 1908 from central and west China.

C. Hookeri -- Leaves elliptic or obovate to elliptic-oblung, on shoots longer, oblong, long-acuminate, crenate-serrulate. Introduced in 1908 from south China and the Himalayas.

C. flagellaris,-- Leaves broad-elliptic or ovate, abruptly acuminate, broad-cuneate, finely serrulate.

C. flavo-copryll -- Leaves long elliptic to elliptic oblong. Crenate serrate to crenate dentate -- Leaves leathery-acuminate.

C. reticulatus -- Leaves oblong elliptic to ovate; finely serrate-acuminate.

**Surface View.**

Upper epidermis.

The species could be divided roughly into two classes according to the nature of the side walls of the cells of the upper epidermis. In paniculatus (Fig. 81), orbiculatus (Fig. 83), and scandens (Fig. 84) the side walls are decidedly undulating. In the rest of the species the walls undulate little or not at all.

There was quite a good deal of difference in the sizes of the upper epidermal cells as seen from the surface. Instead of measuring the width of these cells I counted
the number in one square mm. Paniculatus had the fewest with 800 cells and speciformis the most with 2500. (See table II column 9, page 28.)

Lower Epidermis.

The species might also be divided into two groups according to the nature of the side walls of the cells of the lower epidermis. In paniculatus (Fig. 81), speciformis, orbiculatus (Fig. 83), and scandens (Fig. 84) the walls are very sinuous. The rest while not exactly straight are more nearly so.

These lower epidermal cells also vary in size. The measurements here are made just of epidermal cells and not of the guard cells as actual widths were taken, instead of counting the number of cells in a given area. In flagellaris (Fig. 77), the cells are .012 mm. in breadth and in loeseneri (Fig. 76) glaucophyll (Fig. 72) and paniculatus (Fig. 81), .025 mm. in breadth. The other species studied ranged from these two extremes in size (see table II, page 28, column 10.)

Comparison of Upper and Lower Epidermises from Surface View.

The upper and lower epidermal cells of glaucophyll (Fig. 72) averaged .025 mm. in diameter. In loeseneri (Fig. 76) and speciformis (Fig. 82) the lower epidermal cells are slightly larger than the upper and in the other
species studied, the upper epidermal cells averaged from 0.002 m m. to 0.015 m m. more in diameter than did the cells of the lower epidermis. (See table II, page 28 column 10.)

Stomata.

The stomata occur only on the lower side of the leaf. From surface view they are broadly oval in shape, varying slightly within the species. It was noted that from both the surface view and the cross section that in most species the bordering epidermal cells subtend the guard cells. In reticulatus (Fig. 79), orbiculatus (Fig. 83), and scandens (Fig. 84) the guard cells are subtended very little and in flagellaris (Fig. 77) only slightly more.

The stomata vary in size throughout the genus and within each species. The longest stomata found were in Eoseneri (Fig. 76), being 0.035 m m. and the shortest in flagellaris (Fig. 77) which were 0.016 m m. long. The variation in size of stomata throughout the genus is hardly constant enough to allow it to be used in classification.

In seven species the ordinary epidermal cells reach clear to the guard cells, but in the following, subsidiary cells more or less surround and subtend the
guard cells: flagellaris (Fig. 77), reticulatus (Fig. 79), rosthornianus (Fig. 80), speciformis (Fig. 82), scandens (Fig. 84), rugosus (Fig. 74), hypoleucus (Fig. 83), and angulatus (Fig. 78). In the last three the subsidiary cells do not occur constantly.

The frequency of the stamata in each species will be found in the table, column 11, page 21. Scandens has the fewest with 145 per square millimeter, and orbiculatus, which is very similar to scandens in many ways, is next with 160. Hookeri has the most with 420 per square millimeter.

Venation.

In the following species the tips of the leaves are rather broad: flagellaris (Fig. 98), angulatus (Fig. 121), speciformis (Fig. 123), orbiculatus (Fig. 99), and Hookeri (Fig. 122).

In the rest the tip is more pointed and tapering for some distance back from the tip.

In Angulatus (Fig. 121), speciformis (Fig. 123), flagellaris (Fig. 98), and orbiculatus (Fig. 99) the tip is indented.

In the first column of the table below are given the number of veins of the first order arising from the midrib at distance of 5.7 mm from the tip. In the second column is listed the frequency of the meshes at
4 millimeters from the tip and in an area of four square mm.

It will be seen from the chart that the minimum number of veins of the 1st order given off in 5.7 mm was in rugosus (Fig. 117) in which only four were found to leave the midrib in that distance. In rosthornianus (Fig. 120) twenty four veins left the midrib in 5.7 mm. This was the maximum. The rest ranged between four and twenty four.

The frequency of meshes also varied considerably. The counts were taken over four square millimeters of each leaf. Rugosus (Fig. 117) had the minimum with eleven, and flagellaris (Fig. 98) the maximum with seventy six. There could be no line drawn dividing the species into groups according to the number of meshes.

Certain species had two subsidiary, more or less marginal, ribs on either side of the midrib not far from the tip. In the following species these strong marginal ribs incurved to meet the midrib close to the apex of the leaf: scandens (Fig. 113), Hookeri (Fig. 122), and speciformis (Fig. 123). In the leaves of hypoleucus (Fig. 116), paniculatus (Fig. 118), glaucophyll (Fig. 119), flagellaris (Fig. 98), reticulatus (Fig. 100), and Loeseneri (Fig. 101) there are two marginal ribs, but they join branches of the midrib rather than the mid-
rib itself.

In the leaves of rosthornianus (Fig. 120), orbiculatus (Fig. 99), rugosus (Fig. 117), and angulatus (Fig. 121), there are only vague suggestions of marginal ribs.

The usual width of the midrib at about 5.7 mm. from the tip is from .11 mm. to .14 mm. However, in speciformis (Fig. 123) it is .17 mm. thick, in glaucophyll (Fig. 119) .2 mm. and in Ioeseneri (Fig. 101) it is .25 mm. thick. In these species there are only from 14 to 20 meshes in four square mm. These are not the largest meshes found, but are much larger than the average (about 30 per square mm.).

Cross Section

Stomata.

From a cross section it will be seen that in all cases the subsidiary cells subtend the guard cells more or less. In scandens (Fig. 97) the epidermal cells sub tend the guard cells almost not at all, while in orbiculatus (Fig. 89) and reticulatus (Fig. 96) about one half of the guard cell is subtended. In flagellaris (Fig. 90) about three fourths of the guard cell is subtended, and in all of the rest of the species the guard
cells are completely subtended by the subsidiary cells.

In seven species the cells bordering the guard cells are ordinary epidermal cells but in the following species smaller cells are found to surround the guard cells: flagellaris (Fig. 90), reticulatus (Fig. 96), rosthornianus (Fig. 85), speciformis (Fig. 94), scandens (Fig. 97), rugosus (Fig. 86), hypoleucus (Fig. 91), and angulatus (Fig. 92). This list is found to agree with the observations made from the surface view.

In hypoleucus (Fig. 91) and speciformis (Fig. 94) these subsidiary cells are very small and are entirely covered by the guard cells.

Most of the guard cells project very little above the level of the epidermal cells. In fact, in nine species they project not more than a very little. However, in paniculatus (Fig. 85) and glaucophyll (Fig. 86) they extend above the epidermal cells about one half of their depth. In angulatus (Fig. 92) and Hookeri (Fig. 93) they extend entirely above the epidermis level.

Prominent hornlets project from the cuticle of the guard cells.

Epidermal Cells.

There are very few differences in the upper epidermal cells of the species which I studied. They average about .017 m m. in height by .028 m m. in breadth. Metz
(l. c.) found those in scandens to be .017 mm. in height by .053 mm. in breadth. Stenzel (l.c.) found the cells of paniculatus to be four times as broad as high. I found occasional cells to have this relative size but the average size was less than twice broader than high. For a typical example of the epidermis see Loeseneri (Fig. 146).

The epidermal cells throughout all the species studied are broader than high with the upper walls slightly convex, and the side walls straight. The upper wall is always cutinized. In Loeseneri about the lower one-half of the outer wall of the upper epidermis is cellulose and in rugosus there is an extremely thin layer of cellulose under the cutinized portion. In all of the other species the entire upper wall is cutinized.

Stenzel (l. c.) found in paniculatus that beneath the cuticle of the outer wall is a cellulose layer which usually fills half the cavity. This was not present in the paniculatus which I studied.

In the epidermal cells of glaucophyll and Hookeri even the side walls were cutinized about one half of their depth. In angulatus, speciformis, and Hookeri the cutinized outer wall of the epidermis was slightly thicker than in the other species, and in all species the cutinized upper epidermis was thicker than the lower.
The outer wall of the epidermis above the lateral veins of the first order has a layer of cellulose beneath a cutinized portion, but between the veins the outer wall is cutinized throughout.

Hairs are entirely lacking throughout the genus.

**Hypoderm.**

Hypoderm of two kinds occurs in the leaf. In all of the species here studied a thick hypoderm occurs inside both the upper and lower epidermis in the petiole, midrib, and first lateral veins. The measurements for the depth of this tissue (in a lateral vein of the first order cut near the midrib) will be found in table I, columns 4 and 5, page 27.

As will be seen from this table, there is in all cases, except rosthornianus, more thick walled hypoderm on the under side of the veins than the upper. However, in some cases this hypoderm beneath the upper epidermis extends out beyond the veins. In reticulatus (Fig. 140) it is extended out for .06 m m. and in rugosus for .2 m m. (Fig. 150). Thin walled hypoderm was found occasionally between the veins in Hookeri (Fig. 142), and glaucophyll (Fig. 65 and Fig. 145). Hypoderm of this sort was found almost continuously under the upper and thinner walled epidermis of speciformis (Fig. 64) and was from one to five cells in depth. These hypodermal cells
are larger than the upper epidermal cells, and are evidently for water storage.

Palisade Cells - Cross Section:

The palisade cells vary in height a great deal between the different species, as may be seen in the accompanying chart. Those in flagellaris (Fig. 151) were the shortest, being .02 m m. high and in rosthornianus the highest, being .1 m m. high. A good section of rosthornianus could not be obtained because of the shrunken material, but the figure 140 of reticulatus illustrates the situation in rosthornianus very well. In each species a second row of palisade tissue subtended the first, except in speciformis where the hypoderm was very wide.

There was some little variation in the breadth of the cells but there seemed to be no constant relationship between height and breadth.

Veins:

Lateral veins of the first order from near the center of the leaf were studied in cross section. In every species except angulatus the phloem was found on the under side of the xylem and extending towards the upper side from two thirds to three fourths of the way. In angulatus the phloem entirely surrounded the xylem. The veins varied in height and breadth in about the same degree as the midribs, (see column 6, table II, page 21)
and the discussion of the sizes and shapes of midribs on page 2.

In glaucophyll a sclerenchyma sheath of bast fibers follows the line of the phloem on the lower side. In speciformis there was a little sclerenchyma tissue below the phloem, and above the Xylen on the upper side. In rosthornianus, lignified collenchyma occurs outside the phloem.

**Spongy Parenchyma.**

The spongy parenchyma varies considerably in the different species. In flagellaris and rosthornianus the spongy parenchyma cells are not in regular rows throughout the leaves. In speciformis there are from six to eight rows of cells with the upper two rows irregular. In angulatus there are only five rows of spongy parenchyma and in all of the rest of the species six or seven rows are present.

In hypoleucus, Hookeri, paniculatus, and orbiculatus (Fig. 148) the spongy parenchyma cells are much broader than high. In Loeseneri (Fig. 146) the cells are more nearly round.

**Lower Epidermal Cells.**

The cells of the lower epidermis were found to be lower and narrower than those of the upper, (see Fig. 140) averaging about .021 m m. in breadth by .014 m m.
in height. The cells are very like the upper epidermal cells in shape.

In the following species the outer wall was all cutinized: flagellaris, glaucophyll, Hookeri, angulatus, hypoleucus, and reticulatus. In rosthornianus, orbiculatus, paniculatus, and speciformis, the outer wall was all cutinized between the veins but beneath the lateral veins of the first order there was a thin layer of cellulose under the cutinized portion. In Loeseneri and rugosus there was a thin layer of cellulose present under the entire cutinized portion.

The outer wall of the lower epidermis was somewhat thinner in all thirteen species than the outer wall of the upper.

Midrib:

In all cases both the upper and lower surfaces of the midrib projected more or less prominently beyond the general level of the leaf. (Figs. 140-152). In hypoleucus (Fig. 141), scandens (Fig. 143) and angulatus (Fig. 144) the upper and lower surfaces of the midrib are regular. In Hookeri (Fig. 142) certain epidermal cells are elongated and look a little like hairs. In reticulatus (Fig. 146) a small ridge is found on the lower side of the midrib. In Loeseneri (Fig. 146), rosthorn-
ianus (Fig. 147) and paniculatus (Fig. 149) there is a
definite ridge on the lower side with numerous irregu-
larities along the margins. In the midrib of glauc-
ophyll (Fig. 145) and orbiculatus (Fig. 148) three ridges
are present on the lower side and in the midrib rugosus
(Fig. 150) and flagellaris (Fig. 151) five ridges are
present. In the two latter species and in Loeseneri
(Fig. 146) epidermal cells are elongated on the lower
side until they are inceipient hairs. Speciformis (Fig.
152) with an unusually large midrib, has one large
ridge on the lower side and many irregularities that
amount almost to ridges.

It may be noted that the vascular bundles are lunate,
with more or less infolded edges. In reticulatus (Fig.
140), hypoleucus (Fig. 141), Hookeri (Fig. 142), and
Loeseneri (Fig. 146) the vascular bundles are not incurved
at the edges. In scandens (Fig. 143), angulatus (Fig.
144), and orbiculatus (Fig. 148) the ends are slightly
incurved. In glaucophyll (Fig. 145), rosthornianus (Fig.
147), rugosus (Fig. 150) and flagellaris (Fig. 151) the
infolded ends of the bundle do not curve downward. In
speciformis (Fig. 152) the long upcurved and incurved
ends of the bundle fold back almost against the lower
side of the bundle.

The midribs in the following species show crystals:
flagellaris (Fig. 151), scandens (Fig. 143), Loeseneri (Fig. 146), reticulatus (Fig. 140), hypoleucus (Fig. 141), paniculatus (Fig. 149), and speciformis (Fig. 152), the last three having many crystals.

The midribs of Loeseneri (Fig. 146), glaucophyll (Fig. 145), and rosthornianus (Fig. 147) have sclerenchyma cells just outside the phloem on the under side. Thick walled collenchyma or hypoderm occur under each epidermis and opposite the midrib in about the same proportion as was found about the lateral vein mentioned previously.

The Xylon tissue is much alike in the midribs throughout the species studied. Quite even rows of water tubes are present, from 3-7 cells in length, the average being about five. These rows are close together with few rays in between. The phloem is very narrow.

Margin.

In the following species the collenchyma is found at the edge of the blade; Hookeri (Fig. 155), flagellaris (Fig. 151) and orbiculatus (Fig. 129).

In Loesneri (Fig. 136) the edge is formed of cork. The rest have walls more or less thickened but not decidedly collenchymatous.

In hypoleucus (Fig. 151), angulatus (Fig. 124), and speciformis (Fig. 128), there was no downward curve
to the margin. In those of glaucophyll (Fig. 132), orbiculatus (Fig. 129), rugosus (Fig. 127) and hypoleucus (Fig. 151) there is very slight curvature. In Hookeri (Fig. 135) reticulatus (Fig. 133), rosthornianus (Fig. 154), and paniculatus (Fig. 129) there is a small hook downward. In Loeseneri the margin is slightly curved upward.

The second row of palisade cells is formed close to the edge of the leaf in reticulatus (Fig. 133), rosthornianus (Fig. 154), orbiculatus (Fig. 129), and glaucophyll, (Fig. 132). In Hookeri (Fig. 135) it is formed a little further back and in the rest still further.

A cross section of a tooth of hypoleucus (Fig. 131) was obtained. It was found to be made up of thin walled parenchyma.

**Petiole.**

The photographs of the petiole were taken of sections cut from about midway between the blade and the point of attachment to the stem. The diameter of these sections from the lower margin to the angle between the wings varies considerably. Rosthornianus (Fig. 157) has the smallest diameter of petiole, it being .79 mm in diameter and reticulatus (Fig. 133) has the next smallest, it being .8 mm in diameter. Angulatus (Fig. 164) has the largest petiole, it being 1.7 mm in diameter. The
breadth for each species may be found in column VI, table II, page 28.

The petioles are rather circular in cross section, with two wings toward the upper side. Between the wings the surface may be concave, as in angulatus (Fig. 164), and Loeseneri (Fig. 165), or convex, as in all of the rest of the species.

The lower surface of the petiole is evenly rounded in hypoleucus (Fig. 154), scandens (Fig. 155), and angulatus (Fig. 164). Slight irregularities occur in the surface of the petiole in orbiculatus (Fig. 153), paniculatus (Fig. 159), and flagellaris (Fig. 165). In Hookeri (Fig. 162) and glaucophyll (Fig. 161) the surface is decidedly undulating, and in rugosus (Fig. 156), rosthornianus (Fig. 157), reticulatus (Fig. 158), speciformis (Fig. 160), and Loeseneri (Fig. 163), definite ridges are present on the lower side of the petiole.

The vascular bundles in the petiole have the same general shape as those in the midrib.

Crystals occur in the petioles of the same species, as in the midrib and also in rugosus (Fig. 156), rosthornianus (Fig. 157), and glaucophyll (Fig. 161).

The wings on the upper side of the petiole vary in length, however the longest are not necessarily on the
largest petiole. Comparisons were made of length of wings to the diameter of the petiole from between the wings to the lower margins. The wings of scandens (Fig. 155) are only 7% of the width of the petiole, of orbiculatus 14%, paniculatus 15%, rosthornianus (Fig. 157) and hypoleucus (Fig. 154) 16%, and speciformis (Fig. 160) 31%.
Table I.

<table>
<thead>
<tr>
<th>Column I</th>
<th>The number of lateral veins of the first order given off from the midrib in 5.7 mm.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Column II</td>
<td>The number of meshes in an area of 4 square m m. at 4 m m. from the tip.</td>
</tr>
<tr>
<td>Column III</td>
<td>Thickness of midrib at 5.7 mm. from the tip.</td>
</tr>
<tr>
<td>Column IV</td>
<td>Depth of hypoderm under upper epidermis.</td>
</tr>
<tr>
<td>Column V</td>
<td>Height of hypoderm above lower epidermis.</td>
</tr>
<tr>
<td>Column VI</td>
<td>Percent of length of wings to the diameter of the petiole.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Species</th>
<th>Column I</th>
<th>Column II</th>
<th>Column III</th>
<th>Column IV</th>
<th>Column V</th>
<th>Column VI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rugosus</td>
<td>4</td>
<td>11</td>
<td>.12</td>
<td>.12</td>
<td>.24</td>
<td>20%</td>
</tr>
<tr>
<td>Hypoleucus</td>
<td>8</td>
<td>12</td>
<td>.14</td>
<td>.10</td>
<td>.12</td>
<td>16%</td>
</tr>
<tr>
<td>Hookeri</td>
<td>8</td>
<td>20</td>
<td>.11</td>
<td>.16</td>
<td>.16</td>
<td>22%</td>
</tr>
<tr>
<td>Glaucophyll</td>
<td>10</td>
<td>14</td>
<td>.2</td>
<td>.08</td>
<td>.16</td>
<td>25%</td>
</tr>
<tr>
<td>Loeseneri</td>
<td>11</td>
<td>20</td>
<td>.25</td>
<td>.06</td>
<td>.12</td>
<td>20%</td>
</tr>
<tr>
<td>Speciformis</td>
<td>12</td>
<td>17</td>
<td>.17</td>
<td>.04</td>
<td>.12</td>
<td>31%</td>
</tr>
<tr>
<td>Paniculatus</td>
<td>15</td>
<td>32</td>
<td>.11</td>
<td>.12</td>
<td>.14</td>
<td>15%</td>
</tr>
<tr>
<td>Orbiculatus</td>
<td>16</td>
<td>30</td>
<td>.11</td>
<td>.13</td>
<td>.15</td>
<td>14%</td>
</tr>
<tr>
<td>Flagellaris</td>
<td>16</td>
<td>76</td>
<td>.11</td>
<td>.06</td>
<td>.16</td>
<td>23%</td>
</tr>
<tr>
<td>Reticulatus</td>
<td>19</td>
<td>30</td>
<td>.14</td>
<td>.08</td>
<td>.12</td>
<td>15%</td>
</tr>
<tr>
<td>Angulatus</td>
<td>20</td>
<td>44</td>
<td>.12</td>
<td>.04</td>
<td>.12</td>
<td>22%</td>
</tr>
<tr>
<td>Rosthornianus</td>
<td>24</td>
<td>52</td>
<td>.11</td>
<td>.015</td>
<td>.12</td>
<td>16%</td>
</tr>
<tr>
<td>Scandens</td>
<td>8</td>
<td>32</td>
<td>.11</td>
<td>.14</td>
<td>.15</td>
<td>7%</td>
</tr>
</tbody>
</table>
Table II.

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Column I</td>
<td>Thickness of the leaf.</td>
</tr>
<tr>
<td>Column II</td>
<td>Height of first row of palisade cells.</td>
</tr>
<tr>
<td>Column III</td>
<td>Height of second row of palisade cells.</td>
</tr>
<tr>
<td>Column IV</td>
<td>Height of spongy parenchyma tissue.</td>
</tr>
<tr>
<td>Column V</td>
<td>Number of rows of spongy parenchyma cells.</td>
</tr>
<tr>
<td>Column VI</td>
<td>Dorsi-ventral diameter of petioles (Cut midway between blade and point of attachment to stem.)</td>
</tr>
<tr>
<td>Column VII</td>
<td>Length of blade of leaf (average) in mm.</td>
</tr>
<tr>
<td>Column VIII</td>
<td>Length of blade as given in Rehder (l.c.) (in cm.)</td>
</tr>
<tr>
<td>Column IX</td>
<td>Number of upper epidermal cells in 1 sq. mm.</td>
</tr>
<tr>
<td>Column X</td>
<td>Average diameter of cells of lower epidermis.</td>
</tr>
<tr>
<td>Column XI</td>
<td>Average number of stomata per sq. mm.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Species</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
<th>VIII</th>
<th>IX</th>
<th>X</th>
<th>XI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loeseneri</td>
<td>.44</td>
<td>.08</td>
<td>.06</td>
<td>.28</td>
<td>6to7</td>
<td>1.35</td>
<td>88</td>
<td>*</td>
<td>1700</td>
<td>.025</td>
<td>230</td>
</tr>
<tr>
<td>Speciformis</td>
<td>.44</td>
<td>.06</td>
<td>.06</td>
<td>.28</td>
<td>6to8</td>
<td>1.44</td>
<td>123</td>
<td>*</td>
<td>2500</td>
<td>.021</td>
<td>269</td>
</tr>
<tr>
<td>Rosthomianus</td>
<td>.40</td>
<td>.10</td>
<td>.08</td>
<td>.12</td>
<td></td>
<td>.79</td>
<td>36</td>
<td>4-8</td>
<td>1200</td>
<td>.02</td>
<td>298</td>
</tr>
<tr>
<td>Gleucophyll</td>
<td>.35</td>
<td>.06</td>
<td>.03</td>
<td>1.7to2</td>
<td>6-7</td>
<td>1.2</td>
<td>79</td>
<td>*</td>
<td>900</td>
<td>.025</td>
<td>299</td>
</tr>
<tr>
<td>Reticulatus</td>
<td>.28</td>
<td>.08</td>
<td>.04</td>
<td>.12</td>
<td>7</td>
<td>.8</td>
<td>46</td>
<td>*</td>
<td>1200</td>
<td>.012</td>
<td>388</td>
</tr>
<tr>
<td>L. pulexus</td>
<td>.28</td>
<td>.04</td>
<td>.04</td>
<td>.16</td>
<td>6</td>
<td>.9</td>
<td>76</td>
<td>6-14</td>
<td>1500</td>
<td>.014</td>
<td>290</td>
</tr>
<tr>
<td>Orbicularis</td>
<td>.22</td>
<td>.042</td>
<td>.036</td>
<td>.12</td>
<td>7</td>
<td>1.4</td>
<td>68</td>
<td>5-10</td>
<td>1100</td>
<td>.022</td>
<td>160</td>
</tr>
<tr>
<td>Flagellaris</td>
<td>.16</td>
<td>.02</td>
<td>.02</td>
<td>.095</td>
<td>+</td>
<td>1.2</td>
<td>73</td>
<td>2-5.5</td>
<td>2200</td>
<td>.012</td>
<td>236</td>
</tr>
</tbody>
</table>
Table II (Continued)

<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
<th>VIII</th>
<th>IX</th>
<th>X</th>
<th>XI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rugosus</td>
<td>0.20</td>
<td>0.03</td>
<td>0.02</td>
<td>1.2</td>
<td>6</td>
<td>0.99</td>
<td>48</td>
<td>5-13</td>
<td>950</td>
<td>0.02</td>
<td>255</td>
</tr>
<tr>
<td>Angulatus</td>
<td>0.17</td>
<td>0.02</td>
<td>0.06</td>
<td>0.08</td>
<td>5</td>
<td>1.7</td>
<td>144</td>
<td>10-18</td>
<td>1300</td>
<td>0.018</td>
<td>225</td>
</tr>
<tr>
<td>Hookeri</td>
<td>0.32</td>
<td>0.08</td>
<td>0.06</td>
<td>0.14</td>
<td>6</td>
<td>1.1</td>
<td>123</td>
<td>7-10</td>
<td>1400</td>
<td>0.016</td>
<td>420</td>
</tr>
<tr>
<td>Paniculatus</td>
<td>0.20</td>
<td>0.02</td>
<td>0.02</td>
<td>1.2</td>
<td>7</td>
<td>1.4</td>
<td>70</td>
<td>5-10</td>
<td>800</td>
<td>0.025</td>
<td>356</td>
</tr>
<tr>
<td>Scandens</td>
<td>0.21</td>
<td>0.03</td>
<td>0.02</td>
<td>1.2</td>
<td>9</td>
<td>1.05</td>
<td>103</td>
<td>5-10</td>
<td>1300</td>
<td>0.02</td>
<td>145</td>
</tr>
</tbody>
</table>

* Not in rows
* Number not given
### Table III

**Stem Differences**

- **Column I**: Width of Parenchyma of cortex of one year stem.
- **Column II**: Width of Bast region in the one year stem.
- **Column III**: Length of Bast fibers.
- **Column IV**: Length of wood fibers.

<table>
<thead>
<tr>
<th>Species</th>
<th>Column I</th>
<th>Column II</th>
<th>Column III</th>
<th>Column IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypoleucus</td>
<td>.14</td>
<td>.145</td>
<td>10.24</td>
<td>2.3</td>
</tr>
<tr>
<td>Paniculatus</td>
<td>.12</td>
<td>.15</td>
<td>41.5</td>
<td>.4</td>
</tr>
<tr>
<td>Orbiculatus</td>
<td>.1</td>
<td>.18</td>
<td>18.96</td>
<td>.58</td>
</tr>
<tr>
<td>Scandens</td>
<td>.1</td>
<td>.086</td>
<td>40</td>
<td>1.54</td>
</tr>
<tr>
<td>Reticulatus</td>
<td>.1</td>
<td>.96</td>
<td>30*</td>
<td>.52</td>
</tr>
<tr>
<td>Flagellaris</td>
<td>.14</td>
<td>.185</td>
<td>5.76</td>
<td>.46</td>
</tr>
<tr>
<td>Rugosus</td>
<td>.13</td>
<td>.103</td>
<td>6.24</td>
<td>.37</td>
</tr>
<tr>
<td>Glaucophyll</td>
<td>.08</td>
<td>.09</td>
<td>4.8</td>
<td>.48</td>
</tr>
<tr>
<td>Rosthornianus</td>
<td>.05</td>
<td>.08</td>
<td>7.46</td>
<td>.41</td>
</tr>
<tr>
<td>Speciformis</td>
<td>.1</td>
<td>.10</td>
<td>10</td>
<td>.51</td>
</tr>
<tr>
<td>Loeseneri</td>
<td>.13</td>
<td>.13</td>
<td>12.14</td>
<td>.53</td>
</tr>
<tr>
<td>Hookeri</td>
<td>.2</td>
<td>.14</td>
<td>15.5</td>
<td>.76</td>
</tr>
<tr>
<td>Angulatus</td>
<td>.13</td>
<td>.28</td>
<td>7.2</td>
<td>1.4 to 3.8</td>
</tr>
</tbody>
</table>

* Both ends of this fiber were cut, but it came from the longest piece of material that I had.
STEMS

Cross Section of One-Year-Old Stem

In viewing and comparing the photographs of the one-year-old stems it must be remembered that the sections from scandens (Fig. 166), flagellaris (Fig. 172), Loeseneri (Fig. 174), angulatus (Fig. 176), rugosus (Fig. 178), and hypoleucus (Fig. 180) were cut from material collected in June, while the sections cut from the rest of the species were cut from material collected in September. This three months of additional growth has made some changes in the one-year-old as well as the two-year-old stems. In the younger one-year-old stems the cells of the parenchyma of the cortex are slightly rounder than those in the older one-year-old stems. For an example of this see flagellaris (Fig. 172), a younger stem and reticulatus (Fig. 190), an older stem. Also compare the cortexes in these two photographs and note that in the younger stem there is no periderm but a well formed periderm is present in the older stem. As this periderm is formed the epidermis is gradually sloughed off and by fall it is usually all gone. Because of this fact the epidermal cells could be compared only in the material collected in June. In flagellaris (Fig. 172) and angulatus (Fig. 176) the epidermal cells are pract-
ically the same size as the parenchyma cells just beneath. In scandens (Fig. 166), Loeseneri (Fig. 174), rugosus (Fig. 178), and hypoleucus (Fig. 180), the epidermal cells are larger than the underlying cells, especially in the last species named. The outer wall of the epidermal cells were thicker than the outer walls of the epidermis in all of the species investigated.

Just beneath the epidermis is a parenchymatous tissue which varies in radial width throughout the species studied. The widest zone extended 2 m m. and was found in Hookeri (Fig. 182). The narrowest zone appeared in rosthornianus (Fig. 188) and was .05 m m. wide. Both of these species were collected in the fall. Exact measurements of the width of this tissue will be found in table II, column 111 page 30.

Next comes a region of bast fibers interspersed with parenchyma. This region is found to vary throughout the species considerably, (see Figs. 27-39) and will be described for each species in detail.

C. speciformis (Figs. 27 and 186) - Bast fibers relatively thin walled, much flattened almost to the obliteration of the cavity. Usually flattened tangentially. Numerous parenchyma cells in chains of single rows thru the bast fibers. Width of region 1 m m.
C. reticulatus (Figs. 28 and 190) - Bast fibers less numerous and slightly thicker walled than in speciformis (Fig. 27). Flattened tangentially but not flattened as closely as in speciformis. Also a larger proportion of parenchyma cells not necessarily in rows. Width of region .09 mm.

C. gleucophyll (Figs. 29 and 184) - Fibers mostly flattened radially and placed in radially extended groups. Chains of parenchyma cells in between the groups. Width of the region .09 mm.

C. rosthornianus (Figs. 30 and 188) - Bast fibers thick walled and with small cavities. Flattened in various directions. Few parenchyma cells, occasionally in chains. Bast region narrow.

C. orbiculatus (Figs. 31 and 170) - Bast fibers forming a wide ring around the stem. Fibers very thick walled, some appearing in cross section almost round, and some completely flattened, usually though not always tangentially. Few parenchyma cells, usually in chains. Width of region .18 mm.

C. scandens (Figs. 32 and 166) - Bast fibers in cross section usually small ovals, thick-walled. Thin-walled fibers occasionally folded in the shape of a U. Numerous parenchyma cells, sometimes in chains. Very small opening left in the center of the fiber.
Occasional large intercellular gaps. Width of region 0.096 mm.

C. paniculatus (Figs. 33 and 168) - Bast fibers in groups and parenchyma cells around each group. Fibers not completely flattened. Inner edge of bast fiber wall thickened in scallops. Walls vary in thickness but are usually about the thickness of those in rosthornianus (Fig. 30) width of region, 15 mm.

C. hookeri (Figs. 34 and 182) Bast fibers usually flattened radially. Degree of flatness varies. The hole in the center may be relatively large and isodiametric or it may be almost entirely obliterated. Parenchyma cells are usually in chains between the irregular rows of bast fibers.

C. hypoleucus (Figs. 35 and 180) Bast fibers thick walled and their cavities relatively large. Inner edge of the cell wall undulating. Fibers in radially extended groups. Parenchyma cells numerous. Width of the region 145 mm.

C. angulatus (Figs. 36 and 176). Bast fiber ring very wide. Fibers and cavities unusually large, flattened little. Walls undulating. Little parenchyma interspersed. Width of region 28 mm.

C. flagellaris (Figs. 37 and 172) Bast fibers medium in size with relatively large openings and thin walls. Many parenchyma cells. Fibers in groups. Width of
the region 185 mm.

C. rugosus (Figs. 38 and 178) Bast fibers with walls varying in size from thin to very thin. More or less undulating. Fibers with large cavities. Usually in radially extended groups, with rows of parenchyma between.

C. Loeseneri. (Figs 39 and 174) Bast fibers extremely thin walled, large cavited. Numerous parenchyma cells. A thin row of parenchyma occurs between the bast fibers and the phloem. The phloem is very similar throughout the species. It is in the form of a narrow ring of thin walled, approximately square cells.

The xylem for the first year must be compared in the pictures of the two-year old stems because, as was stated, some of the one-year-old stems were gathered in the spring and some in the fall. The xylem varies noticeably in several particulars. It is extremely wide in rugosus (f. 179) being .72 mm across, but in most of the species it is about .35 mm. wide. In scandens (Fig. 167) it is particularly narrow, being .14 mm wide, and paniculatus (Fig. 169), orbiculatus (Fig. 171), flagellaris (Fig. 173), Loeseneri (Fig. 175) and reticulatus (Fig. 191) it is only slightly wider.

In all of the species investigated, the tracheal tubes are rather numerous in the early growth and are laid down in placed in more or less fan-like groups of
rows. In the following species these fanlike groups are associated with a decided irregularity in the outline of the xylem, scandens (Fig. 166), orbiculatus (Fig. 170), flagellaris (Fig. 172), rugosus (Fig. 178), hypoleucus (Fig. 180) and glaucophyll (Fig. 185). In the rest of the species the outline of the xylem is merely undulating.

There are not a great many tracheal tubes in the one-year-old xylem, except in speciformis (Fig. 187) and glaucophyll (Fig. 185).

The pith is heterogeneous, that is, the cells around the outer edge are alive and bear starch grains and those toward the center are dead and are without starch grain. The pith cells in the center are much thinner walled than those near the outside.

Two-Year-Old-Stems--

The two-year-old stems show well-defined cork, as in fact do the one-year-old stems if examined in the fall. The bast-fiber ring is somewhat wider in the two-year-old stem than in the one-year-old, and the fibers themselves are a little more scattered, that is, large intercellular spaces occur among them. The phloem is about twice as wide radially in the two-year-old stems as in the one-year-old. For a particularly clear demonstration of the above facts see the photographs of the stem of rugosus (Figs. 178 and 179).

In the xylem, great contrasts may be seen in the manner in which the annular ring is developed. In paniculatus (Fig. 169),
Hookeri (Fig. 183) and reticulatus (Fig. 191) it is almost impossible to discern where the second year's growth begins. That is, the tracheal tubes are scattered throughout both year's growth and there is no definite ring of wood fibers at the end of the first year's growth.

The tracheal tubes vary in diameter within a single species and between the different species but the following species have particularly large tracheal tubes (about .075 mm. in diameter); paniculatus (Fig. 169), Loeseneri (Fig. 175), hypoleucus (Fig. 181), glaucophyll (Fig. 185), and speciformis (Fig. 187). The tracheal tubes of scandens (Fig. 167) and orbiculatus (Fig. 171) while comparatively large are much smaller than those of the species listed above (about .045 mm. in diameter).

The amount of xylem formed in the two-year-old stem cannot be compared through out all thirteen of the species investigated since all of the material was not the same age. For that reason the species obtained in June will be compared as one group and those obtained in October will be compared as another group. In the first group would come the following species: scandens (Fig. 167), paniculatus (Fig. 169), flagellaris (Fig. 173), Loeseneri (Fig. 175), angulatus (Fig. 177), rugosus (Fig. 179), and hypoleucus (Fig. 181). The narrowest wood formed by an species in this group is in scandens (Fig. 167). Here the wood is .27 mm. wide. The wood of flagellaris comes next being .33 mm. wide, then Loeseneri (Fig. 175) .41 mm, angulatus (Fig. 177) .42 mm.
hypoleucus (Fig. 181) .44 mm., paniculatus (Fig. 169), 54 mm., and rugosus (Fig. 179) the widest at .65 mm.

In the group of older two-year-old stems we find orbiculatus, (Fig. 171), Hookeri (Fig. 183), glaucophyll (Fig. 185), speciformus (Fig. 187), Rosthornianus (Fig. 189, and reticulatus (Fig. 191). Of these, Hookeri (Fig. 183) possessed the narrowest wood, .38 mm. wide. The wood in orbiculatus (Fig. 171) was .52 mm. in rosthornianus, (Fig. 189) .57 mm. and in glaucophyll (Fig. 185) speciformis (Fig. 185), and reticulatus (Fig. 191, .67 mm. wide.

The medullary rays are usually from one to two cells in breadth.

The cork differs in one way or another between almost every species and will be taken up in detail.

C. scandens (Fig. 40). Epidermis and one layer of subepidermal parenchyma cells persisting. Cork cells relatively thick walled and in somewhat irregular rows.

C. orbiculatus (Fig. 41). Cork is formed immediately beneath the epidermis. Cork cells irregular. Much like scandens except that the sub-epidermal row of parenchyma cells is lacking in orbiculatus.

C. paniculatus (Fig. 42). Epidermis and one row of parenchyma cells (sub-epidermal) persisting. Cork cells quite right angled at the corners. More regular in shape than the cork of scandens. (Fig. 40)

C. reticulatus (Fig. 43). One row of epidermal cells persisting. The inner wall of cells has become greatly thickened.
C. rosthornianus (Fig. 44) Epidermis and one row of parenchyma persisting. The inner wall of the parenchyma cells has become thickened. Cork cells somewhat flattened. The outer 2-5 rows of cells not as flattened as the inner rows. Open spaces occur among the cork cells rarely.

C. flagellaris (Fig. 45) Epidermis and one row of sub-epidermal parenchyma persisting. Both are thin walled and large cavitied. Cork cells flattened in even rows giving a very regular effect.

C. Loeseneri (Fig. 46) Epidermis persisting. Outer wall very thick. Cork cells broader tangentially than those in rosthornianus. (Fig. 44) and flagellaris (Fig. 46). Cork cells flattened.

C. Angulatus (Fig. 47) Everything outside the cork has been sloughed off. Cork cells exactly like those in flagellaris (Fig. 45).

C. glaucophyll (Fig. 48) Epidermal cells persisting. The outer wall is very much thickened, and the side and inner walls extremely thin. Cork layer exceptionally narrow. Cells much flattened.

C. speciformis. (Fig. 49). Epidermis and one row of parenchyma cells persisting. Parenchyma cells very thin walled toward the inside. Cork cells flattened and in less regular rows than those in angulatus (Fig. 47). Cork narrow.
C. rugosus (Fig. 50). Epidermal cells persisting. Outer wall heavily thickened. Side and inner walls thin. Cell cavities not so large or square as those in glaucophyll (Fig. 48). Cork very much flattened just under the epidermis.

C. hypoleucus. (Fig. 51). Only a part of the epidermis persisting. The epidermal cells which have hung on are very thick walled. Between these thick walled epidermal cells the cork cells have pushed on out in a plane with the outer edge of the epidermal cells.

C. Hookeri (Fig. 52). One row of thin-walled parenchyma cells persists outside the cork. The epidermis has been lost. The cork cells are thin walled and possess large cavities.

The thick walled epidermal cells spoken of in describing hypoleucus (Fig. 51), are also present in the following other species; hypoleucus, (Figs. 51 and 67) rosthornianus (Figs. 44 and 71), paniculatus (Figs. 42 and 68) speciformis (Figs. 49 and 69), orbiculatus (Figs. 41 and 70) and reticulatus (Figs. 43 and 66), and may be seen both in the cross sections and from surface view (Figs. 66-71). In hypoleucus (Fig. 68) and rosthornianus (Fig. 71) the cells are thicker walled than in the other species. In reticulatus (Fig. 66) these thick-walled epidermal cells are about twice as frequent as in the other species.

Differences in Stem Structure as Seen in Longitudinal Section of Pith.
The pith tissue as seen in longitudinal section varies from continuous to chambered, and from vertically elongated to isodiametric.

In flagellaris (Fig. 1) and glaucophyll (Fig. 2) the cells are much higher than broad, and the cells of flagellaris are more regular than those in glaucophyll. In Hookeri (Fig. 3) and reticulatus (Fig. 4) the cells are higher and narrower near the wood and shorter and broader in the center. The cells of reticulatus (Fig. 4) are deeply pitted. In hypoleucus (Fig. 5) the cells are higher than broad, as a rule, but the size varies considerably. In rosthorniamis (Fig. 6) and Loeseneri (Fig. 9) the cells are broader than high, though more uniformly so in Loeseneri (Fig. 9). Rugosus (Fig. 7) and angulatus (Fig. 8) have chambered pith. The broken-down cells are more completely obliterated in angulatus (Fig. 8). The pith cells of paniculatus (Fig. 10), scandens (Fig. 11), orbiculatus (Fig. 12) and speciformis (Fig. 13) are as a rule slightly broader than high but are not constantly so.

Medulary Ray Cells as seen in Longitudinal Sections.

The medullary ray cells vary too much in size in any one species to be of taxonomic value. For the figures 18-26 as nearly representative sections as possible were drawn but many deviations from these were seen in the same stems.

However, attention should be called to the fact that
in the following species the medullary ray cells found in the wood were usually about the same size as those found in the bark; rugosus (Fig. 14) reticulatus (Fig. 15), Hookeri (Fig. 16), paniculatus (Fig. 17), and orbiticulatus (Fig. 19). In speciformis (Fig. 18), hypoleucus (Fig. 20) glaucophyll (Fig. 22) and scandeus (Fig. 23), the cells vary in size a great deal but in the wood are on the average higher than those in the bark. In hypoleucus (Fig. 20), flagellaris (Fig. 24), rosthornianus (Fig. 25), and augulatus (Fig. 26) the cells in the wood are noticeably larger than those in the bark. The cells in the wood of angulatus (Fig. 26), are particularly thick walled.

All of the cells are pitted deeply but this is not brought out in the photographs for it would not have shown at this magnification.

Macerations

In macerations a study was made of the length of the bast fibers and wood fibers. See table III, column 3 and 4, page 30.

The wood fibers are from .35 mm. in length in rosthornianus to 3.8 mm. in augulatus. Most of the fibers are less than a millimeter in length and are numerous. The bast fibers are extremely long in some cases, for example in paniculatus a fiber was found to be 4.15 mm.
long. The next longest was in scandens, 4 cm. The shortest was in glaucophyll, 48 cm. The extremely long bast fibers are so loosely attached to the other cells of the bark that they can easily be lifted out with a needle before chronic-acid maceration is begun.

The xylem tissues were studied in longitudinal sections and in macerations.

Many tracheids, tracheal tubes, wood fibers and wood parenchyma were found in all of the species investigated and many transition forms occur which as Stenzel (1.e.) says, makes identification doubtful. Tracheids and wood fibers occurred in abundance, with fewer wood parenchyma. When wood parenchyma did occur it was always pitted. It was found most frequently near the pith. The tracheal tubes are usually pitted but may have spiral or reticulate thickenings. Their cross walls are most often inclined and are slow to disappear.

Key to the species according to the cork and external cell layers.

I. Having sclerotic epidermal cells among the ordinary epidermal cells.
   A. Cork very flattened
      1. Sclerotic parenchyma cells almost forming an interrupted ring outside the cork and other epidermal cells absent - hypoleucus (Fig. 51).
2. Sclerotic epidermal cells among the other epidermal cells

1. Sub-epidermal parenchyma cells thin walled toward the inside-speciformis (Fig. 49).
2. Sub-epidermal parenchyma cells thick walled toward the inside-rosthornianus (Fig. 44).

B. Cork flattened very little.

1. Epidermal cells not thick walled.
   a. Sub-epidermal parenchyma present-paniculatus (Fig. 42).
   b. No sub-epidermal parenchyma present-orbiculatus (Fig. 44).
2. Epidermal cells thick walled — reticulatus

II. No sclerotic cells among the epidermal cells.

A. Cork very flattened.

1. Sub-epidermal parenchyma present-flagellaris (Fig. 45).
2. No sub-epidermal parenchyma present-flagellaris — (Fig.

   a. Cavity in epidermal cells rounded at angles

   1. Cork cells very flattened just under epidermal cells rougosus (Fig. 50).
   2. Cork cells not flattened just under epidermis -Loesenerius (fig. 46).
Augulatus (Fig. 47) comes under this group but could not be placed exactly in the key for the tissues outside the cork had all been sloughed off.

B. Cork not decidedly flattened
   1. Outer wall of sub-epidermal parenchyma very thin Hookeris (Fig. 52)
   2. Outer wall of sub-epidermal parenchyma thick scandens (Figure 40).

Key to the species according to the bast fibers as seen in cross section

I. Bast fibers almost or completely flattened
   A. Usually flattened tangentially
      1. Many bast fibers - speciformis (Fig. 27)
      2. Fibers scattering and few in number - reticulatus (Fig. 28)
   B. Usually flattened radially
      1. Region .09 mm. wide - glaucophyll (Fig. 29)
      2. Region .14 mm. wide - Hookeri (Fig. 34)

II. Bast fibers usually with little or no cavity. Fibers usually oval or round in outline
   A. Bast fibers occasionally folded into the shape of a U.
   B. Bast fibers not folded into the shape of a U. scandens(Fig. 32).
      1. Inner edge of cell wall of fibers very undulating - paniculatus (Fig. 33).
2. Inner edge of cell wall of fibers not undulating
   a. Bast fiber region .08 mm. wide -rostrothornius (Fig. 30)
   b. Bast fiber region .18 mm. wide - orbiculatus (Fig. 31)

III. Relatively large cavity in the bast fibers
A. Bast fiber walls very undulating - augulatus
   (Fig. 36)
B. Bast fiber walls not undulating
   1. Fibers in radially extended groups - (uninterrupted tangentially by parenchyma cells.
      a. Fibers thin walled - loeseneri
         (Fig. 39)
      b. Fibers thick walled - flagellaris
         (Fig. 37)
   2. Bast fiber groups interrupted tangentially by parenchyma cells.

Key to species according to Stem Characters
I. Pith chambered (as seen in longitudinal sections)
   A. Cells extremely flattened - augulatus (Fig. 3)
   B. Cells flattened little - rugosus (Fig. 7)
II. Pith not chambered as seen in longitudinal sections.
   A. Pith cells much taller than broad
      1. Regularly rectangular - flagellaris
         (Fig. 1).
2. Cells not regularly rectangular - *plauco-
phyll* (Fig. 2).

B. Pith cells only slightly taller than broad.
1. Cells round (so that one shows round under
the other) - *Hypooleucus* (Fig. 5).
2. Cells more nearly rectangular.
   a. Cells deeply pitted - *recticulatus*
      (Fig. 4)
   b. Cells not deeply pitted - *Hookerii*
      (Fig. 3).

C. Cells much broader than tall
1. Cells in even rows clear to the center.
   *Loesenerii* (Fig. 9)
2. Cells not in even rows toward the center.
   *rosthornianus* (Fig. 6)

D. Cells very irregular.
1. No definite annular ring - *pariculatus*
   (cross section) (Fig. 169).
2. Definite annualar ring (cross Section) a
   *speciformis* (Fig. 167)
   a. Large tracheal tubes (.065 mm.)
   b. Smaller tracheal tubes (.032 mm.)
   1. Sclerotic parenchyma cells or-
      *biculatus* (Fig. 41)
   2. No sclerotic parenchyma cells
      *scandens* (Fig. 40).
Key from Surface view of leaf and cross section of stomata.

I. Side walls of lower epidermis only, very undulating speciformis (Fig. 82)

II. Side walls of both upper and lower epidermis very undulating

A. Guard cells subtended by epidermal cells, pani culatus (Fig. 87)

B. Guard cells not subtended by epidermal cells.

1. Ordinary epidermal cells reaching clear to guard cells - wall between curved orbiculatus (Fig. 83 and 89)

2. Small straight-walled epidermal cells near the guard cells - scandens (Fig. 84).

III. Side walls of upper and lower epidermal cells only slightly undulating

A. Epidermal cells of upper and lower epidermis averaging the same size (.025) mm. in diameter glaucophyll (Fig. 72)

B. Lower epidermal cells larger than upper - Loezeneri (Fig. 76)

C. Upper epidermal cells larger than lower

1. Guard cells partly subtended by epidermal cells.

   a. Guard cells raised above the surface of the leaf - flagellars (Fig. 90)

   b. Guard cells on level with leaf - reticulatus (Fig. 96)
2. Guard cells subtended more or less completely by epidermal cells.
   a. Guard cells level with surface
      1. Small epidermal cell completely subtending guard cell and not reaching surface of leaf. - *hypoleucus* (Fig. 91)
      2. Small epidermal cells subtending guard cells but reaching surface of leaf. - *rugosus* (Fig. 86)
   b. Guard cells partly raised above level of leaf. - *rosthorianus* (Fig. 85).
   c. Guard cells completely raised above the level of the leaf.
      1. Stomata slightly more than 200 per square mm. - *angulatus* (Fig. 78)
      2. Stomata slightly more than 400 per square mm. - *Hookeri* (Fig. 75).

Key to species from Venation

I. Leaves with broad tip

   A. Tip retuse
      1. Well marked subsidiary, more or less marginal ribs on either side of the midrib.
         a. Scattered incurved serrulations - *flagellaris* (Fig. 98)
         b. Serrations not incurved.
1. Meshes frequent 11 per square mm. - *angulatus* (Fig. 121)
2. Mesh not frequent 4 per square mm. - *speciformis* (Fig. 123)

2. Weak subsidiary ribs - *orbiculatus* (Fig. 99)

B. Tip not retuse - *Hookeri* (Fig. 122)

II. Leaves acute/the tip.

A. Well marked subsidiary ribs persisting and incurving at the apex to meet the midrib - *Scandens* (Fig. 113).
B. Subsidiary ribs not so strong and delequising at the apex.

1. Meshes very wide (5-5 per sq. mm.)
   a. Midrib very thick (2-25 mm. broad at 5.) mm. from tip)
      1. Midrib strongly persisting to apex - *claurophyll* (Fig. 119)
      2. Midrib not strongly persisting to apex - *Loeseneri* (Fig. 101)
   b. Midrib narrow. (14 mm. broad at 5.) mm. from tip.)

2. Meshes narrow (about 8 per sq. mm.)
   a. Midrib spreading at tip - *reticulatus* (Fig. 100)
   b. Midrib not spreading at tip - *Paniculatus* (Fig. 118).

C. Only vague suggestions of subsidiary ribs.
1. Mesh frequent (15 per sq. mm.) rosthornianus (Fig. 120)
2. Mesh infrequent (3 per sq. mm.) rugosus (Fig. 117).

Key to the Species from the Cross Section of the Leaf.

I. Spongy parenchyma cells not in regular rows
   A. Lignified collenchyma outside phloem in lateral veins of the first order. - rosthornianus
   B. Lignified collenchyma not present - flagellaris

II. Six to eight rows of Spongy Parenchyma with only the upper two rows irregular.
   A. In lateral veins of first order - Phloem entirely surrounding xylem - angulatus
   B. Phloem partly around xylem - Loeseneri

III. All rows of spongy Parenchyma, regular
   A. Hyperderm - thin walled under upper epidermis
      1. Near the midrib only.
         a. Thin cellulose layer under cuticle of upper epidermis - rugosus
         b. Upper epidermis entirely cutinized - reticulatus
      2. Hypoderm more widely extended.
         a. Hypoderm almost continuous from 1-5 cells in thickness - speciformis
         b. Hypoderm one cell thick - intermittent
1. Sclerenchyma sheath of bast fibers on outside of phloem of lateral vein of the first order. *glaucophyll.*

2. Sclerenchyma not present — *Hookeri*

B. Thin walled hypoderm not present
   a. Outer wall of lower epidermis all cutinized opposite vein.
      1. Leaf 28 mm. thick — *hypoleucus*
      2. Leaf 21 mm. thick — *scandens*
   b. Outer wall partly cellulose opposite vein.
      1. Length of upper row of palisade quite short (.021 mm.) — *paniculatus*
      2. Length — twice as long (.042 mm.) — *orbiculatus*

Key to Species from cross section of Midrib:

I. Upper and lower margins entire
   A. Leaf about .27 mm. thick, where it emerges from the midrib. *Hypoleucus* (Fig. 141)
   B. Leaf less than .14 mm. thick, where it emerges from the midrib.
      1. Projection of midrib on the upper side about .54 mm. broad — *angulatus* (Fig. 144)
      2. Projection about .27 mm. broad — *scandens* (Fig. 126).
II. Margin entire in outline except for unicellular bumps  
Hookeri  (F. 135).

III. One prominent keel on lower side, with numerous irregularities
A. Leaf very broad and midrib extremely small
   Loeseneri  (F. 146)
B. Midribs large
   1. Vascular arc slightly incurved at the ends
      rosthornianus  (F. 147)
   2. Vascular arc incurved a great deal
      many crystals  speciformis  (F. 152)
   3. Vascular arc nearly flat
      a. Midrib about 1.08 m.m. broad laterally
         reticulatus  (F. 140)
      b. Midrib about .27 m.m. broad laterally
         paniculatus  (F. 149)

IV. Three ridges on the lower side of the midrib
A. Sclerenchyma sheath subtending phloem
   glaucophyll  (F. 145)
B. Sclerenchyma sheath lacking orbiculatus  (F. 148)

V. Five ridges on the lower side of the midrib
A. Xylem Arc sharply incurved  ruposus  (F. 150)
B. Xylem Arc incurved little  flagellaris  (F. 151)
Key to Species from Cross Section of Leaf Margin.

I. No downward curve at margin.
   A. Collenchyma at edge of blade
      1. Collenchyma four cells deep - flagellaris
      2. Collenchyma two cells deep - scandens
   B. No collenchyma at edge of blade
      1. Parenchyma cellat at edge of blade loosely scattered - angulatus
      2. Open spaces in parenchyma but cells not scattered - speciformis

II. Only slight curve downward.
   A. Collenchyma at edge of blade - orbiculatus
   B. No collenchyma at edge of blade
      1. Cells at margin loosely placed
         a. Outer wall of upper epidermal cells flat - hypoleucus
         b. Outer wall of upper epidermal cells convex - rugosus
      2. Cells at margin closely placed - glaucophyll

III. Small hook downward
   A. Collenchyma at edge of blade
      1. Palisade near margin - orbiculatus
      2. Palisade further back - Hookeri
   B. No collenchyma at margin
      1. Open spaces among parenchyma cells - rosthornianus
2. Cells closely packed - reticulatus

IV. Curve upward at margin - Loeseneri

Key to species from cross section of petiole.

I. Upper side of the petiole entirely concave between the wings.
   A. Lower margin regular - angulatus (Fig. 164)
   B. Lower margin irregular - Loeseneri (Fig. 163)

II. Upper margin convex between the wings
   A. Lower margin slightly or not at all repand
      1. No crystals in the phloem
         a. Many crystals outside the phloem - flagellaris (Fig. 165)
         b. Few or none - orbiculatus (Fig. 153)
      2. Crystals in the phloem
         a. Margin between the wings showing three or more ridges - scandens (Fig. 155)
         b. Not ridged
            1. Number of parenchyma cells across lateral diameter of the medullar space about 20 - paniculatus (Fig. 159)
            2. Number of parenchyma cells across lateral diameter of the medullar space about 12 - hypoleucus (Fig. 154).
B. Lower margin with frequent undulations

collenchyma outside phloem - Hookeri (Fig. 162)

C. Undulations few and distant

1. Long wings, (about 20% of the dorsiventral diameter of petiole) - speciformis (Fig. 160)

2. Wings shorter (not more than 20% of the dorsiventral diameter of petiole)

a. Two prominent ridges on the lower side

1. Two elevations between the wings - (rugosus Fig. 156)

2. One elevation between the wings - (glaucophyll Fig. 161)

b. One prominent ridge on the lower side

1. Two wings inclined inward - rosthornianus (Fig. 157)

2. Two wings inclined outward - reticulatus (Fig. 158).
PLATE I
Longitudinal Sections of Pith
X220

Fig. 1 - Celastrus flagellaris
Fig. 2 - " glaucophyll
Fig. 3 - " Hookeri
Fig. 4 - " reticulatus
Fig. 5 - " hypoleucus
Fig. 6 - " rosthornianus
Fig. 7 - " rugosus
Fig. 8 - " angulatus
Fig. 9 - " Loeseneri
Fig. 10 - " paniculatus
Fig. 11 - " scandens
Fig. 12 - " orbiculatus
Fig. 13 - " speciformis
PLATE II

Longitudinal Sections of the Medullary Rays in First the wood, and then the bark.

X201

Fig. 14 - Celastrus rugosus
Fig. 15 - " reticulatus
Fig. 16 - " Hookeri
Fig. 17 - " paniculatus
Fig. 18 - " speciformis
Fig. 19 - " orbiculatus
Fig. 20 - " hypoleucus
Fig. 21 - " Loeseneri
Fig. 22 - " glaucophyll
Fig. 23 - " scandens
Fig. 24 - " flagellaris
Fig. 25 - " rosthornianus
Fig. 26 - " angulatus
PLATE III

Cross Sections of the Bast Fibers

X241

Fig. 27 - Celastrus speciformis
Fig. 28 - " reticulatus
Fig. 29 - " glaucophyll
Fig. 30 - " rosthornianus
Fig. 31 - " orbicularis
Fig. 32 - " scandens
Fig. 33 - " paniculatus
Fig. 34 - " Hookeri
Fig. 35 - " hypoleucus
Fig. 36 - " angulatus
Fig. 37 - " flagellaris
Fig. 38 - " rugosus
Fig. 39 - " Loeseneri
PLATE IV

Cross Sections of the Cork

Fig. 40 - Gelastrus scandens
Fig. 41 - " orbiculatus
Fig. 42 - " paniculatus
Fig. 43 - " reticulatus
Fig. 44 - " rosthornianus
Fig. 45 - " flagellaris
Fig. 46 - " Loeseneri
Fig. 47 - " angulatus
Fig. 48 - " glaucophyll
Fig. 49 - " speciiformis
Fig. 50 - " rugosus
Fig. 51 - " hypoleucus
Fig. 52 - " Hookeri

Longitudinal Sections of the Epidermis of Some One Year Old Stems Before the Formation of Cork.

X213

Fig. 53 - Gelastrus scandens
Fig. 54 - " hypoleucus
Fig. 55 - " Loeseneri
Fig. 56 - " flagellaris
Fig. 57 - " angulatus
PLATE IV (Cont'd)

Fig. 58 - Celastrus rugosus

Cross Sections of Epidermis of some One Year Stems Before
The Formation of Cork.
X273.

Fig. 59 - Celastrus angulatus
Fig. 60 - " rugosus
Fig. 61 - " flagellaris
Fig. 62 - " hypoleucus
Fig. 63 - " Loeseneri

Hypoderm in the Leaf
X213

Fig. 64 - Celastrus speciformis
Fig. 65 - " glaucophyll

Sclerenchyma parenchyma cells on the outside of the Cork.
X213

Fig. 66 - Celastrus reticulatus
Fig. 67 - " hypoleucus
Fig. 68 - " paniculatus
Fig. 69 - " speciformis
Fig. 70 - " orbiculatus
Fig. 71 - " rosthornianus
PLATE V

The Upper and Lower Epidermis of Each Species.

X223

Fig. 72 - Celastrus glaucophyll

Fig. 73 - hypoleucus

Fig. 74 - rugosus

Fig. 75 - Hookeri

Fig. 76 - Loeseneri

Fig. 77 - flagellaris

Fig. 78 - angulatus

Fig. 79 - reticulatus

Fig. 80 - rosthornianus

Fig. 81 - paniculatus

Fig. 82 - speciformis

Fig. 83 - orbiculatus

Fig. 84 - scandens

Cross Section of Stomata

X223

Fig. 85 - Celastrus rosthornianus

Fig. 86 - rugosus

Fig. 87 - paniculatus

Fig. 88 - glaucophyll

Fig. 89 - orbiculatus

Fig. 90 - flagellaris
PLATE V (Cont'd)

Fig. 91 - Celastrus hypoleucus
Fig. 92 - " angulatus
Fig. 93 - " Hookeri
Fig. 94 - " speciformis
Fig. 95 - " Loeseneri
Fig. 96 - " reticulatus
Fig. 97 - " scandens
PLATE VI

Venation

X8.4

Fig. 98 - Celastrus flagellaris
Fig. 99 - orbiculatus
Fig. 100 - reticulatus
Fig. 101 - Loeseneri
Fig. 113 - scandens

Habit Sketch

Reduced to 24% of natural size.

Fig. 102 - Celastrus angulatus
Fig. 103 - scandens
Fig. 104 - reticulatus
Fig. 105 - rugosus
Fig. 106 - glaucophyll
Fig. 107 - hypoleucus
Fig. 108 - flagellaris
Fig. 109 - Hookeri
Fig. 110 - Loeseneri
Fig. 111 - orbiculatus
Fig. 112 - paniculatus
Fig. 114 - speciformis
Fig. 115 - rosthornianus
Fig. 116 - Celastrus hypoleucus
Fig. 117 - " rugosus
Fig. 118 - " paniculatus
Fig. 119 - " glaucophyll
Fig. 120 - " rosthornianus
Fig. 121 - " angulatus
Fig. 122 - " Hookeri
Fig. 123 - " speciformis
PLATE VII

Cross Sections of Leaf Margins.

FIG. 124 - Celastrus angulatus
FIG. 125 - " flagellaris
FIG. 126 - " scandens
FIG. 127 - " rugosus
FIG. 128 - " speciformis
FIG. 129 - " orbiculatus
FIG. 130 - " paniculatus
FIG. 131 - " hypoleucus
FIG. 132 - " glaucophyll
FIG. 133 - " reticulatus
FIG. 134 - " rosthomianus
FIG. 135 - " Hookeri
FIG. 136 - " Loeseneri

Cross Section of Root of Celastrus scandens

FIG. 137 - Old root
FIG. 138 - Younger root.
Fig. 139 - Cross section of root of Celastrus scandens - X74
PLATE X

Cross Sections of Midribs,

X74

Fig. 140 - Celastrus reticulatus
Fig. 141 - " hypoleucus
Fig. 142 - " Hookeri
Fig. 143 - " scandens
Fig. 144 - " angulatus
PLATE XI

Cross Sections of Midribs

X74

Fig. 145 - Celastrus glaucophyll
Fig. 146 - " Loeseneri
Fig. 147 - " rosthornianus
Fig. 148 - " orbiculatus
Fig. 149 - " paniculatus
PLATE XII

Cross Sections of Midribs

X74

Fig. 150 - Celastrus rugosus
Fig. 151 - " flagellaris
Fig. 152 - " speciformis
PLATE XIII

Cross Sections of Petioles

x54

Fig. 153 - Calastrus orbiculatus
Fig. 154 - " hypoleucus
Fig. 155 - " scandens
PICTE XIV

Cross Sections of Petioles

X54

Fig. 156 - Celastrus rogusus
Fig. 157 - " rosthornianus
Fig. 158 - " reticulatus
PLATE XV

Cross Sections of Petioles

Fig. 159. - Celastrus paniculatus X54
Fig. 160. - " speciformis X43
PLATE XVI

Cross Sections of Petioles

Fig. 161 - Celastrus glaucophyll X54
Fig. 162 - " Hookeri X43
PLATE XVII

Cross Sections of Petioles

Fig. 163 - Celastrus Loeseneri X54
Fig. 164 - " angulatus X45
PLATE XVIII

Cross Section of Petiole

X54

Fig. 165 - Celastrus flagellaris.
Fig. 166 - Cross section of one year old stem of Celastrus scandens X74

Fig. 167 - Cross section of two year old stem of Celastrus scandens X74
Fig. 168 - Cross section of a one year old stem of Celastrus paniculatus X74
Fig. 169 - Cross section of a two year old stem of Celastrus paniculatus X74
Fig. 170 - Cross section of a one year old stem of Celastrus orbiculatus X74

Fig. 171 - Cross section of a two year old stem of Celastrus orbiculatus X74
Fig. 172 - Cross section of a one year old stem of Celastrus flagellaris X74

Fig. 173 - Cross section of a two year old stem of Celastrus flagellaris X74
Fig. 174 - Cross section of a one year old stem of Celastrus Loeseneri X74

Fig. 175 - Cross section of a two year old stem of Celastrus Loeseneri X74
Fig. 176 - Cross section of a one year old stem of *Celastrus angulatus* X74

Fig. 177 - Cross section of a two year old stem of *Celastrus angulatus* X74
Fig. 178 – Cross section of a one year old stem of Celastrus rugosus X74
Fig. 179 – Cross section of a two year old stem of Celastrus rugosus X74
Fig. 180 - Cross section of a one year old stem of Celastrus hypoleucus X74
Fig. 181 - Cross section of a two year old stem of Celastrus hypoleucus X74
PLATE XXVII

Fig. 182 - Cross section of a one year old stem of Celastrus Hookeri X74

Fig. 183 - Cross section of a two year old stem of Celastrus Hookeri X74
Fig. 184 - Cross section of a one year old stem of Celastrus glaucophyll X74

Fig. 185 - Cross section of a two year old stem of Celastrus glaucophyll X74
Fig. 166 - Cross section of a one year old stem of 
Celastrus speciformis X74 

Fig. 167 - Cross section of a two year old stem of 
Celastrus speciformis X74
Fig. 188 - Cross section of a one year old stem of Celastrus rosthornianus X74

Fig. 189 - Cross section of a two year old stem of Celastrus rosthornianus X74
Fig. 190 - Cross section of a one year old stem of Celastrus reticulatus X74

Fig. 191 - Cross section of a two year old stem of Celastrus reticulatus X74
THE ROOT

A very brief study was made of the root of scandens (Figs. 137, 138, and 139), to ascertain if caoutchouc was present.

In the cortex of the root and in the outer part of the phloem a brownish product was present. When stained with Sudan III it was a little redder in color and it was thought that this was perhaps caoutchouc. However, when fresh sections were cut and some put thru ether and others thru carbon bisulphide. These reagents would have dissolved out caoutchouc. However, when these sections were stained with Sudan III the brownish red material was still present so it could not have been caoutchouc.

When stained with iodine the sections showed a great deal of starch stored in the form of defined round grains.
CONCLUSION

The first object of this research has been to determine the anatomical situation in the genus Celastrus and upon what sets of characters the species could be distinguished.

The anatomical situation has been set forth in the preceding pages, and I shall make a brief survey of the landmarks throughout the species which are constant. In the leaf one finds the following situation; bifacial character; no trichomes; stomata oval to round, with hooks projecting from the cuticle; stomata on the lower side of the leaf only; upper epidermal cells larger than the lower; and outer wall thicker than the inner; outer wall of epidermal cells cutinized; two rows of palisade cells; midrib extending above the upper epidermis and below the lower; and a single vascular bundle in the midrib and the petiole.

In the stem the following features are constant; the formation of cork by the end of the first year; a bast fiber ring between the parenchyma of the cortex and pericycle; a ring of phloem uniform in breadth; narrow medullary rays; and heterogenous pith.

Certain of these constant characters varied in minor details between the different species, and these as well as other characters less constant throughout all of the
species but constant in one could be used as bases for classification. As an example of a constant character which varies in minor details between the species, may I cite the following examples: a bast fiber ring is always present but a key may be made from the differences in the size and shape of the fibers and their various grouping. Also the cork is always present in the two-year-old stems but here again are differences in the size, shape, and disposition of the cells. In the petiole and midrib there is a single vascular bundle but it is variously shaped. As an example of a character used in classification which is not constant throughout the genus but constant in one or more species, note the following; in certain species a thin-walled hypoderm is found under the upper epidermis in the blade of the leaf, in other species it is absent; the subsidiary marginal ribs parallel to the midrib and near the tip sometimes curve in to join the midrib and sometimes do not; side walls of the epidermal cells may or may not be undulating; subsidiary epidermal cells sometimes subtend the guard cells; the outer walls of the epidermis may be entirely cutinized or partly cellulose; the spongy parenchyma cells occur in regular or irregular rows; the midrib and petioles may have even margins or the margins may be very irregular; and the pith is either chambered
or continuous.

All these various characters have been used in making keys to the identity of the species. The occurrence of crystals was found to be too unstable to allow its use in making keys. Also relative sizes of different features were found to be too uncertain for taxonomic use.

A second purpose of this study was to determine the effect of geographical distribution upon the anatomical characters. As has been stated above, all thirteen of the species studied were alike in numerous respects. The marked similarity of both the stems and the leaves would lead one to assume that there was at one time an ancestor common to all. Since most of the species are native to Eastern Asia it is likely that the genus originated in that quarter of the world. It seems that the mutations and possible hybridizations which gave rise to new species must have occurred chiefly after Asia and North America became separated and after Japan was no longer a part of the continent of Asia. My reason for assuming this fact is the evident close relationship of paniculatus from the Himalayas, orbiculatus from China and Japan, and scandens from North America. It is likely that the original ancestor was very like these for the three are more alike anatomically than they are like any
other species.

As evidence for this statement note the following similarities between these species; the side walls of the upper and lower epidermal cells of these three species are undulating and this is true of no other species. The veins in these species are of about the same frequency. The petioles are very similar; in each of the three the upper margin between the wings in the petiole is convex and the lower margin is regular. This is true of only one other species, hypoleucus which is not especially like these species in other features. The vascular bundle in these species is of the same general shape. There are very few crystals in any of the three. In the stems these species are again found to be very like in structure. The bast fibers are similar and the cork is remarkably similar. The pith cells as seen in longitudinal section are so alike as to make it impossible to distinguish between the three.

One would expect these three species with such distant geographical isolation to show greater anatomical differences than the rest of the species which we know have originated in China, however this is not the case, as will be seen by a comparison of the Chinese species.

Loeseneri, hypoleucus, and rosthornianus; are from Central China. Very little anatomical similarity could
be found in the stomata, venation, midrib, margins, or petioles of the leaves, or of the pith, or bast fibers, of the wood of these three species. Loeseneri and hypoleucus have sclerotic epidermal cells and rosthornianus does not have. In Loeseneri and rosthornianus the wood is somewhat similar though the tracheal tubes are larger in Loeseneri.

Speciformis and rugosus originated in West China. Here again we find more differences than similarities between the two. The epidermal cells, stomata, and margins of the leaves are not alike and the pith, medullary rays, and the bast fibers of the stems are not at all alike. The meshes of the leaves are of about the same frequency.

Hookeri from South China and angulatus, merely listed as originating in China, are not strikingly like any other species.

The origin of the rest of the species is not known.

This would lead one to the conclusion that for one reason or another, which we do not know, those species whose native home is China have been mutating and possibly hybridizing more than the species in the Himalayas or Japan or North America.
BIBLIOGRAPHY


Metz - Anatomie der Laubblätter der Celastrineen
Dissertation Erlangen 1905, 78 pp. separate copy from Beihefte zum botanischen Centralblatt XV.

Moller - Anatomie der Baum Rinden 1876

Pierre - Flore forest. de la Cochinchine XIX 1895

Plitt - Blattstiel, Dissertation, Marburg 1886

Schenck - Anatomie der Lianen, 1893

Solereder - Systematic Anatomy of the Dicotyledons, 1908

Stenzel - Anatomie der Laubblätter und Stämme der Celastraceae und Hippocraceaceae, Breslau 1893

Wehmer - Die Pflanzenstoffe. Phanerogamen 1911.