A COMPARATIVE ANATOMICAL STUDY OF THE
GENUS SORBUS AND SOME OF ITS HYBRIDS

by

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Approved by:

[Signature]
Chairman of Dept.

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The genus Sorbus is composed of deciduous trees and shrubs having buds with imbricate scales, alternate, stipulate, simple and serrate or odd-pinnate leaves, which are usually folded in the bud.

The flowers are white, rarely pink, borne in compound terminal corymbs. There are 5 sepals and 5 petals. The number of stamens ranges from 15 to 20. There are from 2 to 5 carpels each of which is 2-ovuled and either partly free and half superior or wholly connate and inferior. The styles are free or connate at the base. The fruit is a 2 to 5-loculed pome and is usually rather small. The locules have cartilaginous walls and each contains 1 or 2 seeds.

There are about 80 species of Sorbus distributed through the northern hemisphere: in N. America to N. C. and N. Mex; in Asia to the Himalaya Mountains. Some species are found in the northern part of Europe.

The Sorbuses are very attractive when in bloom and most of them bear showy red fruit in autumn.

They belong to the family, Rosaceae, and sub-family, Pomoideae.

(') Rehder -- Manual of Cultivated Trees and Shrubs.
The following key to the genus Sorbus is given by Rehder (Manual of Cultivated Trees and Shrubs - '27).

**SORBUS**

A. Lvs. all regularly pinnate.

B. Fr. small 6-10 mm. thick, berry-like, red, rarely yellow or white.

C. Lfts. 9-17, 1.5-10 cm. long.

D. Fr. red or yellow; styles 2-4

E. Winter-buds glutinous, glabrous or slightly rusty-pubescent.

F. Lfts. acuminate, lanceolate.

G. Lvs. bright green and dull above; lfts. 11-17; infl. 6-12 cm. across: trees.

H. Lfts. acuminate, 4-10 cm. long, with acute or acuminate teeth, slightly pubescent beneath while young.

1. **S. AMERICANA**

HH. Lfts. long-acuminate, 2.5-8 cm. long, with aristate teeth, quite glabrous beneath (except in the var.)

2. **S. COMMIXTA**
GG. Lvs. dark green and lustrous above; lfts. 9-11; infl. glabrous, 4-6 cm. across: shrub  
3. S. SAMBUCIFOLIA

FF. Lfts. rounded or abruptly acute at the apex, oblong.  
4. S. DECORA

EE. Winter-buds not glutinous, woolly-pubescent.

F. Young brts. and lvs. pubescent.

G. Stipules large, persistent  
5. S. POHUASHANENSIS

GG. Stipules small, caducous  
6. S. AUCUPARIA

FF. Young brts. and lvs. glabrous or nearly so.  
7. S. TIANSHANICA

DD. Fr. white: lvs. glaucous and glabrous beneath; rachis usually purple.  
8. S. DISCOLOR

CC. Lfts. 19-29, 8-25 mm. long.

D. Lfts. serrate usually only above the middle: infl. rufous-pubescent: fr. pale rosy-red.  
9. S. VILMORINI

DD. Lfts. serrate from near the base; fr. whitish; infl. nearly glabrous.  
10. S. KOEHNEANA

BB. Fr. 1.5-3 cm. across, apple- or pear-shaped, yellowish, with red cheek and with grit-cells;
styles 5. 11. S. DOMESTICA

AA. Lvs. pinnate only toward the base, the upper part lobed and serrate, occasionally only lobed. (See also Sorbaronia, p. 383)

Leaves simple, lobed or serrate

A. Fr. with persistent calyx.

B. Lvs. glabrous beneath at length, broad-ovate, lobed: ovary inferior: fr. brown, with grit-cells.

13. S. TORMINALIS

BB. Lvs. tomentose beneath or glabrescent and not lobed: ovary half-inferior: fr. usually red, without grit-cells.

C. Lvs. lobed.

D. Lvs. broad-ovate, with 4-6 pairs of veins, usually rounded at base.

14. S. LATIFOLIA

DD. Lvs. ovate to ovate-oblong, with 4-8 pairs of veins, broad-cuneate at base.

15. S. INTERMEDIA

CC. Lvs. sharply and doubly serrate.

D. Fls. white: lvs. white-tomentose beneath.

16. S. ARIA

DD. Fls. pink, with upright petals: lvs. usually glabrous beneath.

17. S. CHAMAEMESPILUS

AA. Fr. with deciduous calyx.

B. Lvs. glabrous beneath or nearly so.
C. Styles usually 2. 18. S. ALNIFOLIA
CC. Styles 5. 19. S. CALONEURA
BB. Lvs. white-tomentose beneath.
C. Lvs. serrulate. 20. S. FOLGNERI
CC. Lvs. lobulate. 21. S. JAPONICA
GEOGRAPHICAL DISTRIBUTION AND INTRODUCTION INTO CULTIVATION

The species of Sorbus and Sorbopyrus which are discussed in this thesis have the following geographical distribution and introduction into cultivation.

S. Aucuparia - L.

This species is sometimes called the European Mountain Ash and is found from Europe to Western Asia. It has long been in cultivation.

S. hybrida - L.

S. hybrida was first found in Scandinavia. It has been cultivated since 1779.

S. intermedia - Pers.

This species is a native of northern Europe and has long been in cultivation.

S. commixta - Hedl.

S. commixta was found originally in Korea, Saghal., and Japan. It has been in cultivation since 1880.

S. Aria - Crantz.

This species is a native of Europe and has long been in cultivation.

S. americana - Marsh.

This species is native from Newfoundland to Manitoba and south to North Carolina and Michigan. It was first introduced into cultivation in 1782.

Sorbopyrus auricularis - Schneid.

This hybrid originated before 1620.
Very little literature has been published on anatomical research within the genus Sorbus. The following summary of previous research is given by Solereder (Systematic Anatomy of the Dicotyledons - 1908).

Petit (Pétiole: Mém. Soc. sc. phys. et nat. de Bordeaux, sér. 3, t. III, 1887, pp. 265-71 and pl. I-III) says that the most widely distributed condition is the presence of 3 or 5 vascular bundles.

Gerard (L'anat. comp. végét. appl. à la classification. Sur les Pomacees, Thèse, Paris, 1884, 67 pp. and 4 pl.) describes the entrance of 3 vascular bundles into the petioles of Pomeae in general (with the exception of S. Aucuparia). He also says that the pericycle contains primary bundles of hard bast, which become united to one another locally by means of stone cells.

Möller (Rindenanat. 1882, pp. 354-74) says that the variously constituted fibers that compose the secondary bast are arranged in connected cylinders disposed concentrically in Sorbus.

Solereder (Systematic Anatomy of the Dicotyledons, 1908) says that the breadth of the medullary rays and the size of the lumina of the vessels vary. Also, spiral thickening of the pitted vessels has been observed.
The ends of the tracheal elements have circular perforations with a network of bars in *S. Aucuparia*.

Molisch (Kohlens. Kalk., in Sitz. Ber. Wiener Akad. Bd. LXXXIV, Abt. 1, 1881, p. 13) says the lumen of the vessels has been observed to be filled with carbonate of lime in the heart-wood of *Sorbus torminalis*.

Gris (Moelle. Nouv. Arch. Mus. d'hist. nat., t. VI, 1870, pp. 269-78 and pl. 17) describes the pith of species of *Sorbus* as being heterogeneous, in which case the peripheral part of the pith is formed of active cells with fairly small lumina and thick walls, while the central part is occupied by empty cells with larger lumina and thinner walls in addition to active cells of the structure described. The active cells of the interior of the pith frequently contain tannin, and in that case are arranged in rows.

Aside from the literature summarized by Solereder, Burgerstein (Vergleichend -- histologische Untersuchungen der Pomaceaen. Sitzungsberichte der Keiserlichen Akad. der Wissenschaften. Naturwissenschaftliche Classe. Band CIV. Abteilung I, 1895, p. 723.) has contributed to the literature on *Sorbus*. He says that in all species of *Sorbus* investigated, a tertiary thickening in the form of a spiral band is formed. The walls of the tracheids are relatively strongly thickened and have bordered
pits placed at a slant with the vertical.

Burgerstein agrees with P. Schulz (Jahrbücher des Königlichen Botanischen Gartens und Botanischen Museums zur Berlin, II Band, 1883. p. 227.) when he says, "Essentially the same picture is presented by the medullary rays of Pirus, Crataegus oxyacantha, Sorbus Aucuparia, Cyconia vulgaris, Mespilus germanica, Cotoneaster vulgaris." Even though this similarity in appearance does exist, Burgerstein says that relative differences do occur which furnish differentiating characters; for instance, the minimum height of medullary ray cells in one genus may be the maximum height in another. Burgerstein observed that all Pomaceae show an essential similarity in the structure of the wood; but some genera (Cydonia, Mespilus, etc.) or groups (Sorbeae) can be distinguished by sections of the wood. However, the species differ less in the structure of the wood than they do in the outer form of their members. See table on following page.

Burgerstein (Weitere Untersuchungen über den histologischen Bau des Holzes der Pomaceen, Nebst Bemerkungen über das Holz der Amygdaleen - Sitzungsberichte der Keiserlichen Akademie der Wissenschaftliche Classe. Band CV. Abtheilung 1. Jahrgang 1896. p. 552.) investigated the wood anatomy of 130 species, varieties, and
I - Name of species  
II - Width of tracheal tubes  
III - Width of tracheids  
IV - Width of wood parenchyma  
V - Height of medullary rays  
VI - Breadth of medullary rays  
VII - Number of rays per sq. mm.

NOTE: Measurements are given in microns.

<table>
<thead>
<tr>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aucuparia</td>
<td>49.3-50.5</td>
<td>14.8-17.2</td>
<td>17.3-17.5</td>
</tr>
<tr>
<td>Aria I</td>
<td>39.0-44.4</td>
<td>15.8-16.1</td>
<td>21.4-22.6</td>
</tr>
<tr>
<td>Aria II</td>
<td>39.0-42.0</td>
<td>14.2-14.9</td>
<td>19.4-20.4</td>
</tr>
<tr>
<td>domestica</td>
<td>40.7-46.5</td>
<td>13.7-16.0</td>
<td>18.5-20.8</td>
</tr>
<tr>
<td>obtusifolia</td>
<td>38.8-42.1</td>
<td>16.5-17.2</td>
<td>21.0-21.4</td>
</tr>
<tr>
<td>suecica</td>
<td>45.4-48.5</td>
<td>15.0-16.3</td>
<td>20.8-21.4</td>
</tr>
<tr>
<td>torminalis I</td>
<td>41.0-44.0</td>
<td>14.6-15.0</td>
<td>18.5-20.4</td>
</tr>
<tr>
<td>torminalis II</td>
<td>38.5-40.5</td>
<td>14.4-15.4</td>
<td>21.4-22.0</td>
</tr>
<tr>
<td>RANGE</td>
<td>38.5-50.5</td>
<td>13.7-17.2</td>
<td>17.3-22.6</td>
</tr>
<tr>
<td></td>
<td>V</td>
<td>VI</td>
<td>VII</td>
</tr>
<tr>
<td>----------------</td>
<td>------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td><em>Aucuparia</em></td>
<td>14.1-15.2</td>
<td>11.5-12.6</td>
<td>11.1-11.8</td>
</tr>
<tr>
<td><em>Aria I</em></td>
<td>16.2-16.7</td>
<td>13.0-14.0</td>
<td>9.0-10.3</td>
</tr>
<tr>
<td><em>Aria II</em></td>
<td>16.1-16.5</td>
<td>13.1-14.0</td>
<td>9.4-10.3</td>
</tr>
<tr>
<td><em>domestica</em></td>
<td>15.8-16.3</td>
<td>12.6-14.4</td>
<td>12.0-12.5</td>
</tr>
<tr>
<td><em>obtusifolia</em></td>
<td>15.9-16.7</td>
<td>12.7-16.0</td>
<td>19.8-10.0</td>
</tr>
<tr>
<td><em>suecica</em></td>
<td>18.4-19.8</td>
<td>15.4-18.0</td>
<td>9.2-11.0</td>
</tr>
<tr>
<td><em>torminalis I</em></td>
<td>14.7-15.4</td>
<td>12.0-13.8</td>
<td>11.2-12.0</td>
</tr>
<tr>
<td><em>torminalis II</em></td>
<td>14.9-15.4</td>
<td>12.0-14.0</td>
<td>11.2-11.5</td>
</tr>
<tr>
<td><em>RANGE</em></td>
<td>14.1-19.8</td>
<td>11.5-16.0</td>
<td>9.0-12.5</td>
</tr>
</tbody>
</table>
hybrids of the Pomaceae. He gives the measurements seen in the table on the following page.

Sargent (The Silva of North America.) says that Pyrus Americana (Sorbus americana) was first distinguished by Humphrey Marshall, the Pennsylvania botanist, who described it in his Arbustum Americanum in 1785, although it is said to have been introduced into English gardens years earlier. It is sometimes planted in Canada and in the northern United States in the neighborhood of houses on account of the beauty of its fruit.

Rehder (Manual of Cultivated Trees and Shrubs, 1927) has included Sorbopyrus, Sorbus, and Pyrus in his classification of plants.
### Table of Measurements

<table>
<thead>
<tr>
<th>I - Name of species</th>
<th>II - Breadth of tracheal tubes</th>
<th>III - Height of Ray cells</th>
<th>IV - Number of rays per sq. mm. of wood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pyrus communis</td>
<td>34-40</td>
<td>14-15</td>
<td>14-15(\frac{1}{2})</td>
</tr>
<tr>
<td>Sorbus Aria</td>
<td>39-44</td>
<td>16-16(\frac{1}{2})</td>
<td>9-10</td>
</tr>
<tr>
<td>P. Bollwilleriana (Sorbopyrus)</td>
<td>35-45</td>
<td>15(\frac{1}{2})-16(\frac{1}{2})</td>
<td>11-11(\frac{3}{4})</td>
</tr>
<tr>
<td>P. bulbiformis</td>
<td>38-43</td>
<td>17-18</td>
<td>10-11</td>
</tr>
</tbody>
</table>

**NOTE:** All measurements are given in microns.
INTRODUCTION TO THE ANATOMICAL STUDY OF
STEMS AND LEAVES

Rehder ('27) and others have classified Sorbus according to its gross structure, but little has been done in the anatomical study of this genus. In my thesis, I am using Rehder's classification of the species studied and I am quoting his general description of the leaves of these species. By means of a detailed anatomical study of S. Aucuparia, S. Aucuparia var., S. Aucuparia pendula, S. Commixta, S. hybrida, S. intermedia, S. americana, S. Aria, and Sorbopyrus with its Pyrus parent, P. communis, I have endeavored to make a comparison of the minute structures of these species in order to determine the relationship existing between the various species.

I was able to obtain fresh material of the stem of S. Aria and the stem and leaves of S. americana. This material was obtained from the Arnold Arboretum the last of April. I placed the fresh material in 95% alcohol and pumped the air out of it. The material was then placed in 70% alcohol and its subsequent treatment was similar to that given the preserved material after it had been placed in 70% alcohol.

The preserved material was collected at the Arnold Arboretum in August. It was first preserved in 4% formaldehyde and later transferred to 70% alcohol. I re-
moved portions of the stems and petioles from the alcohol and placed them in phials containing equal parts of 80% alcohol and glycerine. They remained in this several weeks before being sectioned. Leaves to be bleached for the study of venation were first placed in phials containing a saturated solution of chloral hydrate, where they remained for 7 weeks and were then transferred to a bleaching solution (made by dissolving bleaching powder in water). They remained in this for 1 week and were then rinsed in a 5% solution of hydrochloric acid and again placed in chloral hydrate for 1 week. At the end of this time, they were washed in water and placed in hydrogen peroxide for 1 week after which they were placed in chloral hydrate for 4 days. The tips were then mounted in equal parts of water and glycerine. Drawings were then made of the venation of the leaf tips. It was extremely difficult to bleach leaves that had been preserved, while the fresh leaves were entirely bleached after they had remained in chloral hydrate only 3 days.

Bits of epidermis were stripped from both the upper and lower surfaces of the leaves and were mounted in equal parts of water and glycerine. Drawings which showed a magnification of 530 diameters were made of the epidermis and trichomes.

In order to make sections of the midribs and margins of the leaves it was necessary to first embed the materi-
ial in paraffin. The following method was used:

Pieces about 4 mm. long and 3 mm. wide, were cut from the middle of the midribs and margins. The material was taken from 70% alcohol and placed in each of the following grades of alcohol for hardening:

- 70% alcohol for 2 hours
- 80% alcohol for 2 hours
- 95% alcohol for 2 hours
- 100% alcohol for 2 hours
- 100% chloroform for 2 hours
- 50/50% alcohol and chloroform for 2 hours.

An aluminum capsule was then placed in the phial and enough chloroform left in the phial to cover the capsule for .25 in. A stick of soft paraffin was placed in the phial and allowed to rest on top of the capsule. As much paraffin as possible was allowed to dissolve at room temperature. Then the phial was placed on the oven until no more paraffin would dissolve at that temperature. The cork was then removed from the phial and all undissolved paraffin and the capsule were taken out. The unstoppered phial was then left in the oven at 52 deg. C. until all the chloroform had evaporated. The contents of the phial were poured into paper trays half-filled with melted paraffin and were arranged in orderly fashion. The tray was
plunged into ice water as soon as the surface crust had formed. This method for embedding was taken from Stevens (Plant Anatomy, '24). Blocks of the embedded material were enclosed in hard paraffin and cut on a Jeffrey-Thompson sliding microtome. The sections were placed on a slide and washed with xylene to remove the paraffin. They were then washed in 95% alcohol and chloral hydrate was dropped on the sections at intervals for 1.5 hours. Then wet bleaching powder was placed on top of the sections in chloral hydrate. The sections were kept moist by the addition of more chloral hydrate. After they had been treated in this manner for about 1 hour the chloral hydrate and bleaching powder were washed off with 5% hydrochloric acid. Chloral hydrate was again added and the sections remained in this for another half-hour. They were then washed in water, dehydrated with 95% alcohol and mounted in sandarac. Drawings which showed a magnification of 530 diameters were made of the margins. Photomicrographs were made of the midribs.

The stems and petioles were enclosed in paraffin and sectioned. The petiole sections were made at the middle of the petiole while sections of stems were made near the tip of the youngest internode and of an internode that was several years old. The sections were bleached in chloral hydrate for about 30 min., washed
with water, dehydrated with 95% alcohol and mounted in sandarac. The petiole section of *P. americana*, Fig. 99, was run up in the following grades of xylene: 75% alcohol and 25% xylene, equal parts of alcohol and xylene, and 100% xylene. The section was then mounted in hyrax. It is evident that hyrax is superior to sandarac for the production of clear photomicrographs. Sections of stems and petioles were photographed at a magnification of 33 diameters.

Macerations were made of stem sections by dropping radial sections into hot nitric acid to which a few crystals of potassium chlorate had been added. The nitric acid and macerated sections were poured into water and then dehydrated with 95% alcohol and mounted in sandarac. Drawings were made of the bast fibers, tracheal tube elements, xylem rays and parenchyma cells of the cortex. The drawings show a magnification of 530 diameters.

All drawings were inked and mounted on sheets of cardboard 18"x 27". These were photographed with a dry plate camera. The diaphragm was set at f/6 and an exposure of 25 sec. was given. The plates were developed in a developer made by using one tube of Eastman's Developer dissolved in 360 cc. of water. They were then placed in hypo which was made by dissolving 1 lb. of
Eastman's Kodak Acid Fixing Powder in 1,830 cc. of distilled water. They remained in the hypo for 10 min. and were then washed. Positive prints were made by exposing Rito Hard 31 paper, from 10 to 15 sec. and then developing in developer made by dissolving 1 tube of Eastman's Developer in 180 cc. of water. The prints were then left in hypo for 10 min. before washing. In these photographs, the drawings were reduced about 3.3 times.

Photomicrographs were made by using a photomicrograph apparatus illuminated by a 100 watt frosted Mazda bulb. Cramers Photo Dry Plates, sizes 3½"x3½", 2½"x 2½", and 4"x 5" were exposed for 20 sec. They were then developed in a developer made by dissolving 1 tube of Eastman's developer in 230 cc. of distilled water. The photomicrographs of stems and petioles show a magnification of 33 diameters, while those of the midribs show a magnification of 64 diameters. Prints were made by exposing Rito Hard No. 31 paper from 5 to 10 seconds. These prints were developed in the same manner as the other prints.
Introduction:

Microchemical tests were made on material which had been preserved in 4% formaldehyde.

For determining the presence of starch, a solution of potassium iodide-iodine was used. This gives a dark blue or black reaction with starch.

Two tests were made for proteins. In the first test concentrated nitric acid was placed on the section and was then followed by ammonia. The nitric acid caused the protein to turn yellow and the ammonia deepened the yellow color. For the second test I used a strong solution of potassium iodide-iodine which gave a yellow to brown reaction with protein.

Sudan III was used in testing for fats, oils, resins, cutin and suberin, all of which turn a reddish color when tested in this manner.

Sections to be tested for sugar were placed in a drop of Fehling's solution and covered with a cover glass. They were then heated over a flame until bubbles arose in the solution. If glucose was present orange crystals of cuprous oxide were formed.

In detecting the presence of glucosides, the sections were first tested for sugar and then placed in phials containing Fehling's solution. The phials were stoppered and placed in the paraffin oven for 48 hours. The sections test-
ed only for sugar and those that had been placed in the oven were compared. If glucosides were present, they were converted to sugar while kept in the oven. Therefore, an additional sugar reaction would indicate the presence of glucosides.

A saturated solution of ferric chloride was used in testing for tannin. When tannin was present a dark blue or dark green precipitate was formed.

In testing the crystals that were present in the material, I first used the polariscope to distinguish the crystals. I then placed hydrochloric acid on a section and watched the crystals disappear. In my species all the crystals disappeared without any effervescence which showed that they were crystals of calcium oxalate.

The test for lignin was made by placing a solution of phloroglucin in alcohol on the section and then following this by concentrated hydrochloric acid. This caused the lignified walls to turn a deep reddish violet color.

**Stems**

Starch:

The location of starch was almost identical in all the species of Sorbus studied. Cells containing starch were distributed throughout the cortex, especially in the region immediately external to the interrupted cylinder of primary bast fibers. The rays contain considerable starch. An average of four outer rows of active pith cells showed the
presence of large quantities of starch. Starch was especially abundant in the active cells in the points of the stellate pith. Most of the active cells of the interior pith showed the presence of starch as well as tannin. A few of these cells seemed to contain only starch and a few only tannin. *S. americana* was an exception to this since there was no starch and very little tannin present in the central pith of this species. However, this species was the only one which had an endodermis in the stem.

*Sorbopyrus* is quite different from the species of *Sorbus* examined. In *Sorbopyrus* very little starch is present in the cortex. The numerous rays are filled with starch. It is present in many of the parenchyma cells of the xylem and in some of the parenchyma cells of the phloem. The entire pith of the three-year-old section tested is loaded with starch. The greater abundance of starch in *Sorbopyrus* than in the species of *Sorbus* studied is quite noteworthy. With respect to starch content and distribution, *Sorbopyrus* does not resemble its *Sorbus* parent very closely.

**Tannin:**

Like starch, tannin was similarly located in all species of *Sorbus* studied. Many cells of the cortex contain tannin, notably those of the outer cortex and those surrounding the bundles of primary bast fibers. Tannin is abundant in the rays of the phloem and less abundant in
in the rays of the xylem. Many of the active cells of the peripheral part of the pith as well as many of the active cells of the interior pith, contain tannin. S. americana contained less tannin than the other species studied. The similarity in location of starch and tannin in Sorbus is quite striking. With the exception of the rays, greatest quantities of tannin are found where greatest quantities of starch are found.

In Sorbopyrus, large quantities of tannin are found in the outer cortex and smaller quantities in the region of the primary bast fibers. Some tannin is found in the rays and in some of the cells of the pith (all of which are active in Sorbopyrus).

The difference in distribution of tannin in Sorbopyrus and Sorbus is quite evident. In Sorbopyrus, greatest quantities of tannin are found in the regions where smallest quantities of starch are found.

Proteins:

Proteins were present in some of the cells of the cortex in Sorbus. The phloem gave a protein reaction. A small amount of protein was present in the rays of the phloem. Some of the active cells in the peripheral part of the pith contained protein. Some of the active cells of the interior pith contained protein as well as other substances.

Very little protein is present in the cortex of Sor-
Some is present in the phloem and rays. Nearly all of the cells of the pith contain large amounts of protein.

Fats and Oils:

I found no volatile oils present. Fats or oils are found in some of the cells of the cortex, the rays, and in the sclerenchymatous cells in the peripheral part of the pith. This is true of all species of Sorbus that were tested with the exception of S. Aucuparia, which contained very little oil.

Oil is rather abundant in Sorboppyrus, especially in the collenchyma of the cortex. Other cortical cells as well as ray cells and some pith cells, contained oil.

Cutin and Suberin:

The Sudan III test showed from 4 to 6 rows of cork cells around the stem. One could see that other layers of cork had sloughed away in most instances. The outer walls of the remaining epidermal cells showed a cutin reaction more or less. A cuticle which was about 1.5 times as thick as the outer wall, reacted with Sudan III.

Sugars:

No glucose was present in the species tested.

Glucosides:

Especially large amounts of glucosides were found in
in the cortex.

Lignification:

The bast fibers of the cortex and phloem, the xylem, and pith cells showed lignified walls.

Calcium Oxalate:

Rhombic crystals of calcium oxalate are scattered throughout the cortex and are frequently found in the active pith cells. They are often found in great abundance in the inner cortex. There are many prismatic crystals of calcium oxalate in the phloem of Sorbus and Sorbopyrus. There were a few rosette crystals in the pith of Sorbopyrus but Sorbus did not contain this type of crystal.

Petioles

Starch:

In Sorbus, some of the cells of the cortex often contained starch as well as protein. A few of the active cells of the medulla, especially those bordering the phloem, contained starch. Starch was present in small quantities in the xylem rays and in the phloem.

In Sorbopyrus, large quantities of starch were found in the xylem rays. A single, interrupted, row of cells containing starch bordered the bast fibers on the convex side of the vascular arc. A similar starch sheath had not been observed in the stem of Sorbopyrus but a similar starch sheath had been observed in both the stem and petiole of
Tannin:

Some of the collenchyma cells, especially the three rows nearest the epidermis, contained tannin. Tannin was particularly abundant in the collenchyma on the concave side of the petiole. Cells containing tannin are scattered throughout the parenchyma of the cortex. Tannin is abundant in the cells of the medulla which border the vascular arc. Most of the tannin in Sorbus is found in the rays, especially in the external phloem rays.

In S. intermedia, tannin is found in cells of the internal phloem of the bicollateral bundle, and in cells between the bundles of bast fibers around the vascular arc. This is the only species in which I observed this distribution of tannin. The petiole of S. americana showed no tannin reaction.

Proteins:

Many protein granules were present in some of the cells of the cortex, especially in S. intermedia. In all species, some of the active cells of the medulla which bordered the phloem, contained granules of protein. Protein was present in the phloem in rather large quantities. Small amounts were seen in some of the rays.

Fats and Oils:

I could not detect the presence of any fats or oils in
the petioles of Sorbus or Sorbopyrus.

Cutin and Suberin:

The outer walls of the epidermis of Sorbus are only slightly cutinized. A cuticle which is about 1.5 times as thick as the outer wall is usually quite evident. The outer and part of the radial walls of the epidermis of Sorbopyrus and Pyrus are well cutinized. The cuticle is difficult to distinguish in these species.

Sugars:

I could not detect the presence of any sugar in Sorbus or Sorbopyrus.

Glucosides:

The sections gave a good glucoside reaction. In Sorbus, glucosides were present in some of the cells of the cortex, especially in the collenchyma on the concave side of the section. The active cells, of the medulla, bordering the vascular arc contain glucosides. The rays and phloem show an abundance of glucosides.

Sorbopyrus contains more glucosides than Sorbus. From 3 to 5 rows of the outer collenchyma show large quantities of glucosides. Many of the cells of the cortex, especially those bordering the vascular arc, contain glucosides. Many of the cells of the medulla, especially those bordering the vascular arc, show a good glucoside reaction. The medullary rays and phloem contain glucosides.
Lignification:

Nearly all of the parenchymatous cells between the vascular arc and the concave side of the petiole have lignified cell walls. In Sorbus Aucuparia, the presence of cells, with lignified walls, in the inner cortex above the vascular arc is quite noticeable. They are more numerous and scattered in this region in S. Aucuparia than in the other species studied. The bast fibers and xylem showed lignification in all species.

In Sorbopyrus, only about three rows of cells bordering the concave side of the vascular arc showed lignification. A few parenchymatous cells adjoining bundles of bast were lignified. The bast fibers and xylem showed lignification.

Calcium Oxalate:

Prismatic and rosette crystals of calcium oxalate were scattered throughout the cortex of the petioles of Sorbus and Sorbopyrus.

Midribs

Starch:

Only a trace of starch was found in the midribs of Sorbus and Sorbopyrus and that was limited to the rays.

Tannin:

Tannin was rather abundant in the midribs of Sorbus,
with the exception of S. americana in which there was practically no tannin. Small amounts were sometimes found in the first and second rows of hypodermal cells. The bundles of bast fibers are usually bordered, on the convex and radial sides, by cells containing tannin. Most of the cells in the first three rows of the medulla which border the phloem contain tannin. Much of the tannin is found in the rays, especially in the phloem.

In Sorbopyrus, the first and second rows of hypodermal cells contain tannin. Numerous cells of the medulla show the presence of tannin. Much tannin is found in the rays, especially in the phloem, and in cells bordering the bundles of bast fibers.

Proteins:

Protein is found in a few of the hypodermal cells in Sorbus. Much protein is found in the cells of the medulla where it borders the phloem.

In Sorbopyrus, protein is found in the first two rows of hypodermal cells. Many cells of the medulla contain protein. Rows of cortical cells containing protein radiate from the convex side of the vascular arc. The phloem and rays contain protein.

Fats and Oils:

Only a trace of fats or oils was seen in but one species of Sorbus, namely, S. aucuparia.
I could not detect the presence of any fats or oils in Sorbopyrus.

Cutin and Suberin:

The outer walls of the epidermis of Sorbus were very slightly cutinized while those of Sorbopyrus and Pyrus were well cutinized. A cuticle was usually quite evident in species of Sorbus but was hard to distinguish from the cutinized wall in Sorbopyrus and Pyrus.

Sugars:

No glucose was present in the midribs of Sorbus or Sorbopyrus.

Glucosides:

Glucosides are found quite abundantly in the collenchyma of the cortex. They are also found in some of the parenchyma cells of the cortex. The cells of the medulla which border the phloem and the rays gave a good glucoside reaction.

Glucosides in Sorbopyrus are found in regions similar to those of Sorbus. The chains of cells radiating from the vascular arc contain glucosides in addition to protein. Glucosides are more abundant in Sorbopyrus than in Sorbus.

Lignification:

The cell walls of the bast fibers and xylem were lignified. In most species there were active cells of the
medulla which bordered the vascular arc. These cells had lignified walls.

Calcium Oxalate:

Prismatic and rosette crystals of calcium oxalate were abundant in the cortical cells of Sorbus. These crystals were less abundant in Sorbopyrus and were found mainly in cortical cells bordering the region of bast fibers.
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Primary Tissues

Epidermis:

The epidermis, Fig. 63, is composed of cells that have a radial diameter of .0175 mm. and an average tangential diameter of .03 mm. As seen from the surface, the cells are square, with a breadth of about .03 mm. Their length is approximately .03 mm. All of the walls have about the same thickness which is .002 mm. The outer wall shows a slight cutin reaction. A cuticle with an average thickness of .005 mm. is found on the surface.

Primary Cortex:

In a stem which was cut in April of its first year's growth, Fig. 63, the radius is 2.56 cm. The primary cortex has a width of .64 mm. There are 2 rows of relatively thin-walled collenchyma beneath the epidermis. There are 31 rows of parenchyma cells in the cortex, Fig. 1d. The walls of these cells have an average thickness of .0025 mm.

Bundles of bast fibers are found in the inner cortex. The walls of these fibers are somewhat lignified but have not yet attained their maximum thickness. The primary bast fibers, Fig. 1a, have an average cross-diameter of .02 mm. and an average length of .44 mm. The cavities in the section showing early growth of the first year,
have an average diameter of .01 mm. In a section showing two year's growth, Fig. 64, the primary bast fibers have an average diameter of .0175 mm. while their cavities have a cross-diameter of about .0025 mm. The width of the bundles of bast ranges from 1 to 11 cells.

Phloem and Xylem:

In a section of early growth of the first year, Fig. 63, the phloem region has a width of .16 mm. The sieve tube elements have an average cross-diameter of .015 mm. and an average length of .12 mm. The companion cells have the same average length but their cross-diameters are only .005 mm. A few longitudinal rows of parenchyma cells are seen in the phloem of this species. These cells have an average breadth of .0075 mm. and an average vertical length of .02 mm. They are almost entirely filled by a single calcium oxalate crystal. Twenty-four protoxylem points slightly indent the pith. Spirally thickened protoxylem elements are found in each of these points. The elements have an average cross-diameter of .03 mm. The metaxylem is not essentially different from the secondary xylem.

Pith:

The pith is heterogeneous. The thick-walled active cells of the central pith have an average cross-diameter of .05 mm. and an average vertical length of .035 mm.
The outer part of the pith is composed entirely of thick-walled active cells. The 3 outermost rows of active cells show a decrease in cross-diameter and an increase in vertical length until the row lying next to the protoxylem elements is composed of relatively thin-walled cells having an average cross-diameter of .01 mm. and an average length of .07 mm. The thin-walled, inactive cells of the pith have cross-diameters ranging from .07 mm. to .12 mm. and vertical length ranging from .03 mm. to .05 mm.

Secondary Tissues

Periderm:

Phellogen is formed from the epidermis very early the first year. In the two-year stem there are from 2 to 3 rows of cork cells found beneath the epidermis. These cork cells have an average radial diameter of .02 mm. and an average tangential diameter of .03 mm. Their vertical length is approximately .03 mm. The phelloderm cells are relatively small and thin-walled.

Phloem:

I found no secondary bast fibers in the phloem of a stem that was cut early the second year, Fig. 64. Likewise, I was unable to find any stone cells in this stem.

Xylem:

The rays alternate with from 1 to 3 rows of tracheal
elements. The rays are from 1 to 2 cells in width and from 2 to 30 cells in vertical length, Figs. le and lf. As seen in tangential section, the rays of this species are of the typical Sorbus kind, Fig. le and lf. They are greatly elongated at the ends. The ends are only 1 cell wide and are composed of cells which are greatly elongated vertically. The cells range from .02 mm. to .08 mm. in vertical length.

The walls of the tracheal elements are densely pitted, sometimes with a mixture of circular and reticulate pits, Fig. lb. This species has as many reticulate pits as S. Aria. The tracheal elements have an average cross-diameter of .02 mm. and an average length of .32 mm. There is an average of 552 tracheal elements per sq. mm. of cross-section.

I was unable to find any tracheids although fiber tracheids, Fig. lc, were present but relatively few in number when compared with most of the species studied (S. aucuparia with its varieties and S. hybrida are excepted). The fiber tracheids have an average cross-diameter of .012 mm. and an average length of .24 mm.
Primary Tissues

Epidermis:

The cells of the epidermis have an approximate radial diameter of .0075 mm. and a tangential diameter of .02 mm. The inner walls average .0025 mm. in width while the cutinized outer wall and cuticle have a combined thickness of .0075 mm. Only a few epidermal cells remain on sections of very early growth of the first year, Fig. 65.

Primary Cortex:

The one-year-old stem, Fig. 65, had a radius of about 1.44 mm. The cortex is .48 mm. wide and is composed of about 14 rows of collenchyma, Fig. 2d. The parenchyma cells have a radial diameter of .0175 mm. to .0225 mm. and a tangential diameter ranging from .02 mm. to .06 mm. They range from .02 mm. to .06 mm. in vertical length. Relatively small bundles of bast fibers are arranged somewhat cylindrically in the inner cortex, Fig. 2a. This bast region ranges in width from 0 to 5 cells. The walls of the bast fibers average approximately .0075 mm. in thickness while their cavities have an average diameter of .0025 mm. The fibers are approximately .57 mm. in length. No stone cells were seen in this variety.

Phloem and Xylem:

The phloem region is about .16 mm. in width in a one-
year stem. The sieve tubes have an average length of .1 mm. and an average breadth of .015 mm. The companion cells have an average length of .1 mm. and a diameter of .005 mm.

Numerous longitudinal rows of small cells, each almost entirely filled by a single rhombic crystal of calcium oxalate, are found in the phloem. These cells have average cross-diameters of .005 mm. and a length of .02 mm.

There are about 23 xylem points that indent the pith slightly. The protoxylem is found in these points. The protoxylem elements have spiral thickenings. They have a diameter of .002 mm. There are approximately 2 rows of these elements. The metaxylem elements have oblong-ovate end perforations which are traversed by bars.

Pith:

The pith is heterogeneous. The central part consists mainly of empty cells which have diameters ranging from .02 mm. to .06 mm. and a length of .03 mm. Their walls are approximately .003 mm. thick. The thick-walled cells of the central pith have diameters ranging from .02 mm. to .025 mm. and a vertical length of .03 mm. while their walls have a thickness of .005 mm. These cells contain starch and tannin. In the peripheral part of the pith is a cylinder of the active cells which are slightly longer, vertically, than those of the interior pith and have walls .0075 mm. thick. From this cylinder outward are rows of
cells that have walls of decreasing thickness while the cells have walls that are approximately .0015 mm. thick. These cells have a diameter of approximately .01 mm. and are about .04 mm. long. Some of the cells of the peripheral part of the pith have pointed ends. All of the active pith cells have numerous unbordered pits.

**Secondary Tissues**

**Periderm:**

The epidermis produces phellogen early the first year, Fig. 65. Early growth of the first year shows 3 rows of cork cells. A two-year stem shows about 5 rows of cork and it is evident that some cell layers have sloughed away. The cork cells have a radial diameter of about .01 mm. and a tangential diameter approximating .02 mm while the cells are close to .03 mm. in length, vertically.

**Phloem:**

There is an almost continuous cylinder of bast in the secondary phloem, Fig. 66. This cylinder varies from 0 to 5 cells in width. The secondary bast fibers have walls which measure approximately .0075 mm. in thickness and they have cavities that measure approximately .0015 mm. in diameter. These secondary bast fibers are approximately .2 mm. long. The primary phloem breaks down during the third year.
Xylem:

Radial strips of xylem from 1 to 4 rows of cells wide alternate with the rays. The rays are from 1 to 2 cells wide and from 1 to 21 cells deep, vertically, Figs. 2e and 2f. As seen in a tangential section, Fig. 2f, the rays are 1 cell wide at the ends and 2 cells wide in the middle. The end cells are elongated vertically while this is not true of the cells in the middle of the ray. The lengths of the cells vary from .01 mm. to .04 mm. in this species.

The tracheal elements are densely pitted and have the end walls entirely dissolved out, Fig. 2b. They average about .2 mm. in length and .02 mm. in diameter. There are approximately 759 tracheal tubes per sq. mm. of cross-section.
Primary Tissues

Epidermis:

The epidermis has been replaced by cork on a one-year stem which was cut in August, Fig. 67.

Primary Cortex:

In a one-year stem having a radius of 1.44 mm., the primary cortex is approximately .32 mm. wide, Fig. 67. It is composed of about 5 rows of collenchyma cells, Fig. 67, and 19 rows of parenchyma cells, Fig. 3d. The parenchyma cells have a tangential diameter of .02 mm. to .04 mm. and a radial diameter of .02 mm. to .03 mm. Their vertical length is from .02 mm. to .04 mm. Their walls are about .003 mm. thick.

Arc-like bundles of primary bast fibers form an interrupted cylinder in the inner cortex. These fibers have walls approximately .0075 mm. thick and cavities with a diameter of about .002 mm., Fig. 3a. They are about .79 mm. long vertically. The bast region of the inner cortex ranges from .0-11 cells in width.

Phloem and Xylem:

The phloem region is approximately .12 mm. wide. The sieve elements are approximately .06 mm. long and have an average cross-diameter of .01 mm. The companion cells have an average length of .06 mm. and a cross-diameter of
.005 mm. Crystals of calcium oxalate are found in longitudinal rows of small parenchyma cells in the phloem. Each cell is almost entirely filled by a single rhombic crystal.

There are 20 xylem points that slightly indent the pith. Protoxylem elements with spiral thickenings are found in these points.

The metaxylem tracheal elements closely resemble the secondary xylem elements. However, the metaxylem elements differ from those of the secondary xylem in having the end walls so dissolved out as to leave an elliptical opening with bars across it.

Pith:

The pith is heterogeneous. The active cells of the central pith have a diameter of about .03 mm. and a vertical length of .04 mm. Their walls are about .0025 mm. thick. The inactive cells of the central pith have diameters ranging from .04 mm. to .08 mm. Their vertical lengths vary from .03 mm. to .06 mm. Their walls are about .0012 mm. thick. Approaching the margin we find a cylinder composed of 2 rows of active cells whose average diameter is .03 mm. and vertical length .04 mm. Each succeeding row of cells, outside of this cylinder, shows a decrease in thickness of cell wall and diameter, and a great increase in vertical length until the cells border-
ing the protoxylem have a diameter of .0175 mm. and vertical length of .06 mm. while their walls are approximately .02 mm. thick.

Secondary Tissues

Periderm:

Phellogen is formed from the epidermis early the first year, Fig. 67. A one-year stem cut in August shows about 3 rows of cork cells. These cells have radial diameters of .02 mm., tangential diameters around .03 mm. and a vertical length of .02 mm.

Phloem:

The secondary phloem closely resembles the primary phloem. I was unable to get a stem that was more than one year old but in such a stem I was unable to find any secondary bast fibers in cross-section. However, in a radial section there are evidences of the formation of secondary bast fibers. These appear to be about .32 mm. long and have cross-diameters of about .005 mm.

Xylem:

The rays alternate with strips of xylem which are from 1 to 3 tracheal elements wide. The rays vary from 1 to 2 cells in width and from 1 to 56 cells in vertical length. As seen in a tangential section, Fig. 3f, the rays have tapering ends which are only 1 cell wide while the middle of the ray is 2 cells wide. The cells at the
ends of the ray are much elongated vertically while the cells at the middle of the ray are not at all elongated. The vertical lengths of the ray cells in this species range from .0075 mm. to .05 mm.

There are many tracheal elements in this species compared with the number in S. commixta. There are about 483 tracheal tubes per sq. mm. of cross-section. These elements have a diameter of about .04 mm. and vertical length of about .3 mm., Fig. 3b. They are densely pitted with reticulate pits and patches of scalariform pits. The circular pits are not wanting in this species either.

A few tracheids are present. They have an average diameter of .0125 mm. and length of .1 mm.

Fiber tracheids are more abundant and have vertical lengths varying from .32 mm. to .72 mm. They have an average diameter of about .005 mm. There are relatively few tracheids of any kind in this species.
Primary Tissues

Epidermis:

The epidermis of a young one-year stem has been replaced by cork, Fig. 68.

Primary Cortex:

The one-year-old stem studied has a radius of 1.76 mm., Fig. 68. The primary cortex is .8 mm. wide and is composed of about 10 rows of collenchyma and 17 rows of parenchyma cells, Fig. 4d. The parenchyma cells have diameters of .01 mm. to .04 mm. and vertical lengths of approximately .04 mm. Their walls are approximately .005 mm. thick.

An interrupted cylinder composed of isolated bundles of bast fibers is found in the inner cortex. This bast region varies from 0 to 5 cells in width. The fibers have cell walls ranging from .005 mm. to .0075 mm. thick and cavities which are about .001 mm. in diameter. These fibers are approximately .72 mm. long, Fig. 4a.

Phloem and Xylem:

In a section of a one-year stem the phloem region is .0375 mm. wide. The sieve tube elements have an average length and cross-diameter of .1 mm. and .018 mm. respectively. The companion cells have an average length of .1 mm. and an average cross-diameter of .008 mm.

There are 16 xylem points which indent the pith.
slightly. About 2 radial rows of spiral protoxylem elements are found in these points. The elements are about 0.0175 mm. in diameter.

The metaxylem elements are about 0.02 mm. in diameter. Their end walls are dissolved out with the exception of fine bars which form a coarse mesh across the opening.

Pith:

The pith is heterogeneous. The central pith contains large, empty, thin-walled cells and a lesser number of smaller, thick-walled cells which contain starch and tannin. The thin-walled cells have diameters varying from 0.04 mm to 0.07 mm. and have an average vertical length of 0.04 mm. Their walls are only 0.001 mm. thick. The thick-walled cells in the central pith have diameters varying from 0.02 mm. to 0.04 mm and are about 0.02 mm. deep, vertically. Their walls are from 0.005 mm. to 0.0075 mm. thick. Near the periphery of the pith is a cylinder of active cells which have the same approximate dimensions as the active cells of the central pith. The rows of cells outside this cylinder show a decrease in width of cavity and thickness of cell wall. The outermost row of cells is composed of cells with an average diameter and length of 0.01 mm. and 0.04 mm. respectively. Their walls are about 0.001 mm. thick.
Secondary Tissues

Periderm:

The epidermis produces phellogen early the first year, Fig. 68. An average of 3 rows of cork and 3 rows of phellogen may be seen on the one-year stem by the middle of August. Other layers of cork have sloughed away. In a five-year-old stem the oldest phelloderm cells have thickened their walls considerably -- sometimes to the extent of .01 mm., Fig. 69.

Phloem:

The primary phloem begins to break down about the second or third year. The elements of the secondary phloem are very irregular as seen in cross-section, Fig. 69. The secondary phloem contains an almost entire cylinder of secondary bast fibers. Other and younger concentric arcs of bast fibers may be seen in the secondary phloem. The secondary bast fibers have walls averaging .0075 mm. in thickness and cavities averaging .0012 mm. in diameter. Their lengths averaged about .12 mm. Tannin sacs having an average length and breadth of .08 mm. and .015 mm. respectively, are found in the secondary phloem. Numerous longitudinal rows of small parenchyma cells are found in the secondary phloem. Each cell is almost entirely filled by a single rhombic calcium oxalate crystal. These cells have an average cross-diameter of .0075 mm.
and an average length of .0175 mm. I found no stone cells in this species or any of its varieties.

Xylem:

The rays alternate with radial strips of xylem which are from 2 to 5 tracheal elements wide. The rays are usually 1 or 2 cells wide and from 1 to 30 cells deep, vertically. A tangential section of the stem, Fig. 4f, shows the rays to be very elongated and pointed at the ends. The ends of the ray are only 1 cell wide while the middle of the ray is 2 cells wide. The end cells are greatly elongated, vertically, while the middle cells are not so elongated. The vertical lengths of the ray cells range from .015 mm. to .05 mm.

The tracheal elements, Fig. 4b, are densely pitted like those of all the species of Sorbus studied. They have a length of approximately .24 mm. and diameter of .035 mm. Their walls are .002 mm. thick. The end walls are completely dissolved out leaving a circular or sometimes elliptic opening. As seen in cross-section, there is an average of 690 tracheal tubes per sq. mm.

Fiber tracheids measuring from .08 mm. to .36 mm. in length and about .015 mm. in diameter, are found throughout the xylem. Most of the fiber tracheids have circular pits while a few have elliptic pits. There are relatively few tracheids of any kind in this species.
SORBUS HYBRIDA (S. aucuparia x S. intermedia)

Primary Tissues

Epidermis:

The epidermal cells have an approximate radial diameter of .015 mm. and tangential diameter of .02 mm. The epidermis gives rise to phellogen in very early growth.

Primary Cortex:

In a young stem, Fig. 70, having a radius of 1.76 mm., the cortex is approximately .64 mm. wide and is composed of approximately 10 rows of collenchyma and 15 rows of parenchyma cells. The parenchyma cells have an average diameter and length of .04 mm. Their walls are approximately .005 mm. to .007 mm. thick, Fig. 9a.

Bundles of primary bast in the inner cortex, encircle the phloem region, Fig. 70. The thickness of wall of the bast fibers averages about .01 mm. while their cavities are about .0025 mm. in diameter. These bast fibers are approximately 1.2 mm. long, Fig. 9a. The bundles of bast fibers range in width from 0-5 cells in the one-year section.

Phloem and Xylem:

The phloem region in a one-year stem is approximately .14 mm. wide. The sieve tube elements have an average length of .1 mm. and an average cross-diameter of .017 mm.
The companion cells have an average length of 11 mm. while their cross-diameter is .007 mm.

About 29 protoxylem points indent the pith more or less. The protoxylem elements are spiral; their average cross-diameter is about .02 mm.

Pith:

The pith is heterogeneous, with a greater abundance of thin-walled cells in the center. The thin-walled cells in the center of the pith have cell walls which are .005 mm. thick and cavities that range from .03 mm. to .05 mm. in diameter. These cells are approximately .04 mm. long. The thick-walled cells of the central pith have walls approximately .01 mm. thick and cavities with diameters of approximately .03 mm. Their cavities are about .03 mm. long. In the peripheral part of the pith is a cylinder of thick-walled cells which closely resemble those in the central pith. The rows of cells outside this cylinder show a decrease in thickness of cell wall and increase in length until the row of cells bordering the protoxylem is composed of cells approximately .1 mm. long and having diameters of .01 mm. Their walls are close to .0015 mm. in thickness. These cells have oblique end walls.

Secondary Tissues
Periderm:

Phellogen is produced by the epidermis early the first year, Fig. 70. A young one-year section shows two rows of cork cells. The radial and vertical dimensions of the cork cells are approximately .02 mm. while their tangential diameter is about .017 mm. Cells of the phelloderm have about the same radial and tangential dimensions as the cork cells but they often become elongated. As they become older their walls thicken immensely, often attaining a thickness of .01 mm.

Phloem:

An almost continuous cylinder of secondary bast is found in the secondary phloem, Fig. 71. The cylinder has an average width of about 4 cells. Other bundles of bast are scattered throughout the phloem. The secondary bast fibers have walls about .01 mm. thick and cavities about .0012 mm. in diameter. Their average length is .56 mm. In older stems much of the primary phloem is dead and crushed against the bast of the inner cortex. The secondary phloem contains numerous longitudinal rows of small parenchyma cells. Each cell is almost entirely filled by a single, rhombic crystal of calcium oxalate. Stone cells varying from .02 mm. to .06 mm. in length and having average cross-diameters of .03 mm. are found adjoining the secondary bast fibers.
Xylem:

The rays alternate with sections of xylem which are from 1 to 3 tracheal elements wide. The rays are from 1 to 2 cells wide and from 1 to 60 cells deep, vertically. As seen in a tangential section, Fig. 9f, the rays are elongated vertically and pointed at the ends. The pointed ends are only 1 cell wide and are composed of much elongated cells. The vertical lengths of the ray cells range from .015 mm. to .08 mm.

The tracheal elements have diameters averaging .05 mm. and an average length of .3 mm., Fig. 9b. Their sides are densely pitted and their end walls are entirely dissolved out. There is an average of 690 tracheal elements per sq. mm. of cross-section.

A few tracheids are found with end walls at right angles to the vertical wall. These average about .08 mm. in length and .0175 mm. in diameter. Their walls are approximately .002 mm. thick. Most of the tracheids in this species are fiber tracheids. These are .0175 mm. in cross-diameter and average .38 mm. in length, Fig. 9c.
Primary Tissues

Epidermis:

The inner walls of the epidermal cells are approximately .005 mm. thick. The outer wall and cuticle have a combined thickness of .0075 mm. In the very early growth of the first year, from 1 to .2 rows of cork underlie the epidermis but the epidermis is still almost intact, Fig. 72.

Primary Cortex:

In a one-year-old stem section having a radius of 1.44 mm., the primary cortex is approximately .64 mm. wide and is composed of about 30 rows of cells, Fig. 72. The 15 outer rows are collenchyma while the inner rows are parenchymatous cells with walls averaging .005 mm. in thickness. The average diameter of the parenchyma cells is .04 mm., Fig. 5d.

Bundles of primary bast fibers form an interrupted cylinder in the inner cortex and closely border the phloem. This cylinder is from 0 to 6 cells in width. The walls of the fibers are approximately .01 mm. thick; the cavities have a diameter of approximately .0025 mm. and the length of the fibers is about .555 mm., Fig. 5a.
Phloem and Xylem:

The phloem of a one-year stem, with a radius of 1.44 mm., is about .01 mm. wide. In cross-section the elements appear very irregular in shape. The sieve tube elements have an average length of .065 mm. and an average cross-diameter of .0125 mm. The companion cells have the same approximate length as the sieve elements but their cross-diameter is only .005 mm.

About 20 unequal xylem points indent the pith more or less. The protoxylem is found in these points. The elements are of the spiral type. They have an average diameter of .01 mm.

Pith:

The pith is heterogeneous, i.e., made up of thin-walled empty cells interspersed with thick-walled starch-containing cells. The cavities of the thin-walled cells average .06 mm. in diameter. The wall is approximately .0025 mm. thick and the length of the cell ranges from .04 to .08 mm. The cavities of the thick-walled cells range in diameter from .01 to .04 mm. The walls are about .007 mm. thick and the length of the cell is approximately .04 mm. The peripheral pith cells are much elongated and measure about .08 mm. in length and .02 mm. in diameter. Their walls are approximately .002 mm. thick. As one looks from this region of elongated cells to the central part of the pith, he sees intermediate stages between these
cells and the thick-walled cells of the pith. A cylinder of thick-walled cells of the pith borders the region of elongated cells but farther in, the thick-walled cells are scattered among the large thin-walled cells of the central pith. All cells of the pith have unbordered pits. The thick-walled cells of the pith contain starch and tannin.

Secondary Tissues

Periderm:

Periderm forms very early the first year, Fig. 72. It is found immediately beneath the epidermis. In a section of early growth of the first year, there are from 1 to 3 layers of cork cells while in a section of a twelve-year-old stem there are 6 rows of cork cells surrounding the stem, Fig. 73.

Phloem:

In two-year-old, or older, stems the primary phloem begins to break down. Secondary bast fibers are scattered throughout the secondary phloem, Fig. 73. The walls of these cells average about .0075 mm. in thickness. The cavities have an average diameter of .0025 mm. and the fibers are approximately .28 mm. long. This species does not have, in the phloem, elongated cells containing tannin. Longitudinal rows of small parenchyma cells containing calcium oxalate crystals are found in the phloem. Each rhombic crystal almost entirely fills a parenchyma cell.
The cells have an average length of .02 mm. and an average breadth of .075 mm.

Stone cells varying in length from .0225 mm. to .06 mm. and having a width of .03 mm., border the bundles of secondary bast fibers. These cells contain tannin and as a rule are not pointed. Other pointed stone cells which do not contain tannin are found in the bundles of secondary bast fibers. These stone cells have an average length of .06 mm. and an average width of .02 mm.

Xylem:

The rays alternate with from 1 to 3 radial rows of tracheal elements. The rays are from 1 to 2 cells wide and from 1 to 56 cells deep, vertically. The rays as seen in tangential section, Fig. 5f, have elongated and pointed ends which are only 1 cell wide. The cells at the ends of the rays are greatly elongated, vertically, while those at the middle of the ray are not elongated. The vertical lengths of the cells ranges from .02 mm. to .08 mm.

The tracheal elements, Fig. 5b, are densely pitted and the end walls are completely gone. They average about .04 mm. in diameter and are approximately .2 mm. long. There is an average of 345 tracheal elements per sq. mm. seen in cross-section.

There are numerous fiber tracheids throughout the xylem. These average .25 mm. in length and .01 mm. in cross-
diameter, Fig. 5c. Tracheids which are approximately 0.1 mm. long and 0.01 mm. wide are found but they are few in number.
Primary Tissues

Epidermis:

The epidermal cells average about .025 mm. in tangential diameter and .0175 mm. in radial diameter. The inner walls are about .003 mm. thick while the outer wall and the cuticle have a combined thickness of .0075 mm. The epidermis early produces phellogen and 2 rows of cork cells are found on a one-year stem in August, Fig. 74.

Primary Cortex:

In a one-year stem having a radius of 1.4 mm., the primary cortex is .36 mm. wide, Fig. 74. It is composed of about 4 rows of relatively thin-walled collenchyma and about 15 rows of parenchyma cells. The parenchyma cells have diameters ranging from .02 mm. to .04 mm. while the average thickness of cell wall is .0025 mm., Fig. 10d.

An interrupted cylinder of isolated bundles of bast fibers is found in the inner cortex. This cylinder varies from 0 to 13 cells in width. The primary bast fibers are approximately .69 mm. long with cell walls .005 mm. thick and cavities .001 mm. in diameter, Fig. 10a.

Phloem and Xylem:

The phloem region in a one-year stem is approximately .06 mm. wide. The sieve tube elements have an average
length and diameter of .07 mm. and .0125 mm. respectively. The companion cells have the same approximate length but their cross diameters are approximately .007 mm.

The protoxylem is composed of the usual spirally thickened elements. These elements are found in the xylem points which slightly indent the pith. There are 20 such points. The metaxylem is not essentially different from the secondary xylem.

Pith:

The pith is heterogeneous but the central pith contains very few thick-walled, active cells compared with the other species studied. The diameters of the thin-walled cells vary from .03 mm. to .08 mm. Their vertical lengths vary from .02 mm. to .05 mm. The thick-walled cells have an average diameter of .03 mm. and vertical length of .0175 mm. Near the peripheral part of the pith is a cylinder of two rows of active cells having an average diameter of .025 mm. and an average vertical length of .03 mm. Exterior to this cylinder the rows of cells gradually decrease in thickness of cell-wall and diameter until the cells of the outer row have a diameter of approximately .01 mm.; a vertical length of .06 mm., and cell walls which are .005 mm. thick. Their vertical length is about .06 mm.

Secondary-Tissues
Periderm:

By August of the first year a periderm containing 2 rows of cork cells is at hand, Fig. 74. These cells have a tangential diameter of about .03 mm. and a radial diameter near .0175 mm. Their vertical length is .03 mm. In stems which are several years old, a phelloderm is present with walls appreciably thickened, up to .0125 mm. The epidermis scales off the first year and leaves the cork exposed.

Phloem:

The primary phloem starts to break down during the second year and small bundles of bast fibers have been formed scatteringly throughout the secondary phloem, Fig. 75. The amount of these bast fibers is relatively small compared with most species of Sorbus studied. Parenchyma cells containing tannin are found in the phloem region. The secondary bast fibers have walls approximately .01 mm. thick and cavities measuring about .0012 mm. in diameter. The cells of the secondary phloem have an average radial diameter of .01 mm. and a tangential diameter of approximately .02 mm. The radial walls of the young phloem cells are quite noticeably thicker than the tangential walls. Stone cells having a length up to .07 mm. and cross-diameters of approximately .03 mm. are found in close association with the primary bast fibers. These cells are empty.
and very irregular in shape.

Longitudinal rows of small parenchyma cells containing calcium oxalate crystals are found in this species. As in all other species studied, each parenchyma cell is almost entirely filled by a single rhombic crystal. The cells have a breadth of .0075 mm. and an average length of .02 mm.

Xylem:

The rays alternate with strips of xylem which have a width of from 1 to 4 tracheal tubes. The rays are from 1 to 2 cells wide and from 1 to 27 cells deep, vertically. As seen in a tangential section, Fig. 10f, the rays are much elongated and pointed at the ends. The ends are one cell wide and composed of cells that are greatly elongated vertically, while the middle of the ray is two cells wide and is composed of cells that are not elongated vertically. The vertical lengths of the cells range from .01 mm. to .05 mm.

The xylem of this species contains many fiber tracheids, Fig. 10c. These fiber tracheids have an average length of .15 mm. and diameters ranging from .005 mm. to .0075 mm. The tracheal elements have densely pitted lateral walls while the end walls are entirely dissolved out leaving a circular perforation, Fig. 10b. The tracheal elements have an average length of .32 mm. and an average diameter of .02 mm. There is an average of 345 tracheal
tubes per sq. mm. as seen in cross-section.
Primary Tissues

Epidermis:

The epidermal cells have an average radial diameter of .025 mm. and a tangential diameter of .03 mm. The inner walls and the uncutinized part of the outer wall have an average thickness of .005 mm. A cuticle having a thickness of about .0075 mm. is present. Phellogen is formed from the epidermis very early the first year and in a one-year old stem an average of two layers of cork cells may be seen beneath the epidermis.

Primary Cortex:

In a year-old stem having a radius of 1.2 mm., Fig. 76, the primary cortex is .4 mm. wide. Beneath the periderm are 5 layers of relatively thin-walled collenchyma. The parenchyma region is 12 cells wide. The average thickness of cell wall in the parenchyma cells is .002 mm., Fig. 6d.

An interrupted region of primary bast fibers is found in the inner cortex, Fig. 6a. The bast region ranges from 0 to 12 cells in width. The fibers have an average length of .4 mm. The cavities have an average diameter of .001 mm. while the walls are approximately .015 mm. thick.
Phloem and Xylem:

The phloem region of a one-year stem is .04 mm. wide. The sieve tube elements have an average length of .08 mm. and an average cross-diameter of .015 mm. The companion cells have the same average length as the sieve tubes but their cross-diameter is only .005 mm. Longitudinal lines of parenchyma cells are found in the phloem. These cells have an average breadth of .005 mm. and an average length of .0175 mm. Each cell is almost completely filled by a single calcium oxalate crystal.

Ten xylem points indent the pith of the year-old stem. A few spiral protoxylem elements are found in each of these points. None of the protoxylem elements show annular thickenings. The spirally thickened elements have a diameter of .03 mm. The metaxylem does not differ essentially from the secondary xylem.

Pith:

The pith is heterogeneous. The thick-walled active cells of the central pith have average cross-diameters of .04 mm. and range in vertical length from .02 to .07 mm. However, most of these cells have a vertical length of about .04 mm. The active cells are more numerous near the outer border of the pith. The 9 outer rows of cells are composed entirely of active cells. In the peripheral part of the pith the rows of cells decrease in thickness of wall and radial and tangential diameters until those that lie
next to the protoxylem elements are prosenchymatous and have an average length of .14 mm. and an average cross-diameter of .01 mm.

The thin-walled, empty cells found only in the central pith have cross-diameters ranging from .03 mm. to .06 mm., while their vertical lengths have a range from .03 mm. to .06 mm.

Secondary Tissues

Periderm:

The phellogen formed from the epidermis the first year forms periderm relatively slowly, since a two-year stem shows only one additional layer of cork cells, Fig. 76 and 77. The cork cells have a radial diameter of .015 mm. and an average tangential diameter of .022 mm. while their average vertical length is .02 mm. The phelloderm is composed of small thin-walled parenchyma cells and has a width of about 2 cells.

Phloem:

The secondary phloem contains an almost uninterrupted cylinder of bast fibers, Fig. 77. The cylinder ranges from 0 to 7 cells in width. These fibers have an average length of .18 mm. while their cavities have a cross-diameter of about .002 mm. The average thickness of the walls is .005 mm. Stone cells are frequently found associated
with the secondary bast fibers. The stone cells have radial and tangential diameters and vertical lengths of .03 mm. These cells are developed from phloem rays.

**Xylem:**

The xylem rays alternate with from 1 to 3 rows of tracheal elements. The rays are 1 to 2 cells wide and from 4 to 60 rows deep, vertically. A tangential section, Fig. 6f, shows that the rays have elongated ends which are one cell wide and are composed of greatly elongated cells. The cells in the middle of the rays are not elongated vertically. The vertical lengths of the ray cells range from .02 mm. to .05 mm.

The tracheal elements have an average length of .32 mm. and an average cross-diameter of .04 mm., Fig. 6b. Their lateral walls are densely pitted and often have a mixture of circular and reticulate pits. Reticulate pitting is more prevalent in this species than in the other species that were studied, with the exception of *S. americana*. There is an average of 483 tracheal tubes seen in cross-section per sq. mm. of surface.

Tracheids are more numerous in this species than in the other species studied, with the possible exception of *S. commixta*. They have an average cross-diameter of .01 mm. and an average length of .08 mm.

Fiber tracheids, Fig. 6c, are numerous. They have an
average cross-diameter of .01 mm. and an average length of .24 mm.
SORBOPYRUS AURICULARIS

**Primary Tissues**

**Epidermis:**

The epidermis is composed of cells measuring about 0.0175 mm. radially and 0.03 mm. tangentially. The inner walls are about 0.0025 mm. thick while the cutinized outer wall and the cuticle have a combined thickness of 0.005 mm. Epidermis is found on only very young stems and is soon replaced by cork, Fig. 78.

**Primary Cortex:**

The primary cortex in a one-year stem having a radius of 1.68 mm., is about 0.48 mm. in width and is composed of approximately 23 rows of cells. The parenchyma cells of the cortex have relatively thin walls, Fig. 7d. The walls have an average thickness of about 0.005 mm. There are 5 rows of rather thin-walled collenchyma just beneath the periderm.

An interrupted cylinder of bast is found in the inner cortex. This bast region has a maximum width of 10 cells. The walls of the primary bast fibers average about 0.01 mm. in thickness and the average length of the fiber is approximately 0.9 mm., Fig. 7a.

**Phloem and Xylem:**

The phloem of a one-year stem is about 0.08 mm. wide
and consists of approximately 14 rows of cells. In cross-section, the phloem elements vary greatly in shape and size. The sieve elements have an average length of 1.08 mm. and an average breadth of .01 mm. The companion cells have the same average length but their average radial and tangential diameters are .005 mm.

Longitudinal rows of small parenchyma cells containing calcium oxalate crystals are extremely numerous in this genus. As in Sorbus and Pyrus, the crystals almost entirely fill the cell. The crystal-containing cells in this species have lengths varying from .02 mm. to .03 mm. and cross-diameters varying from .01 mm. to .015 mm. Cells containing these crystals are found in both the primary and secondary phloem.

Protoxylem is found in each of the 33 xylem points which indent the pith. The xylem elements have spiral thickenings and are approximately .035 mm. wide. The meta-xylem is not essentially different from the secondary xylem.

Pith:

The pith is composed entirely of active cells which are loaded with stored food. The cell walls average about .0075 mm. in thickness and have numerous unbordered pits. The diameters of their cavities range from .005 mm. to .06 mm. and their lengths from .03 mm. to .08 mm. The
longer sclerenchymatous cells are found in the peripheral part of the pith, especially at the protoxylem points. Their diameters average .01 mm. and their lengths .08 mm.

Secondary Tissues

Periderm:

Exceedingly young stems show the formation of periderm from the epidermis. In the year-old stem studied, there are from 3 to 4 layers of cork beneath the epidermis, Fig. 78. Most of the epidermis has scaled off. The three-year-old stem shows from 3 to 5 rows of cork and no epidermis, Fig. 79.

Phloem:

The secondary phloem shows numerous bundles of secondary bast fibers, Fig. 79. The walls of these fibers are only slightly thinner than those of the primary bast. The bundles of bast have an average thickness of 5 cells. In a cross-section of a three-year-old stem the older elements of the phloem are seen to be crushed but aside from this, the thin-walled cells of the phloem show no change. Long cells (probably companion cells) containing tannin are present in the phloem. These cells average about .14 mm. in length and .01 mm. in width.

Stone cells containing tannin and ranging in length from .01 mm. to .02 mm. and ranging in breadth from .015
mm. to .02 mm. are found in close association with the secondary bast fibers.

Xylem:

From 1 to 4 radial rows of tracheal elements alternate with the rays. The rays are usually one cell wide and from 1 to 50 cells deep. The tracheal elements are densely pitted and their end walls are entirely dissolved out, Fig. 7b. They average about .15 mm. in length and .025 mm. in diameter. There is an average of 552 tracheal elements per sq. mm. in a cross-section of stem.

As seen in tangential section, Fig. 7f, the rays are quite pointed at the ends and are 1 cell wide. The cells in the ends of the ray are greatly elongated, vertically, while the cells in the middle of the ray are not elongated. The vertical lengths of the cells vary from .015 mm. to .06 mm.

Fiber tracheids are scattered throughout the xylem, Fig. 7c. They average about .36 mm. in length and about .02 mm. in width. The walls of some of these fibers are relatively thin and often have small, elongated pits which are obliquely arranged.

Tracheids which are about .1 mm. long and .01 mm. wide, are found throughout the xylem. Their end walls are usually at right angles to the lateral wall.
Primary Tissues

Epidermis:

The epidermal cells average .02 mm. in radial diameter and .04 mm. in tangential diameter. Epidermis is present on both one- and two-year stems even though cork is formed beneath it early the first year, Figs. 80 and 81. The outer epidermal wall is cutinized.

Primary Cortex:

In a stem having a radius of 1.92 mm., the primary cortex is .72 mm. wide and is composed of approximately 5 rows of thin-walled collenchyma and 15 rows of parenchyma cells, Fig. 8d. The average thickness of the walls of the parenchyma is .0025 mm.

An interrupted cylinder of bast is found in the inner cortex. This cylinder is very irregular in width and varies from 0 to 7 cells in radial diameter. The walls of the primary bast fibers average about .0075 mm. in thickness while the length of the fiber is approximately .5 mm. The cavities are .0025 mm. in diameter, Fig. 8a.

Phloem and Xylem:

In a section of the early growth of the first year, the phloem region averages .1 mm. in width. The sieve elements have an average radial and tangential diameter
of .015 mm. and an average length of .07 mm. The companion cells have about the same average length as the sieve tube elements but they have an average radial and tangential diameter of .01 mm.

Longitudinal rows of small parenchyma cells, each containing a single calcium oxalate crystal, are found in both the primary and secondary phloem of this species. These cells have an average length and cross-diameter of .02 mm. and .0075 mm., respectively.

Twenty-seven xylem points indent the pith. Each of these points contains protoxylem elements which have spiral thickenings and have an approximate diameter of .0175 mm.

Pith:

All of the pith cells are active. The walls have numerous unbordered pits; they are approximately .005 mm. thick. The cells bordering the xylem are vertically elongated. Their average diameter is .01 mm. while their average length is about .06 mm. The cells of the interior pith average about .04 mm. in length and .03 mm. in diameter.

Secondary Tissues

Periderm:

Cork is formed beneath the epidermis in the early growth of the first year. In a section of first year
growth there are 4 rows of cork cells beneath the epidermis. The two-year-old stem section shows the same number of rows of cork cells but the epidermis has scaled off to a greater degree, Fig. 81. The average radial diameter of a cork cell is approximately .015 mm. while the approximate length of a cell is .0175 mm. The tangential diameter is slightly greater than the radial diameter.

Phloem:

The secondary phloem has an almost continuous cylinder, of secondary bast fibers, which is quite uniformly 4 cells wide, Fig. 81. This cylinder is interrupted only by the rays passing through it. The average thickness of the walls of the secondary bast fibers is .0035 mm. Their cavities average .0025 mm. in diameter and their length is approximately .5 mm. There are long tannin-containing cells in the phloem which have an average length of about .06 mm. and an average diameter of .01 mm.

Numerous stone cells are found in close association with both the primary and secondary bast fibers. The stone cells have lengths varying from .02 mm. to .04 mm., while their radial and tangential diameters vary from .02 mm. to .03 mm. Many of the stone cells are box-like and regular in shape but some are pointed and irregular in shape.
Xylem:

The rays alternate with a strip of xylem which is from 1 to 3 tracheal tubes broad. The rays are usually 1 cell wide and from 2 to 57 cells deep. The rays as seen in tangential section, Fig. 8f, are not tapering at the end like those of Sorbus, nor do they have elongated cells at the ends.

The tracheal elements, Fig. 8b, are approximately .24 mm. long and about .02 mm. wide. Their lateral walls are densely pitted while the end walls are entirely dissolved out. There is an average of 552 tracheal elements per sq. mm. of cross-section.

Tracheids ranging in length from .06 mm. to .1 mm., are found in the xylem.

Fiber tracheids, Fig. 8c, which average about .3 mm. in length and .0075 mm. in width are found throughout the xylem. They are quite numerous in this species.
SUMMARY TO THE STUDY OF STEMS

The stem structure varies considerably in the genus, Sorbus, even though the variations in the stems may be less than those seen in the outer form of the species.

Phellogen is formed from the epidermis early the first year. All of the two-year-old stems have the epidermis at least partially displaced by cork cells. The outer walls of the epidermis have the same approximate thickness as the inner walls. They are more or less cutinized. A cuticle which is about 1.5 times as thick as the outer wall is present. As seen from the surface, the epidermal cells are square or slightly rectangular; however, I was unable to strip epidermis from most of the stems due to the early formation of cork. In S. Aucuparia, S. hybrid, and S. commixta, the old phelloderm cells become much elongated and their walls often become thickened to the extent of .01 mm. In the other species the periderm remained parenchymatous.

In all species the primary cortex contains collenchyma cells and parenchyma cells which are interspersed with bundles of bast fibers. However, S. americana differs from the other species in that it has an endodermis bordering the primary bast fiber region and so delimiting this as a part of the pericycle. The number of rows of collenchyma cells ranges from 2 in S. americana to 15 in S. intermedia; S. hybrid and S. intermedia have abun-
dant collenchyma. These two species have relatively thick-walled collenchyma while S. Aucuparia and its two varie-
ties have walls of medium thickness and the remaining spe-
cies have relatively thin-walled collenchyma. The number
of rows of parenchyma cells ranges from 12 in S. Aria to
31 in S. americana. The width of the parenchyma cells ran-
ges from .002 mm. in S. Aria to .006 mm. in S. hybrida.

The primary bast fibers are variously grouped in the
genus. S. Aucuparia pendula, S. commixta, S. Aucuparia,
S. americana and S. Aria have variously shaped bundles of
fibers but the characteristic bundles of these species are
large and arc-shaped. They are almost concentric with the
phloem region of the stem. S. Aucuparia var. has 2 concen-
tric, interrupted, cylinders of primary bast fibers while
Sorbopyrus has only one slightly interrupted cylinder. S.
hybrida and S. intermedia have relatively small, round,
isolated bundles of bast fibers in the inner cortex. The
primary bast fibers range in length from .25 mm. in Sor-
bopyrus to 1.2 mm. in S. hybrida. The average length is
about .6 mm. The cross-diameters of the fibers do not
vary greatly; neither do the cross-diameters of their cav-
ities. These diameters average about .015 mm. and .002 mm.
respectively.

No secondary bast fibers were found in S. commixta
and S. americana. In all the other species, bundles or
interrupted cylinders of secondary bast fibers were found
in the secondary phloem. In most of the species having secondary bast fibers, the fibers were arranged in the form of an interrupted cylinder. *S. intermedia* was the only species in which there were only a few fibers and those were scattered throughout the secondary phloem. The secondary bast fiber region ranged in average width from 1.5 cells in *S. intermedia* to 4 cells in *S. hybrida* and *Sorbopyrus*. The secondary bast fibers in all the species studied had approximately the same average length, which was around .2 mm. Their average cross-diameters were approximately .01 mm.

Stone cells were not present in *S. Aucuparia* and its varieties, nor were they present in *S. Aria* and *S. americana*. *S. hybrida* and its parent, *S. intermedia*, had stone cells with lengths varying from .02 mm. to .06 mm. and cross-diameters of .03 mm. These cells were in close association with both the primary and secondary bast fibers. In *Pyrus communis*, some of the stone cells had lengths varying from .03 mm. to .07 mm. with a cross-diameter of about .03 mm. In *Sorbopyrus*, the stone cells were about .02 mm. long, vertically, and had a cross-diameter of .02 mm. Most of the stone cells observed in these species appear to have been produced from ray cells. In *P. communis* and *Sorbopyrus*, the stone cells often contain tannin.

As seen in cross-section, the phloem elements are very irregular in shape. Their tangential diameters are
usually slightly greater than their radial diameters. The cross-diameters of the companion cells range from .005 mm. in most of the species, to .008 mm. in S. Aucuparia, while the vertical lengths vary from .06 mm. in S. Aucuparia pendula to .12 mm. in S. americana. The companion cells in most of the species have an average length of about .07 mm. S. americana is again extreme in having unusually long companion cells and sieve elements.

The sieve tubes have cross-diameters ranging from .01 mm. in Sorbopyrus and S. Aucuparia pendula to .018 mm. in S. Aucuparia. The length of the sieve elements ranges from .065 mm. in S. intermedia to .12 mm. in S. americana. The average length is .084 mm.

There are numerous small parenchyma cells in the phloem, each of which contains a single prismatic calcium oxalate crystal. The cells have breadths ranging from .05 mm. to .01 mm. in Sorbopyrus. The average cross-diameter is .0075 mm. The radial length of these cells is about the same in all of the species studied. It ranges from .0175 mm. to .02 mm.

There is some variation in the dimensions of the tracheal elements of the various species but this was usually true within any given species. The average cross-diameter of tracheal elements of the different species varied more than their average lengths. The cross-diameters ranged from .02 mm. to .05 mm. while their lengths ranged from
The tracheal elements were densely pitted. The most prevalent type of pits was circular pitting but reticulate pitting was quite common, especially in *S. Aria* and *S. americana*. Both types of pitting were often seen on the same element. The end walls of the secondary tracheal elements were dissolved out leaving a circular or elliptical opening. The number of tracheal elements per sq. mm. varied considerably. *S. intermedia* and *S. commixta* had approximately 300, *S. americana*, *Sorbopyrus*, *S. Aria* and *S. Aucuparia pendula* had 500, while *S. hybrida*, *S. Aucuparia*, and *S. Aucuparia var.* had approximately 700 per sq. mm.

The metaxylem elements did not differ essentially from those of the secondary xylem except in *S. Aucuparia* and its varieties, where a mesh of bars was left across the elliptical opening in the end walls of the tracheal elements. Solereder ('08) described a network of bars across the circular perforations in the tracheal elements of *S. Aucuparia*. I should limit this occurrence to the tracheal elements of the metaxylem because I did not find any such network in the secondary tracheal elements.

The protoxylem elements in all of the species studied had spirally thickened walls. This is true for *P. communis* as well as for *Sorbus*.

Only a few tracheids were found in *Sorbus*. Some species did not show the presence of any. Those that were
observed have cross-diameters ranging from .01 mm. to .0175 mm. while their lengths range from .08 mm. to .1 mm.

Fiber tracheids were numerous in the species studied, however, S. Aucuparia and its varieties and S. hybrida had relatively few fiber tracheids compared with the other species. Fiber tracheids were found in both the metaxylem and the secondary xylem. Their average cross-diameters ranged from .006 mm. in S. commixta to .02 mm. in Sorbopyrus. The species showed little agreement in cross-diameters of fiber tracheids. Little agreement was shown in the lengths of the fiber tracheids. They varied within a single species as well as between species. Their average lengths ranged from .15 mm. in S. commixta to .48 mm. in S. Aucuparia var. Most of the fiber tracheids had circular pits but some had elongated pits which were set aslant in the walls. I was unable to find tracheids with tertiary thickenings which were described by Burgerstein ('95).

Xylem parenchyma cells are almost entirely wanting in this genus. Only a few species contain any xylem parenchyma cells.

Wood fibers are entirely absent in all of the species studied.

Xylem rays are very numerous and alternate with 1 to 3 rows of tracheal elements. They usually range from 1 to 2 cells in width. A width of 3 cells is very uncommon. The vertical length of the rays ranges from 1 to 60 cells.
There is always a great variation within a single species. The variation in the vertical lengths of individual xylem ray cells is very striking. At either end of the ray, as seen in tangential section, are single, elongated cells ranging in length, in the various species, from .04 mm. to .08 mm. The middle of the ray is 2 cells wide and is composed of cells which range in length from .0075 mm. to .02 mm. depending upon the species.

In all the species of Sorbus studied, the pith was heterogeneous. This term is used by Gris ("70) to describe pith that is composed of both active and inactive cells, the activity of a cell being determined by the presence of stored starch. The central pith is composed mainly of large thin-walled empty cells with a few vertical rows of thick-walled active cells scattered throughout. Sometimes several rows of the active cells are grouped together. Many of the pith cells are almost isodiametric. The thin-walled cells have cross-diameters ranging from .02 mm. to .12 mm. S. americana was unusual in having cells with a cross-diameter of .12 mm. The active cells have cross-diameters ranging from .02 mm. to .05 mm. Most pith cells have an approximate vertical length of .04 mm. regardless of whether they are active or inactive. Toward the outer part of the pith the number of active cells increases until the outermost rows of cells are composed entirely of active cells. In this region of active pith,
the outermost rows of cells (usually about 5 outer rows) show a gradual decrease in thickness of wall and length of their cross-diameters together with an increase in vertical length until the outermost row of cells bordering the primary xylem is very thin-walled and prosenchymatous. The cells of the outermost pith have an average cross-diameter of .01 mm. and an average length of .045 mm. The walls of the active cells often have a thickness of .01 mm. and are densely pitted. Sorbopyrus resembles its Pyrus parent in having its pith composed entirely of thick-walled active cells which are loaded with starch.

The greatest differences seen in these species of Sorbus are the following:

1. The collenchymatous hypoderm ranges from 2 to 15 cells in width.
2. The maximum width of the bundles of primary bast fibers ranges from 5 to 13 cells.
3. The secondary bast in the phloem varies from total absence to a region having a maximum width of 7 cells.
4. The rays have maximum vertical lengths ranging from 21 cells to 60 cells.
5. The number of tracheal elements seen per sq. mm. in cross-section ranges from 345 to 759.

The species of Sorbus that I studied are similar in the following respects:
1. Phellogen is formed from the epidermis early in the first year.

2. A region of collenchyma is found beneath the periderm.

3. Bundles of primary bast fibers are found in the inner cortex.

4. The elements of the phloem have extremely delicate walls.

5. There are no wood fibers.

6. The tracheids, fiber tracheids, active pith cells and xylem ray cells are densely pitted.

7. There are extremely few xylem parenchyma cells.

8. There are few or no tracheids aside from fiber tracheids.

9. The pith is heterogeneous.

10. Tannin is abundant.

11. Numerous calcium oxalate crystals are found in the phloem and primary cortex.
## STEMS

I - Name of species.

II - Diameter and length of primary bast fibers.

III - Diameter and length of tracheal elements.

IV - Diameter and length of fiber tracheids.

**NOTE:** All measurements are given in microns. Dimensions are given in their respective order.

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SORBUS AMERICANA

General Features

The leaves are compound and have from 11 to 17 leaflets. The leaflets are lance-oblong to lanceolate, acuminate, 4 to 10 cm. long, sharply serrate, light green above, slightly pubescent beneath whin young, pale beneath and soon glabrous. The leaflets have an average thickness of .14 mm.

Epidermis:

There are very few thichomes in the epidermis of this species, Fig. 29, and those are found only on the lower epidermis. They are simple and have an average length of .88 mm. and an average length of cross-diameter which is .025 mm. There is a bend near the base of the trichome which causes the trichome to resemble those of S. Aucuparia.

The inner and outer walls of both the upper and lower epidermises are not cutinized and have about the same average thickness of .008 mm. The cuticle has an average thickness of .003 mm.; it is found on both the upper and lower epidermises. However, the cuticle on the lower epidermis is very uneven in thickness and gives the lower surface of the leaf a very rugose appearance when viewed through a microscope.
The upper epidermal cells have a cross-diameter of .04 mm. as seen from the surface and a depth of .01 mm., Figs. 36 and 18.

The lower epidermal cells have an average cross-diameter of .04 mm. as seen from the surface and a depth of .075 mm., Figs. 37 and 18. Stomata are found only on the lower epidermis. There are 207 stomata per sq. mm.

**Mesophyll**

There are two rows of palisade cells, Fig. 18. The upper row consists of cells having an average cross-diameter of .01 mm. and an average length of .035 mm. while the cells of the lower row have an average cross-diameter of .01 mm. and an average length of .02 mm. There is an average of 10,557 upper palisade cells per sq. mm. or 51 per stoma.

The cells of the spongy mesophyll are irregular in shape and irregularly arranged, Fig. 18. They have an average diameter of .0175 mm. Bast fibers rarely occur in the veins of this species.

**Midrib**

In general shape, a cross-section of the midrib is semi-circular, Fig. 83. A section made at the middle of a leaflet shows that the midrib has a width of .6 mm. and a thickness of .6 mm. The epidermal cells have an average diameter of .02 mm. as seen in cross-section. There are
from 2 to 3 rows of collenchyma surrounding the midrib. The ground parenchyma cells have an average cross-diameter of .03 mm.

The vascular arc is composed of a fan-shaped vascular bundle. There are no bast fibers bordering the convex side of the vascular arc as in all of the other species studied.

Margin

The structure of the margin of a leaflet in this species does not differ essentially from that of the remainder of the blade, Fig. 17. In some margins of this species a small vein running parallel to the margin is found .06 mm. from the edge of the blade while in other sections a vein is found .14 mm. from the margin.

The outer walls of the epidermis have about the same thickness as the inner walls, which is about .005 mm. They are slightly cutinized and are covered with a cuticle which has a thickness of about .008 mm.

Venation

As seen from the surface the leaflet has a few prominent veins and a fine network of small veins embedded in the mesophyll, Fig. 62. There is an average of 9 meshes and 20 free vein endings per sq. mm. (This seemingly large number of free vein endings as compared with the other species studied is probably due to the fact that
fresh leaves of this species were bleached and showed the vein endings more clearly than the bleached leaves that had been preserved in 70% alcohol.)

**Petiole**

The petiole as seen in cross-section has a width of 2.4 mm. and a thickness of 2.4 mm., Fig. 99. The general form of a cross-section of a petiole is round. The epidermal cells have an average cross-diameter of .03 mm. The inner and outer walls of an epidermal cell have about the same thickness, which is approximately .005 mm. A cuticle which has a thickness of about .007 mm. is present.

From 2 to 3 rows of collenchyma are found on the lower side of the petiole while 5 rows of collenchyma are found on the upper side. The ground parenchyma cells surrounding the vascular arc have diameters ranging from .03 mm. to .08 mm.

The vascular arc is composed of a single, large, crescent-shaped vascular bundle (formed by the fusion of 3 bundles) and two small bundles, one in line with either end of the large bundle. All of the bundles are bicollateral. The convex side of the vascular arc is bordered by a region of bast fibers which ranges in width from 0 to 10 cells.

Stipules of this species have an average length of 1 cm. and an average width of 2 mm.
SORBUS AUCUPARIA VAR.

General Features

The leaves of this species are compound and have 9 to 15 leaflets which are oblong to oblong-lanceolate, acute or obtusish, 2 to 5 cm. long, serrate, usually entire in the lower third, dull green above, glaucous beneath and pubescent, at least when young. The leaflets are approximately .16 mm. thick.

Epidermis

There are relatively few trichomes in this variety. Most of the trichomes that are present are found along the principal veins. The trichomes are simple and slightly wavy and have an average diameter of .0175 mm. and an average length of .96 mm., Fig. 33.

The outer epidermal walls are only slightly thicker than the inner walls. They have a thickness of about .005 mm. and are uncutinized. A cuticle which has an average thickness of about .008 mm. is present. The cuticle of the lower epidermis has great variations in thickness. This gives the lower epidermis a rugose appearance when seen through the microscope.

The upper epidermis is composed of cells having an average diameter of .04 mm. and depth of .03 mm., Figs. 44 and 14. No trichomes are present on the upper epidermis.

The lower epidermis, Fig. 45, is composed of cells
having an average cross-diameter of .04 mm. and a depth of .02 mm. Trichomes are found in this epidermis.

The upper epidermis has no stomata but the lower has an average of 140 stomata per sq. mm.

**Mesophyll**

There are two rows of palisade cells in this variety, Fig. 14. Cells of the upper row have an average length of .04 mm. and breadth of .015 mm. while those of the lower row have the same approximate breadth but an average length of .03 mm. In this variety there is an average of 6,875 upper palisade cells per sq. mm. of surface, or 49 per stoma.

The cells of the spongy mesophyll are irregularly arranged and have an average diameter of .02 mm.

The bundle sheath is quite evident in the cross-section of veinlets but there are fewer bast fibers present than in Sorbopyrus or Pyrus.

**Midrib**

The midrib, Fig. 89, is somewhat heart-shaped in cross-section and has 4 slight lobes on the convex side. It has an average width of .76 mm. and depth of .4 mm. The epidermal cells are slightly pointed, giving the sides of the midrib a corrugated appearance. They have an average diameter of .0175 mm. There are two rows of collenchyma beneath the epidermis on the convex side of the sec-
tion. All of the ground tissue cells on the concave side are collenchymatous. The average diameter of the cavities of the collenchymatous cells is .015 mm. while the average diameter of the ground parenchyma cells is .03 mm.

A single, large, heart-shaped, bundle forms the vascular arc in this section. The convex side of the arc is bordered with bast fibers interspersed with parenchyma cells. This region is from 0 to 7 cells wide.

**Margin**

The leaflets have blunt margins, Fig. 13, which do not differ essentially from the remainder of the blade. A small vein running parallel to the margin is found .12 mm. from the tip of the margin. The epidermal cells of the margin are more nearly regular in shape and size than elsewhere. The cuticle at the margin has the same average thickness as elsewhere.

**Venation**

A few large veins may readily be seen on the surface, Fig. 57, but there is a dense network of small veins embedded in the mesophyll, which is not so clearly defined. The leaflets of this variety have an average of 20 meshes and 8 free vein endings per sq. mm.

**Petiole**

In cross-section the petiole of this variety is ovate
with the pointed end flattened and slightly lobed, Fig. 91. The petioles average about 1.75 mm. in length, 1.04 mm. in width and 1.28 mm. in thickness. A section taken at the base of the petiole shows the entrance of 6 bundles into the petiole but in a section taken near the middle of the petiole, there is one large lunate, bicollateral bundle and two small bundles -- one in line with either end of the large bundle. The convex side of the arc has a border of bast fibers. This bast region ranges from 0 to 7 cells in width.

The epidermal cells have an average depth of .02 mm. Their outer walls are of the same approximate thickness as the inner walls and are only slightly cutinized. They have an average thickness of .001 mm. A cuticle having an average thickness of .01 mm. is found on the surface.

There is an average of 3 rows of collenchyma beneath the epidermis. These cells have cavities averaging .0225 mm. in diameter while the parenchyma cells of the ground tissue have an average diameter of .0275 mm.
SORBUS AUCUPARIA PENDULA

General Features

The leaves are compound and have from 9 to 15 leaflets which are oblong to oblong lanceolate, acute or obtusish, 2 to 5 cm. long, serrate, usually entire in the lower third, dull green above, glaucescent beneath and pubescent, at least when young. The are approximately .2 mm. thick.

Epidermis

There are extremely few trichomes found on leaves of this variety, Fig. 34. Those that are present are found on the lower epidermis of the leaf. They have an average length of .64 mm. and an average diameter of .0175 mm. They have decided curves near their bases which characterize the species to which they belong.

The inner and outer walls of both the upper and lower epidermises are not cutinized and have an average thickness of .005 mm. The cuticle on both leaf surfaces has an average thickness of .08 mm. but the thickness varies greatly on the lower side and gives the surface a very rugose appearance.

The upper epidermal cells, Figs. 50 and 16, have an average cross-diameter of .03 mm. and an average depth of .03 mm.

The lower epidermal cells, Fig. 51, have an average
diameter of .03 mm. while their average depth is .0225 mm. Their walls have an average thickness of .0015 mm.

There are no stomata on the upper epidermis but the lower epidermis has an average of 111 stomata per sq. mm.

**Mesophyll**

There are two rows of palisade cells, Fig. 16. The cells of the upper row have an average diameter of .0125 mm. and an average length of .045 mm. while the cells of the lower row have an average length of .03 mm. and an average diameter of .015 mm. There is an average of 9,375 upper palisade cells per sq. mm., or 84 cells per stoma.

The cells of the spongy mesophyll are irregularly arranged and have an average diameter of .02 mm. There is very little sclerenchymatous strengthening tissue in the small veins of this species.

**Midrib**

The midrib is somewhat heart-shaped in cross-section, Fig. 86. It has an average width and thickness of .4 mm. The epidermal cells have an average diameter of .015 mm. There are from one to 3 rows of relatively thick-walled collenchyma beneath the lower epidermis. The entire ground tissue, between the upper epidermis and vascular arc, is composed of collenchymatous cells. The collenchyma cells have cavities averaging .01 mm. in diameter while the ground parenchyma cells have cavities .02 mm. in di-
ameter.

The one, fan-shaped, bundle constitutes the vascular arc. This bundle extends quite near to the upper epidermis and its convex side is bordered by a region of relatively thin-walled bast fibers. This tissue varies from 0 to 6 cells in width.

Margin

The structure of the blunt margin in this variety is not essentially different from that of the remainder of the blade, Fig. 15. A small vein is found .08 mm. from the smaller end of the margin of the blade. The vein is parallel to the margin of the leaf.

Venation

As seen from the surface, the leaflet has a few prominent veins and a dense network of small veins embedded in the mesophyll, Fig. 54, and 5 free vein endings per sq. mm.

Petiole

The petiole has an average length of 2.25 mm., and average width of 1.2 mm., and an average thickness of 1.36 mm. In general form the section of the petiole is broad-ovate with the smaller end slightly indented, Fig. 92. The outer walls of the epidermis on the petiole give a slight cutin reaction and have a thickness of .01 mm. The inner walls have approximately the same thickness. The
cuticle has a thickness of .01 mm. The epidermal cells have an average diameter of .0175 mm. There are approximately 3 rows of collenchyma beneath the epidermis, all around the petiole. These cells have cavities averaging .02 mm. in diameter. The diameter of the ground parenchyma cells ranges from .02 mm. to .04 mm.

The vascular arc is composed of one large and two small vascular bundles. In this section, which was taken near the middle of the petiole, one small bundle is found in line with either end of the large bundle. In a cross-section made at the base of the petiole, three isolated bundles are seen to enter from the stem. The vascular arc almost entirely encloses a central portion of ground tissue or pith. The bundles are bordered on the convex side by an interrupted tissue of bast fibers. This region varies in width from 0 to 9 cells.

The stipules of this species average .04 mm. in length.
SORBUS AUCUPARIA

General Features

The leaves are compound, with 9 to 15 leaflets which are oblong to oblong-lanceolate, acute or obtusish, 2 to 5 cm. long, serrate, usually entire in the lower third, dull green above, glaucescent beneath and pubescent at least when young. The leaflets are approximately .16 mm. in thickness.

Epidermis

A few simple, wavy trichomes are found on the under side of the leaf, especially along the principal veins, Fig. 30. They have a decided bend near their base. They have an average length of .64 mm. and an average cross-diameter of .015 mm. Both the inner and outer walls of the leaf epidermis have a thickness of about .005 mm. and are not cutinized. The cuticle on both surfaces has an average thickness of .01 mm. but the thickness is quite irregular on the lower surface, thus giving the leaf a rugose appearance.

The upper epidermis, Fig. 48, is composed of cells which have an average cross-diameter of .0425 mm. and depth of .03 mm.

The lower epidermis, Fig. 49, of the blade is composed of cells having average cross-diameters of .02 mm. and depths of .03 mm.
There are no stomata in the upper epidermis but the lower epidermis has an average of 115 stomata per sq. mm.

**Mesophyll**

There are two rows of palisade cells in the mesophyll Fig. 28. The cells of the upper row have an average length of .0425 mm. and average cross-diameter of .01 mm. while the cells of the lower row have an average cross-diameter of .01 mm and an average length of .03 mm. There is an average of 9,375 upper palisade cells per sq. mm. of surface or 81 upper palisade cells per stoma.

The spongy mesophyll cells are irregularly arranged and have an average diameter of .02 mm.

The bundle sheath is quite evident in veins of the first order but little sclerenchymatous strengthening tissue is found near the small veins.

**Midrib**

The midrib is heart-shaped as seen in cross-section, Fig. 82, and has an average width of .48 mm. and an average thickness of .4 mm. The epidermal cells are triangular and give the midrib a rough appearance. The cavities of the epidermal cells have an average tangential diameter of .015 mm. and an average radial diameter of .02 mm.

There are from 2 to 3 rows of collenchyma beneath the lower epidermis while the entire ground tissue between the upper epidermis and the vascular arc is composed of col-
lenchymatous cells. The parenchyma cells of the ground tissue surrounding the vascular arc, have diameters ranging from .01 mm. to .03 mm. The vascular arc is composed of a single collateral bundle which is bordered on the convex side by a continuous region of bast. This zone ranges in width from 1 to 6 cells. It is thicker in the middle and tapers toward the sides.

**Margin**

The cellular structure of the margin is not essentially different from that of the rest of the blade, Fig. 27. A small vein running parallel to the edge of the leaf, is found about .08 mm. from the margin. The epidermal cells at the margin are more nearly the same size but the thickness of their walls and the cuticle is about the same as elsewhere.

**Venation**

As seen from the surface, there are a few prominent veins and a dense network of small veins embedded in the mesophyll, Fig. 58. There is an average of 16 meshes and 10 free vein endings per sq. mm. of surface.

**Petiole**

The petiole has an average length of 4.5 cm., and an average width of 1.6 mm. while its depth is 1.76 mm., Fig. 95. Its general shape in cross-section is ovate, with the
pointed end irregularly flattened. The outer walls of the epidermis on the petiole give a slight cutin reaction. Both inner and outer walls have an average thickness of .01 mm. The cuticle has an average thickness of .01 mm. The epidermal cells have an average cross-diameter of .02 mm. From 4 to 6 rows of collenchyma are found beneath the epidermis. The greater width of the collenchymatous zone is found on the somewhat flattened side of the petiole. The collenchyma cells have an average diameter of .02 mm. while the average diameter of the ground parenchyma cells is .03 mm.

As seen in a cross-section taken near the middle of the petiole, the vascular arc is composed of one large bundle, which is formed by the fusion of 3 smaller bundles, and two isolated small bundles -- one in line with either end of the large bundle. These bicollateral bundles almost completely surround a central pith. The convex side of the bundles is bordered by an interrupted zone of bast fibers. This region varies from 0 to 9 cells in width. At the base of the petioles of S. Aucuparia are finger-like glands digitately arranged. They have an average length of .48 mm. The stipules of this species range from .04 mm. in S. Aucuparia pendula to .06 mm. in S. Aucuparia.
SORBUS HYBRIDA (S. Aucuparia x S. intermedia)

General Features

The leaves of this species are obovate to oblong-ovate or oblong, 7 to 12 cm. long and average .24 mm. in thickness. There are 7 to 10 pairs of veins below. The leaves have from 1 to 4 pairs of oblong decurrent leaflets, acute or acutish and serrate toward the apex. The upper part of the leaf is lobed. The entire leaf is tomentose beneath.

Epidermis

Trichomes are found over the entire lower epidermis of the leaf, Fig. 32. They are simple but slightly curly and have an average length of 1.44 mm. and a breadth of .0175 mm.

The outer epidermal walls are not cutinized and have the same average thickness as the other walls of the cell. The average thickness of the walls is .005 mm. A cuticle with an average thickness of .0075 mm. is present on both epidermis. The lower epidermis is extremely rugose in appearance due to the unequal thickening of the cuticle.

The upper epidermis of the leaf is composed of cells with an average diameter of .05 mm. and a depth of approximately .035 mm.

The cells of the lower epidermis have an average diameter of .03 mm. and a depth of .02 mm. Their walls are approximately .002 mm. thick. There is an average of 210
stomata per sq. mm. in the lower epidermis, Fig. 43.

**Mesophyll**

There are two rows of palisade cells, Fig. 24. The upper row is composed of cells with an average length of .05 mm. and diameter of .0125 mm., while the cells of the lower row have an average length and diameter of .03 mm. and .0125 mm. respectively. There is an average of 6,875 upper palisade cells per sq. mm., or 33 per stoma.

The cells of the spongy mesophyll average .025 mm. in diameter. Like *S. intermedia*, all the veins of this species are bordered with only a slight amount of relatively thick-walled protenchyma.

**Midrib**

The midrib has an average width of 1.1 mm. and an average depth of .7 mm. In cross-section, Fig. 84, it is somewhat rectangular in shape. The average diameter of the cavities of the epidermis is .02 mm. There is an average of two rows of relatively thick-walled collenchyma beneath both epidermises. These cells have cavities averaging .022 mm. in diameter while the parenchyma cells of the ground tissue have cavities averaging .04 mm. in diameter.

A single, lunate vascular bundle forms the vascular arc. The convex side of the arc is bordered with a region of bast which is from 2 to 4 cells wide. An average of 2 rows of protenchyma cells border the concave side.
Margin

The margin of this leaf is relatively blunt, Fig. 23. Both the lower and upper epidermal cells of the margin are of about the same size, having an average depth of .03 mm. The cuticle is somewhat thicker at the margin than elsewhere. A small vein running parallel to the margin is found about .14 mm. from the edge of the margin.

Venation

When viewed from the surface the leaf is seen to have a few large veins and a fine network of smaller veins embedded in the mesophyll, Fig. 60. There is an average of 14 meshes and 6 free vein endings per sq. mm. of surface.

Petiole

The petiole is semi-circular in cross-section, with two shallow lobes on the top, Fig. 93. It measures 2.56 mm. in width, 1.92 mm. in depth, and 1.7 mm. in length. The epidermal cell cavities are quite pointed and have an average diameter of .02 mm. The outer epidermal walls are slightly cutinized and have a thickness of .006 mm. which is the same thickness as that of the inner walls. A cuticle having a thickness of .01 mm. is present.

Beneath the epidermis are 3 rows of collenchyma which entirely surrounds the petiole. Most of the collenchyma cells are on the somewhat concave side of the petiole. The collenchyma cells have an average cavity diameter of
while the average diameter of the parenchyma cells of the ground tissue is .04 mm. At the base of the leaf, 5 distinct vascular bundles enter the petiole. Midway up the petiole, three of the bundles fuse to form one large bicollateral bundle while each of the other two bundles remain isolated and one is found paralleling the lateral edge of the large bundle. The entire arc is horse-shoe-shaped. The convex side of the arc has a border of bast fibers. The width of this zone varies from 0 to 9 cells. The small, isolated bundles are almost surrounded by bast fibers.
SORBUS INTERMEDIA

General Features

The leaves of this species are simple and elliptic to obovate-oblung. They average 8 cm. in length and .2 mm. in thickness. They have short, broad irregularly serrate lobes. The petioles average 1.75 cm. in length.

Epidermis

Simple trichomes averaging 1.6 cm. in length and .015 mm. in breadth cover the entire lower surface of the leaf and are as numerous near the margin as elsewhere, Fig. 31. They are slightly wavy and twisted.

The upper epidermis of the leaf is composed of cells from .04 mm. to .1 mm. long and from .03 mm. to .04 mm. broad, Figs. 40 and 12. The depth of the cells varies from .02 mm. to .05 mm. There is a cuticle on both the upper and lower epidermises which has an average thickness of .003 mm. It is unevenly thickened on the lower epidermis and gives that side of the leaf a rugose appearance when seen through the microscope. The outer walls are not cutinized and have the same approximate thickness, of .005 mm., as the inner and radial walls.

The lower epidermal cells are irregular and have an average cross-diameter of .03 mm. and a depth of 101 mm. to .02 mm., Fig. 41 and Fig. 12. There is an average of
166 stomata per sq. mm. in the lower epidermis.

**Mesophyll**

There are two rows of palisade cells in the leaves of this species, Fig. 12. The cells of the upper row average .045 mm. in length and .015 mm. in diameter while those of the lower row average .035 mm. in length and .015 mm. in cross-diameter. An average of 6,250 upper palisade cells are found per sq. mm. of surface. This is an average of 37 upper palisade cells per stoma.

The spongy parenchyma cells have an average diameter of .0225 mm. Few large intercellular spaces are seen in this species.

The bundle sheath is quite noticeable in sections of small veins but there is scarcely any sclerenchymatous strengthening tissue to be seen.

**Midrib**

The midrib is elliptical in shape, with an average width of .88 mm. and an average depth of .8 mm., Fig. 85. The epidermal cells are relatively small, their cavities averaging .02 mm. in diameter while the cavities of cells comprising the ground tissue have an average diameter of .04 mm. From 1 to 2 rows of collenchyma are found beneath the epidermis.

The vascular arc is composed of one collateral bundle. The convex side of the arc is bordered with a bast region.
which ranges from 0 to 5 cells in width.

Numerous small intercellular spaces are found throughout the ground tissue.

**Margin**

The leaf margin is blunt and has a structure similar to the rest of the blade, Fig. 11. A small vein is found .06 mm. from the edge of the blade. The cuticle is slightly thicker at the margin and the epidermal cells are more nearly regular in shape and size than elsewhere on the blade.

**Venation**

As seen from the surface, the blade of this species has numerous large veins and a fine network of small veins Fig. 55. There is an average of 18 meshes and 6 free vein endings per sq. mm.

**Petiole**

The average length of the petiole is 1.75 cm. while its width and depth are 1.28 mm. and 1.34 mm. respectively, Fig. 94. In general shape a cross-section of a petiole is ovate with the pointed end flattened and upward.

The outer epidermal wall is slightly cutinized and has a thickness of .006 mm. which is about the same as that of the other walls of the cell. A cuticle measuring .015 mm. in thickness is present. The epidermal cells have cavities averaging .0225 mm. in diameter. From 4 to
6 rows of collenchyma are found beneath the epidermis all around the petiole. These cells have cavities with an average diameter of .03 mm. The cortical parenchyma cells have diameters ranging from .03 mm. to .06 mm.

The vascular arc consists of one, large, crescent-shaped, bicollateral bundle and three small bundles, -- one at one end and two in line with the other end of the large crescent-shaped bundle. The convex side of the vascular bundles has an almost uninterrupted border of bast fibers. The border is from 0 to 10 cells in width. The phloem on the concave side of the arc is bordered by two rows of thick-walled prosenchyma cells of the ground tissue.
SORBUS COMMIXTA

General Features

The leaves are compound and have 11 to 15 leaflets. The leaflets are elliptic-lanceolate, long-acuminate, 2.5 cm. to 8 cm. long, sharply and sometimes doubly serrate, with acuminate or aristate teeth and glaucous beneath. The leaflets are approximately .18 mm. thick.

Epidermis

This is the only species studied in which the leaves are free from trichomes.

The upper epidermis, Fig. 46 and Fig. 26, is composed of cells having an average cross-diameter of .04 mm. and an average depth of .02 mm.

The lower epidermis, Figs. 47 and 26, is composed of cells having an average cross-diameter of .04 mm., an average depth of .015 mm. and wavy walls.

The outer walls of the upper and lower epidermises are not cutinized and have the same average thickness as the inner cell walls. For the upper epidermis, this thickness is .005 mm. while for the lower epidermis the thickness is .003 mm. The upper surface of the leaf is covered by a cuticle having a thickness of .0025 mm. while the cuticle on the lower surface has an average width of .005 mm.

There are no stomata in the upper epidermis but the
lower epidermis has an average of 140 stomata per sq. mm.

**Mesophyll**

There are two rows of palisade cells, Fig. 26. Cells of the upper row have an average length of .05 mm. and an average cross-diameter of .01 mm., while cells of the lower row have the same average diameter but an average length of .03 mm.

An average of 11,250 upper palisade cells occurs per sq. mm. of leaf surface. This is an average of 80 upper palisade cells per stoma.

Cells of the spongy mesophyll are irregularly arranged and have an average cross-diameter of .01 mm.

**Midrib**

The midrib is somewhat heart-shaped in cross-section. It has an average width of .48 mm. and an average depth of .48 mm. The epidermal cells have cavities averaging .02 mm. in cross-diameter. Their walls are slightly cutinized and have a thickness of .008 mm. The cuticle has about the same thickness as the wall.

From 1 to 2 rows of collenchyma underlie the lower epidermis of the midrib of this species. Collenchyma constitutes the ground tissue between the upper epidermis and the vascular arc. These collenchyma cells have cavities averaging .02 mm. in cross-diameter. The ground parenchyma cells surrounding the vascular arc have an average diameter of .03 mm.
The vascular arc is composed of a single broad, cordate, bundle. The convex side of the bundle is bordered by a region of relatively thin-walled bast fibers. The bast region ranges from 0 to 6 cells in width.

Margin

The margin, Fig. 25, is not essentially different from the rest of the blade although the outer walls of the epidermal cells and the cuticle are thicker at the margin than elsewhere. A small vein which runs parallel to the upper and lower surfaces of the blade, is found at a distance of .2 mm. from the edge of the leaf. There is a small amount of collenchyma at the very edge of the margin in this species. This is not found in the other species of Sorbus studied.

Venation

As seen from the surface, there are a few prominent veins and a network of smaller veins embedded in the mesophyll, Fig. 61. There is an average of 12 meshes and 7 free vein endings per sq. mm.

Petiole

Petioles of this species have an average length of 3 mm., Fig. 97. As seen in cross-section, the petiole is ovate with the pointed end depressed to a depth of .08 mm. It has an average width of 1.23 mm. and an average thickness of 1.6 mm.
The epidermis has an outer wall which averages .01 mm. in thickness and gives only a slight cutin reaction. The thickness of the outer wall is approximately the same as that of the inner walls in both the upper and lower epidermises. The cuticle has an average thickness of .015 mm.

From 2 to 3 rows of collenchyma are found beneath the epidermis completely surrounding the petiole. Their cell cavities average .02 mm. in diameter. The cavities of the ground parenchyma cells range from .03 mm. to .05 mm. in cross-section. The vascular arc is composed of one large crescent-shaped bicolateral bundle and two smaller bundles one in line with either end of the large bundle. Of the 5 bundles entering the petiole, three fuse to form the large bundle. The convex sides of the bundles are bordered by a bast fiber region from 0 to 11 cells wide. The concave sides are bordered by relatively thin-walled prosenchyma cells.

Stipules of this species have an average length of .01 mm.
SORBOPYRUS AURICULARIS

General Features

The leaves of this species are broad-elliptic, short-acuminate, usually rounded at the base, 6 to 10 cm. long, irregularly and coarsely serrate or doubly serrate and pubescent beneath. They have an average thickness of .16 mm.

Epidermis

A few curly trichomes, Fig. 35, are found on the lower side of the leaf, especially along the larger veins. They have an average diameter of .015 mm. and an average length of .64 mm.

The upper epidermal cells, Figs. 38 and 22, have cross-diameters averaging .04 mm. and a depth of .03 mm. The lower epidermal cells, Figs. 39 and 22, have cavities which average .03 mm. in cross-diameter and .015 mm. in depth. There are no stomata in the upper epidermis but the lower epidermis has approximately 297 stomata per sq. mm.

The combined thickness of the outer epidermal wall and the cuticle is about .008 mm. The outer part of the radial walls shows some cutinization.

Mesophyll

There are two rows of palisade cells in this species, Fig. 22. The cells of the upper row have an average diameter of .015 mm. while their length is .045 mm. The cells
of the lower row have average cross-diameters of .015 mm. and an approximate length of .03 mm. An average of 8,125 upper palisade cells occurs per sq. mm. of leaf surface. This gives an average of 27 upper palisade cells per stoma.

The cells of the spongy mesophyll are irregularly arranged and average about .02 mm. in cross-diameter.

Bast fibers almost surround the small veins of the leaf. Those on the under side of the veins have the thicker walls.

Midrib

The midrib, as seen in cross-section, is semi-circular in shape, Fig. 88, and it measures 1.28 mm. in width and 1.12 mm. in thickness. The outer epidermal walls are cutinized. The outer walls and the cuticle have a combined thickness of .012 mm.

Three rows of collenchymatous cells are found beneath the lower epidermis and a group of collenchymatous cells occurs just beneath the upper epidermis in the middle of the section. The parenchyma cells have cavities averaging .05 mm. in cross-diameter.

A single, crescent-shaped, bundle occupies the central part of the midrib. The xylem on the convex side of the vascular arc is bordered by a zone of bast fibers which ranges in width from 0 to 10 cells. The phloem on the concave side of the arc is bordered by a region of thin-walled prosenchymatous cells,
Numerous small intercellular spaces are found throughout the ground tissue.

Margin

The leaf has a blunt margin, Fig. 21, and the cuticle here is comparatively thick while the epidermal cells are somewhat elongated radially. A small vein is found .12 mm. from the edge of the blade. While the mesophyll of the margin does not closely resemble that of other parts of the blade, the epidermis is still quite similar to that found on other parts of the blade.

Venation

When viewed from the surface, the leaf is seen to have a few prominent veins and numerous smaller veins which are embedded in the mesophyll, Fig. 56. In this species there are 9 meshes and 2 free vein endings per sq. mm. of leaf surface.

Petiole

The length of the petiole in this species averages 2.5 cm. In cross-section it is semi-circular in shape, Fig. 98. It has a width of 1.36 mm. and a thickness of .1.28 mm. The outer and radial walls of the epidermal cells are cutinized. They have approximately the same thickness of .01 mm. A relatively thin cuticle is present and has a thickness of .005 mm. The epidermal cells are relatively small compared with the cells of the fundamental tissue.
As seen in cross-section they have cavities approximately .01 mm. in diameter, while the collenchymatous cells beneath them have cavities approximately .03 mm. broad.  

On the convex side of the petiole there are 2 rows of collenchyma beneath the epidermis and on the concave side there is an average of 8 rows of collenchyma beneath the epidermis.  

The vascular arc is composed of a single, bicollateral bundle. The phloem on the convex side of the arc is bordered by a zone of bast fibers ranging in width from 0 to 8 cells. The phloem on the concave side is bordered by 2 to 3 rows of thin-walled prosenchyma.
PYRUS COMMUNIS

General Features

The leaves are simple, orbicular-ovate to elliptic, acute or short-acuminate, subcordate to broad cuneate, 2 to 8 cm. long, crenate-serrulate and glabrous or villous when young. The petioles are slender and from 1.5 cm. to 5 cm. long. The leaf has an average thickness of .24 mm.

Epidermis

The outer walls of the leaf epidermis are slightly thicker than the inner walls; they have an average thickness of .008 mm. and are cutinized. A cuticle having an average thickness of .004 mm. is found on both leaf surfaces.

The upper epidermis is composed of cells having an average diameter of .03 mm., and an average depth of .0225 mm., Figs. 52 and 20. There are no stomata or trichomes present in the upper epidermis.

The lower epidermis, Figs. 53 and 20, is composed of cells having an average diameter of .03 mm. and a depth of .0175 mm. Only a few trichomes are found on the lower epidermis. Most of them are found near the margin. There are approximately 117 stomata per sq. mm. in the lower epidermis.
Mesophyll

There are two rows of palisade cells, Fig. 20. The upper row is composed of cells having an average length of .04 mm. and an average cross-diameter of .01 mm. The lower row is composed of cells having the same diameter but their average length is .03 mm. There is an average of 14,283 upper palisade cells per sq. mm. of surface, or 122 per stoma.

The cells of the spongy mesophyll are loosely arranged and have an average diameter of .02 mm.

There is more strengthening sclerenchyma in the small veins than is seen in Sorbus.

Midrib

As seen in cross-section, Fig. 90, the midrib of this species is almost circular in form. Its hemi-spheres extend out about equally on both the upper and lower sides of the blade. It has an average diameter of .48 mm.

The outer walls of the epidermal cells and the outer parts of the radial walls show cutinization. The outer walls and the cuticle have a combined thickness of .0125 mm.

There are no rows of collenchyma cells beneath the epidermis. The ground parenchyma cells have cavities with an average diameter of .02 mm. The vascular arc is composed of a collateral bundle which is bordered dorsal-
ly and ventrally by a region of bast fibers. The bast region is from 2 to 5 cells wide. The upper bast region is composed of cells having slightly greater cross-diameters than those on the lower side.

**Margin**

The structure of the leaf margin is quite different from that of other parts of the blade, Figs. 19 and 20. The margin tapers considerably, the epidermal cells are elongated in depth and their outer walls and cuticle are much thicker than elsewhere on the blade. The outer .06 mm. of the margin is composed entirely of collenchyma.

A small vein running parallel to the edge of the leaf is found .12 mm. from its margin.

**Venation**

When viewed from the surface, the leaf is seen to have numerous prominent veins and a network of small veins embedded in the mesophyll, Fig. 59. There is an average of 17 meshes and 8 free vein endings per sq. mm. of surface.

**Petiole**

The average length of the petiole is 3 cm. while its width and thickness are 1.2 mm. and .9 mm., respectively.

The outer walls and outer parts of the radial walls of the epidermis of the petiole give a cutin reaction. The cutinized outer wall and the cuticle have a combined
thickness of .015 mm. The epidermal cells have cavities averaging .02 mm. in diameter.

Immediately below the epidermis and completely surrounding the petiole are from 2 to 3 rows of collenchyma. The cavities of the collenchyma average .025 mm. in cross-diameter while the ground parenchyma cells have cavities averaging .035 mm. in diameter.

The vascular arc is composed of a single, collateral bundle. The convex side of the bundle is bordered by an irregular zone of bast fibers. This zone ranges from 0 to 4 cells in thickness. The concave side of the arc is bordered by a zone of thin-walled prosenchymatous cells.

In general form of cross-section, the petiole is fan-shaped, Fig. 96.
The leaves vary greatly in general form. Those of *S. Aucuparia* and its varieties and *S. hybrida*, *S. commixta* and *S. americana*, are regularly pinnate. The leaves of *S. hybrida* are pinnate only toward the base while the upper part is lobed and usually serrate. *S. Aria* and *S. intermedia* have simple leaves. The length of the leaflets ranges from about 2 cm. to 5 cm. in *S. Aucuparia* and its varieties. In *S. americana* and *S. commixta* the average length is about 7 cm. The thickness of the leaflets is quite uniform for all of the species having regularly pinnate leaves as well as those having simple leaves. It averages about .18 mm. *S. intermedia* has a leaf thickness of about .24 mm. which is greater than that of either of its parents.

Considerable variation is seen in the trichomes of this genus. The leaves of *S. commixta* are glabrous. Those of *S. Aucuparia* and *S. americana* are pubescent beneath when young but may become glabrous. *S. hybrida*, *S. intermedia* and *S. Aria* have wooly trichomes on the lower surface of the leaf. *Sorbopyrus* has a few simple trichomes on the lower surface. The length of the trichomes ranges from .64 mm. in *S. Aucuparia*, *S. Aucuparia* var., and *Sorbopyrus* to 1.6 mm. in *S. intermedia*. In all of the species the trichomes are simple.

The lower epidermal cells are irregular in shape and
have average cross-diameters, as seen from the surface, of .03 mm. The depth of the cells varies from .01 mm. to .03 mm. Considerable variation is shown in the depth of the cells within a single species.

The cells of the upper epidermis are somewhat rectangular or square as viewed from the surface. Their cross-diameters average about .04 mm.; their depths vary from .01 mm. in S. americana to .04 mm. in S. intermedia. The cells show much variation in size within a given species.

The outer walls of both the upper and lower epidermal cells are not at all, or only slightly cutinized and have about the same average thickness as the inner walls. A cuticle is present in all species. The cuticle on the lower epidermis is more or less irregularly thickened and gives the epidermis a very rugose appearance when seen through a microscope. Stomata are found only on the lower epidermis of the leaf and are relatively few in number. The number per sq. mm. ranges from 111 in S. Aucuparia pendula to 210 in S. hybrida.

Two rows of palisade cells are present in all of the species studied. The dimensions of these cells are quite similar in all the species but showed some variation even within a single species. The average cross-diameter and of the upper row of palisade cells are .0125 mm. and .045 mm., respectively, while the lower row of palisade cells have an average cross-diameter and length of .015 mm. and
.03 mm., respectively. The number of upper palisade cells per sq. mm. of surface ranges from 6,250 in S. intermedia to 11,250 in S. commixta.

The cells of the spongy mesophyll are usually somewhat ovate with an average diameter of .02 mm.

The midrib as seen in cross-section is broad-cordate in general form. The width of a cross-section made at the middle of the midrib ranges from .4 mm. in S. Aucuparia pendula to 1.28 mm. in Sorbopyrus. The thickness ranges from .4 mm. in S. Aucuparia and its varieties to 1.12 mm. in Sorbopyrus. Little difference is seen in the dimensions of midribs in simple leaves and in leaflets. An average of 2 rows of collenchyma is found beneath the epidermis in the midribs of S. Aucuparia and its varieties, S. hybrida, S. intermedia, S. americana and in Sorbopyrus. More collenchyma is found above the vascular arc than below it. In these species some collenchyma is found beneath both the upper and lower epidermis. In S. commixta, little collenchyma is found beneath the lower epidermis but the entire region between the vascular arc and the upper epidermis is composed of collenchyma.

In all the species of Sorbus, with the exception of S. americana, and in Sorbopyrus, the convex side of the fan-shaped vascular arc is bordered with a region of bast fibers which ranges from 0 to 6 cells in width. In S. americana there are no bast fibers. The concave side of the arc is
usually bordered by a few rows of prosenchymatous cells which contain starch and tannin.

As seen from the surface, the leaves of Sorbus have a few prominent veins and a dense network of small veins which are embedded in the mesophyll. The average number of meshes per sq. mm. of surface is about 16, while the average number of free vein endings per sq. mm. is about 8. Few bast fibers and little phloem are found in the veins of Sorbus.

The leaf margins of Sorbus do not differ essentially from the remainder of the blade in structure. Usually the epidermal cells are of a more nearly uniform size at the margin and in a few cases the cuticle is somewhat thicker. The leaf margin of Sorbopyrus resembles its Pyrus parent in having a region of collenchyma re-enforcing the margin. In this species, too, the cells are irregularly arranged and of irregular shape in the margin while the blade shows the regular arrangement of two rows of palisade cells. The margin of a Sorbopyrus leaf is noticeably thinner than the rest of the blade. The same is true of *P. communis*.

The characteristic shape of the petiole as seen in cross-section is ovate, with the pointed end indented more or less. The epidermal cells of the petioles are very small. Their outer walls have the same approximate thickness as the inner walls and are cutinized. A cuticle is present in all species but it is often difficult to dis-
tistinguish it from the cutinized outer wall.

An average of about 3 rows of collenchyma is found beneath the epidermis in *S. Aucuparia* var., *S. Aucuparia pendula*, *S. commixta*, *S. hybrida*, and *Sorbopyrus*. *S. americana* has only two rows of relatively thin-walled collenchyma encircling the petiole while *S. Aucuparia* and *S. intermedia* have from 4 to 10 rows of collenchyma encircling the petiole. Most species show a decidedly larger amount of collenchyma on the upper side of the petiole than on the lower side.

The vascular arc is located in the center of the parenchymatous tissue of the petiole. Three vascular bundles enter the bases of the petioles of *Sorbopyrus*, *S. intermedia*, and *S. Aucuparia pendula*; 5 vascular bundles enter the petioles of *S. americana*, *S. commixta*, *S. hybrida*, and *S. Aucuparia*. I noted the entrance of 6 bundles in the petiole of *S. Aucuparia* var. In cross-sections made near the middle of the petiole the following species have a vascular arc composed of 1 large and 2 small vascular bundles: *S. americana*, *S. Aucuparia* and its varieties, and *S. hybrida*. *Pyrus communis* and *Sorbopyrus* each have only one bundle while *S. intermedia* has 1 large and 3 small bundles. The vascular arcs in *Sorbus* and *Sorbopyrus* are composed of bi-collateral bundles that are bordered on the convex side by a region of bast fibers and on the concave side by a region of prosenchyma. The petiole of *Sorbopyrus* showed
an endodermis immediately outside of the bast region. A similar endodermis is seen in S. americana.

The leaves of species of Sorbus have the following common characteristics:

1. Trichomes, if present, are found only on the lower epidermis. All trichomes are simple.
2. Stomata are found only in the lower epidermis.
3. The outer walls of the epidermal cells are all of the same approximate thickness as the inner walls.
4. There are two rows of palisade cells in the mesophyll.
5. There are relatively few free vein endings.
6. The structure of the leaf margin is quite similar to that of the remainder of the blade.
7. The vascular bundles of the petioles are bicolateral.

The leaves of Sorbus show the following variations:

1. The number of vascular bundles entering the petiole is usually 3 or 5 but a sixth bundle was seen in one species.
2. Trichomes varying in length from .64mm. to 1.6 mm. are found while one species was glabrous.
3. The number of stomata ranges from 111 per sq. mm. to 210 per sq. mm.
4. The amount of collenchyma found in the midrib and
petiole varies greatly in the different species.

5. The general form of the leaf ranges from simple leaves like those of S. intermedia to pinnately compound leaves like those of S. Aucuparia.
LEAVES

I - Name of species.
II - Diameter and length of trichomes.
III - Diameter and depth of upper epidermal cells.
IV - Diameter and depth of lower epidermal cells.
V - Number of stomata per sq. mm.

NOTE: All measurements are given in microns. Dimensions are given in their respective order.

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A COMPARISON OF S. HYBRIDA AND ITS PARENTS

Burgerstein ('95) describes S. hybrida as being a hybrid between S. Aria (Aria nivea) and S. Aucuparia while Rehder ('27) gives the parentage as S. Aucuparia and S. intermedia. I am inclined to agree with Rehder because I see more similarity between S. hybrida and S. intermedia (see conclusion) than I see between S. hybrida and S. Aria, therefore, I am assuming that S. Aucuparia and S. intermedia are the parents of S. hybrida.

S. hybrida and its parents each show an approximate average of 2 rows of cork cells formed beneath the epidermis of a one-year stem. As the phelloderm becomes older the cells elongate, vertically, and the walls thicken in S. Aucuparia and S. hybrida but this is not true for S. intermedia.

S. intermedia has an average of 15 rows of collenchyma beneath the periderm in a one-year stem while S. Aucuparia and S. hybrida each have an average of 10 rows. The collenchyma is relatively thick-walled in all 3 species. There is an average of about 16 rows of parenchyma cells in the cortex of each species. The walls of these cells have the same average thickness.

The primary bast fibers are arranged in isolated bundles in the inner cortex of all of these species. The bundles have a maximum width of 5 cells in every case.
The dimensions of the fibers show noticeable variations. The cross-diameters in S. Aucuparia, S. hybrida and S. intermedia are .013 mm., .022 mm., and .0225 mm., respectively, while their respective lengths are .72 mm., 1.2 mm. and .555 mm.

In all species the secondary bast fibers are arranged in a much interrupted cylinder in the secondary phloem. The maximum width of this cylinder is 8 cells, in S. hybrida, which is twice the maximum width of the secondary bast region in either of its parents. There is considerable variation in the cross-diameters and length of the secondary bast fibers in these species. The cross-diameters in S. Aucuparia, S. hybrida, and S. intermedia are .0165 mm., .021 mm., and .0175 mm., respectively, while their respective lengths are .12 mm., .56 mm., and .28 mm., respectively.

In the phloem, the sieve tube elements, companion cells, and parenchyma cells show no essential difference in their respective dimensions in the 3 species.

There is a difference in the vertical lengths of the rays. The maximum length is 30 cells in S. Aucuparia, 60 cells in S. hybrida and 56 cells in S. intermedia.

The pith is heterogeneous in all three species.

In brief there is very little difference in the stems of S. Aucuparia, S. hybrida and S. intermedia. The greatest variations were seen in the dimensions of the primary
and secondary bast fibers. *S. hybrida* differed from both of its parents in having a much broader zone of bast and longer bast fibers.

The general form of the leaves of *S. hybrida* is a blend between that of its parents. While the leaves of *S. hybrida* are classed as compound, they resemble the simple leaves of *S. intermedia* more closely than they resemble the compound leaves of *S. Aucuparia*. The main difference between the leaves of *S. hybrida* and *S. intermedia* is that in *S. hybrida* from 1 to 4 pairs of oblong leaflets are found below the broad, lobed, upper part of the leaf.

The leaves of *S. hybrida* resemble those of *S. intermedia* in having woolly trichomes on the lower surface. The leaves of *S. Aucuparia* are only pubescent beneath and may even be glabrous beneath when they are old. In all three species the trichomes are simple.

*S. hybrida* exceeds both of its parents in leaf thickness which averages .24 mm. while the leaves of *S. intermedia* and *S. Aucuparia* average .2 mm. in thickness and .16 mm. in thickness, respectively.

As seen from the surface, the upper epidermal cells of *S. hybrida* and its parents are somewhat hexagonal. The average cross-diameters of the upper epidermal cells of *S. Aucuparia*, *S. hybrida*, and *S. intermedia* are .0425 mm., .05 mm., and .03 mm., respectively. The average depth of
the epidermal cells varies slightly, being .035 mm. for each of the 3 species.

The lower epidermal cells are irregular in shape as seen from the surface. In all 3 species they have an average cross-diameter of about .0275 mm. In S. Aucuparia, S. hybrida and S. intermedia the depths of the lower epidermal cells are .03 mm., 102 mm., and .01 mm., respectively.

The number of stomata per sq. mm. is somewhat greater in S. hybrida than in either of its parents. S. Aucuparia has an average of 115, S. hybrida has an average of 210, and S. intermedia has an average of 166 stomata per sq. mm. In all 3 species the stomata are found only in the lower epidermis.

All of the species have 2 rows of palisade cells. There is an average of 9,375 upper palisade cells per sq. mm. of leaf surface in S. Aucuparia, while S. hybrida has an average of 6,250. The dimensions of the upper palisade cells are almost the same for each species, averaging in cross-diameter .0125 mm. and in length .045 mm. The lower palisade cells have an average cross-diameter of .0125 mm. and an average length of .03 mm.

The cells of the spongy mesophyll are irregularly arranged and have an average cross-diameter of .02 mm.

The general shape of the midribs as seen in cross-section is semi-circular. In these 3 species the epider-
mal cells of the midrib are relatively small. An average of two rows of collenchyma found beneath the lower epidermis is common to all. The region between the concave side of the vascular arc and the upper epidermis is composed entirely of collenchymatous cells. The region between the collenchymatous hypoderm and the convex side of the vascular arc is composed of parenchymatous cells which have an average cross-diameter approximating .04 mm. in these 3 species. The vascular arcs of these species are essentially alike. They are composed of a fan-shaped collateral bundle which is bordered on the convex side by a region of bast fibers and on the concave side by about 2 rows of prosenchyma.

As in all of the Sorbus species studied, these species show a few prominent veins and a dense network of small veins embedded in the mesophyll. There is an average of 16 closed meshes per sq. mm. of surface in S. hybrida and its parents, and relatively few free vein endings.

The leaf margins of these are similar and show essentially the same structure as the rest of their blades.

The general shapes of cross-sections of petioles of S. hybrida and its parents are quite similar. They are ovate with the pointed end somewhat indented. Cross-sections taken at the middle of the petiole show consider-
able variation in width and thickness. The widths of the petioles of *S. Aucuparia*, *S. hybrida*, and *S. intermedia* are 1.6 mm., 2.56 mm., and 1.28 mm., respectively. Their respective thicknesses are 1.76 mm., 1.92 mm., and 1.34 mm.

The epidermal cells of these species are relatively small. Their outer walls are rounded in *S. Aucuparia* and *S. intermedia* but in *S. hybrida* the outer walls are pointed. The thickness of the outer walls does not exceed that of the inner walls. The cuticle on the epidermis of *S. hybrida* is slightly thicker than that of *S. Aucuparia*, which has a thickness of .01 mm. The cuticle of *S. intermedia* has an average thickness of .015 mm.

An average of 5 rows of collenchymatous hypoderm is found beneath the epidermis of *S. Aucuparia* and *S. intermedia* while *S. hybrida* has an average of 7 rows of collenchyma beneath the epidermis.

The vascular arc is surrounded by a region of parenchyma. In all 3 species the bundles of the vascular arc are bicolateral. They are bordered on the convex side by a region of bast fibers and on the concave side by 2 or 3 rows of proenenchyma. The vascular arc, as seen in cross-section at the middle of the petiole, is composed of 1 large and 2 small bundles in *S. Aucuparia* and *S. hybrida*. In *S. intermedia* it is composed of a single large bundle.

The number of vascular bundles entering the petiole in *S. Aucuparia* and *S. hybrida* is 3, while the other species has 5.
A COMPARISON OF SORBOPYRUS AURICULARIS AND ITS PARENTS

The hybrid between S. Aria and P. communis is variously named by different authors. The following names are listed in Rehder ('27) -- Manual of Cultivated Trees and Shrubs: Sorbopyrus auricularis - Schneid., Pyrus auricularis - Knoop, P. Pollveria - L., P. Bollwylleraiana - DC., S. Bollwylleraiana - Zabel, Bollwilleria a - Zabel. Rehder uses the name Sorbopyrus auricularis for the hybrid and I am following his usage.

In comparing Sorbopyrus auricularis and its parents, I shall call attention to the most outstanding features of the species concerned.

All three species have an average of 3 rows of cork cells formed beneath the epidermis the first year and an average of 5 rows of collenchyma found beneath the periderm at this stage. The collenchyma cells are relatively thin-walled. The number of layers of parenchyma cells found in the cortex is 12 in S. Aria, 18 in Sorbopyrus, and 15 in P. communis. The average thickness of the walls of the parenchyma is slightly greater in Sorbopyrus than in either of its parents.

The primary bast fibers in these species are arranged in an interrupted cylinder in the inner cortex. The maximum width of the primary bast cylinder is 12 cell lay-
ers in S. Aria, 10 layers in Sorbopyrus, and 7 layers in P. communis. The cross-diameter and the length of the fibers are essentially the same in the 3 species.

The secondary bast fibers are arranged similarly in all the species. They form an interrupted cylinder in the secondary phloem. The maximum width of this region is 7 cell layers in S. Aria, 8 layers in Sorbopyrus and 4 layers in P. communis. The cross-diameters of the secondary bast fibers are essentially the same but the average length of the fibers is somewhat greater in Sorbopyrus.

Stone cells are quite numerous in Sorbopyrus and P. communis. Most of the stone cells are box-shaped and are probably formed from ray cells. There are some fibrous stone cells found in association with the bast fibers. I was unable to find any stone cells in S. Aria.

The sieve tube elements, companion cells and parenchyma cells containing calcium oxalate crystals, have almost the same average lengths but the cross-diameter of the sieve tube elements is somewhat greater in P. communis than in either of the other two species. The cross-diameter of the parenchyma cells as well as their number is greater in Sorbopyrus than in either of its parents.

Considerable variation is seen in the dimensions of the tracheal elements of Sorbopyrus and its parents. The average cross-diameter of the tracheal elements in S. Aria is .04 mm., which is about twice the average cross-diamet-
ers in the other two species. The length of the elements in S. Aria averages about .32 mm. which is about twice the average length in the other 2 species.

A few tracheids were found in each of the species. They had approximately the same dimensions in all 3 species.

Numerous fiber tracheids were present in the metaxylem and the secondary xylem. They are somewhat longer and have greater cross-diameters in Sorbopyrus than in either of its parents.

Sorbopyrus resembles its Pyrus parent in having homogeneous pith which is loaded with starch. The central pith of S. Aria contains numerous thin-walled empty cells.

In cross-section, the general form of the petiole of Sorbopyrus is intermediate between that of the Sorbus type and P. communis. In all three species the epidermis is composed of relatively small cells; however, Sorbopyrus resembles the Sorbus type by having extremely small epidermal cells. From 3 to 6 rows of collenchymatous hypoderma are common to all three of the types studied. The ground parenchyma cells are similar in all. In P. communis, bundles of bast fibers closely border the phloem on the convex side of the vascular arc and other thinner-walled bast fibers border the concave side of the xylem. In Sorbus, the bast region is continuous and borders only the convex side of the arc, while the concave side of the arc is bordered by thin-walled prosenchymatous cells.
arrangement if bast fibers in the petioles of Sorbopyrus resembles that of Sorbus quite closely. Sorbopyrus differs from Pyrus and probably from its Sorbus parent in having a starch sheath bordering the convex side of the vascular arc. The vascular bundles in the petioles of Sorbopyrus and Sorbus are bicollateral while those of Pyrus are collateral.

As seen in cross-section, the general form of the midrib of Sorbopyrus is quite similar to that of Sorbus and quite dissimilar to that of P. communis. The epidermal cells are quite similar in all three species. Sorbopyrus differs from both parents by having a broad zone of collenchyma beneath both epidermises of the midrib.

In general shape, the margin of Sorbopyrus most closely resembles that of P. communis. In depth of epidermis, Sorbopyrus is intermediate between Sorbus and Pyrus. The most outstanding feature in comparing the margins is the amount of collenchyma found in them. While collenchyma is absent in the margin of the Sorbus type, it is found abundantly in the margins of both Sorbopyrus and P. communis.

The most outstanding feature in comparing stem sections of these species is the structure of the pith. Both Sorbopyrus and Pyrus have a homogeneous pith while Sorbus does not.

In brief, Sorbopyrus resembles the Sorbus type in the following respects:
1. The epidermal cells of the petiole are very small.
2. Thin-walled prosenchyma is found on the concave side of the vascular arc of the petiole and midrib.
3. The vascular bundle of the petiole is bicolateral.
4. In general shape of midrib cross-section.
5. In having thin-walled prosenchyma above the vascular arc of the midrib.

Sorbopyrus resembles P. communis in the following ways:
1. By having a bast region, composed of isolated bundles, bordering the convex side of the vascular arc.
2. In general shape of margin.
3. In abundance of collenchyma in the margin.
4. By having homogeneous pith in the stem.

Sorbopyrus differs from both of its parents in the following ways:
1. By having the bundles of bast fibers, bordering the vascular arc, interspersed with parenchyma cells.
2. By the presence of a starch sheath on the convex side of the vascular arc of the petiole.
3. By having a broad zone of collenchymatous hypo-derm in the petiole.
KEY TO STEMS

A. No secondary bast fibers present in phloem.
   B. Stone cells in close association with primary bast fibers.  
      S. COMMIXTA

BB. No stone cells present in region of primary bast.
   C. An average of 5 rows of collenchyma and 19 rows of parenchyma found in the primary cortex. Average thickness of collenchyma wall .0075 mm.  
      S. AUCUPARIA PEND.

CC. An average of 2 rows of collenchyma and 31 rows of parenchyma found in the primary cortex. Average thickness of collenchyma wall .004 mm.  
      S. AMERICANA

AA. Secondary bast fibers present in the phloem.
   B. Primary bast fibers arranged in relatively small, round bundles in inner cortex.
      C. Relatively few secondary bast fibers scattered throughout the phloem.  
         S. INTERMEDIA

CC. An interrupted cylinder of secondary bast in the phloem.  
      S. HYBRIDA

BB. Primary bast fibers arranged in an almost continuous cylinder of arc-like bundles. Secondary bast fibers arranged in an almost continuous cyl-
inder in the phloem.

C. Old cells of phelloderm elongated, vertically, with walls often .01 mm. thick.  
   S. AUCUPARIA

CC. Old cells of phelloderm thin-walled and parenchymatous.  
   S. ARIA

BBB. Primary bast fibers arranged in 2 distinct, concentric cylinders.  
   S. AUCUPARIA VAR.
KEY TO PETIOLES OF SORBUS

A. Three vascular bundles entering petiole.
   B. Average number of cell layers of collenchyma surrounding the petiole 3.  S. AUCUPARIA PEND.
   BB. Average number of cell layers of collenchyma surrounding the petiole 5.  S. INTERMEDIA

AA. Five vascular bundles entering the petiole.
   B. Average number of cell layers of collenchyma surrounding petiole 2.
      C. Collenchyma relatively thin-walled; averaging .004 mm. in thickness.  S. AMERICANA
      CC. Collenchyma relatively thick-walled; averaging .008 mm. in thickness.  S. COMMIXTA

BB. Average number of cell layers of collenchyma surrounding the petiole 5; cell layers varying from 5 to 6.  S. AUCUPARIA

BBB. Average number of cell layers of collenchyma surrounding the petiole 3. Cavities of epidermis sharply angled on outer side.  S. HYBRIDA

AAA. Six vascular bundles entering the petiole.  S. AUCUPARIA VAR.
KEY TO MIDRIBS OF SORBUS

A. No bast fibers present on convex side of vascular arc.
   B. Cell walls of collenchymatous hypoderm beneath upper epidermis average .01 mm. in thickness.  
      S. AUCUPARIA PEND.

BB. Cell walls of collenchymatous hypoderm beneath upper epidermis average .005 mm. in thickness.  
      S. AMERICANA

AA. Bast fibers present on convex side of vascular arc.
   B. Bast region almost continuous, averaging 3 cells in width; walls of collenchyma beneath upper epidermis averaging .005 mm. in thickness.
      C. Walls of bast fibers uniform in thickness; average thickness .003 mm.  
         S. COMMIXTA

CC. Walls of bast fibers not uniform in thickness; range of thickness from .0025 mm. to .0075 mm.  
      S. INTERMEDIA

BB. Bast region almost continuous, averaging 4 cells in width;
      C. Walls of collenchyma beneath the upper epidermis averaging .01 mm. in thickness.  
         S. AUCUPARIA

CC. Walls of collenchyma averaging .005 mm. in thickness.  
      S. HYBRIDA

BBB. Bast region very irregular in width; averaging 1.5 cells in width.  
      S. AUCUPARIA VAR.
<table>
<thead>
<tr>
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<td>Pyrus communis</td>
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<td>S. intermedia</td>
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<td>S. commixta</td>
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**Key to Elements**

- a. Primary bast fiber
- b. Tracheal tube element
- c. Fiber tracheid
- d. Parenchyma cells of the cortex
- e. Ray cells as seen in radial section
- f. Ray cells as seen in tangential section
CROSS-SECTION OF MARGIN AND BLADE

Fig. 11. Margin of S. intermedia
Fig. 12. Blade of S. intermedia
Fig. 13. Margin of S. Aucuparia var.
Fig. 14. Blade of S. Aucuparia var.
Fig. 15. Margin of S. Aucuparia pendula
Fig. 16. Blade of S. Aucuparia pendula
Fig. 17. Margin of S. americana
Fig. 18. Blade of S. americana
Fig. 19. Margin of Pyrus communis
Fig. 20. Blade of Pyrus communis
Fig. 21. Margin of Sorbopyrus auricularis
Fig. 22. Blade of Sorbopyrus auricularis
Fig. 23. Margin of S. hybrida
Fig. 24. Blade of S. hybrida
Fig. 25. Margin of S. commixta
Fig. 26. Blade of S. commixta
Fig. 27. Margin of S. Aucuparia
Fig. 28. Blade of S. Aucuparia
EPIDERMIS AND TRICHOMES
XL62

Trichomes

Fig. 29. S. americana  Fig. 33. S. Aucuparia var.
Fig. 30. S. Aucuparia  Fig. 34. S. Aucuparia pen.
Fig. 31. S. intermedia  Fig. 35. Sorbopyrus
Fig. 32. S. hybrida

Upper and Lower Epidermis

Fig. 36. Upper epidermis of S. americana
Fig. 37. Lower epidermis of S. americana
Fig. 38. Upper epidermis of Sorbopyrus
Fig. 39. Lower epidermis of Sorbopyrus
Fig. 40. Upper epidermis of S. intermedia
Fig. 41. Lower epidermis of S. intermedia
Fig. 42. Upper epidermis of S. hybrida
Fig. 43. Lower epidermis of S. hybrida
Fig. 44. Upper epidermis of S. Aucuparia var.
Fig. 45. Lower epidermis of S. Aucuparia var.
Fig. 46. Upper epidermis of S. commixta
Fig. 47. Lower epidermis of S. commixta
Fig. 48. Upper epidermis of S. Aucuparia
Fig. 49. Lower epidermis of S. Aucuparia
Fig. 50. Upper epidermis of S. Aucuparia pendula
Fig. 51. Lower epidermis of S. Aucuparia pendula
Fig. 52. Upper epidermis of Pyrus communis
Fig. 53. Lower epidermis of Pyrus communis
VENATION OF LEAF

X28

Fig. 54. S. Aucuparia pen.
Fig. 55. S. intermedia
Fig. 56. Sorbopyrus
Fig. 57. S. Aucuparia var.
Fig. 58. S. Aucuparia
VENATION OF LEAF

X28

Fig. 59. Pyrus communis
Fig. 60. S. hybrida
Fig. 61. S. commixta
Fig. 62. S. americana
CROSS-SECTION OF STEM

X33

Fig. 63. One-year stem of S. americana

Fig. 64. Old stem of S. americana
CROSS-SECTION OF STEM

x33

Fig. 65. One-year stem of S. Aucuparia var.

Fig. 66. Old stem of S. Aucuparia var.
Fig. 67. One-year stem of S. Aucuparia pen.
CROSS-SECTION OF STEM

X33

Fig. 68. One-year stem of S. Aucuparia

Fig. 69. Old stem of S. Aucuparia
CROSS-SECTION OF STEM

X33

Fig. 70. One-year stem of S. hybrida

Fig. 71. Old stem of S. hybrida
CROSS-SECTION OF STEM

X33

Fig. 72. One-year stem of S. intermedia

Fig. 73. Old stem of S. intermedia
CROSS-SECTION OF STEM

X33

Fig. 74. One-year stem of S. commixta

Fig. 75. Old stem of S. commixta
CROSS-SECTION OF STEM

X33

Fig. 76. One-year stem of S. Aria

Fig. 77. Old stem of S. Aria
CROSS-SECTION OF STEM

X33

Fig. 78. One-year stem of Sorbopyrus

Fig. 79. Old stem of Sorbopyrus
CROSS-SECTION OF STEM

X33

Fig. 80. One-year stem of Pyrus communis

Fig. 81. Old stem of Pyrus communis
CROSS-SECTION OF MIDRIB

X64

Fig. 82. S. Aucuparia
Fig. 83. S. americana
Fig. 84. S. hybrida
Fig. 85. S. intermedia
GROSS-SECTION OF MIDRIB

X64

Fig. 86. S. Aucuparia pendula
Fig. 87. S. commixta
Fig. 88. Sorbopyrus auricularis
Fig. 89. S. Aucuparia var.
Fig. 90. Pyrus communis
CROSS-SECTION OF PETIOLE

Fig. 91. S. Aucuparia
Fig. 92. S. Aucuparia pendula
Fig. 93. S. hybrida
Fig. 94. S. intermedia
Fig. 95. S. Aucuparia
CROSS-SECTION OF PETIOLE

X33

Fig. 96. Pyrus communis
Fig. 97. S. commixta
Fig. 98. Sorbopyrus auricularis
Fig. 99. S. americana
I have endeavored to compare various species of Sorbus and Sorbus hybrids and I have tried to discover the relationships which exist between the various species as well as those existing between the genus Sorbus and the genus Pyrus.

One species of Sorbus studied, namely, S. americana, was originally found in America; one species, S. commixta, was originally found in Japan and Korea, while the remaining species are native to northern Europe.

Rehder ('27) noted an external similarity between the Asiatic and American species. I have observed numerous similarities in my detailed anatomical study of these two species. There is a close resemblance in the venation of the leaves, Figs. 61 and 62. The resemblance in the leaf venation of these two species is greater than that existing between any other species studied. There are only two cell layers of collenchyma surrounding the petiole of these species, while petioles of other species show a greater number of rows. Secondary bast fibers are absent in the phloem of two-year stems of both S. commixta and S. americana while two-year stems of all the other species studied showed their presence. One striking difference exists between S. americana and all other species studied, including S. commixta, and that is in the presence of an
endodermis in the stem and petiole of S. americana. However, S. americana and S. commixta resemble each other more closely than either resembles the European species. The similarities existing between the Asiatic and American species indicate that these two types which are found in different continents may be closer to the original stock than the European type is. It seems as if the European Sorbus has undergone more mutations.

Since species of Sorbus have been found native to Asia, Europe, and America, and Pyrus has been found originally only in Asia and Europe, one might surmise that Pyrus is a younger genus than Sorbus, or it too, would have been native in America. The close resemblance between the genus Sorbus and the genus Pyrus, and the ease with which the two genera cross, leads one to wonder whether Pyrus may have had a Sorbus ancestry.

From my study of Sorbus, I have noted that S. Aucuparia pendula often differs as much from S. Aucuparia as any two species differ from each other. Probably the most noticeable difference between S. Aucuparia pendula and S. Aucuparia is in the length of the internodes. The variety has long pendulous branches due to the greater length of its internodes. The region of primary bast fibers is fully twice as wide in S. Aucuparia pendula as in S. Aucuparia. The fiber tracheids of the variety have
a smaller cross-diameter and greater length than those of S. Aucuparia. There are fewer free vein endings per sq. mm. of leaf surface and only 3 bundles entering the petiole in the variety, while S. Aucuparia has 5 bundles. The variety has only 5 layers of collenchyma in the primary cortex of a one-year stem while S. Aucuparia has 10 layers. In width of primary cortex of one-year stems, number of rows of collenchyma in the primary cortex, number of rows of fibers in the primary bast fiber region, and in the number of tracheal elements per sq. mm. of cross-section of stem, S. Aucuparia pendula closely resembles S. commixta. From these observations, I believe it is quite probable that S. Aucuparia pendula is a hybrid instead of a variety of S. Aucuparia and that one of its parents may be S. Aucuparia and the other, S. commixta.

Fewer differences were observed between S. Aucuparia and S. Aucuparia var. and many similarities were seen. From my observations, I believe that S. Aucuparia var. is truly a variety of Aucuparia.

S. hybrida has many characteristics in common with S. Aucuparia and S. intermedia. For this reason and others I believe it is a hybrid between these two species instead of between S. Aucuparia and S. Aria as Burgerstein ('95) suggests. S. hybrida does not closely resemble S. Aucu-
paria and more closely resembles S. intermedia than S. Aria in the following ways: width of the primary cortex of one-year stem - hybrida .64, intermedia .64, Aria .4; thickness of collenchyma of cortex - hybrida relatively thick, intermedia relatively thick, Aria relatively thin; number of rows of parenchyma in primary cortex of one-year stem - hybrida 15, intermedia 15, Aria 12; average thickness of wall of parenchyma of primary cortex - hybrida .006 mm., intermedia .005 mm., Aria .002 mm.; number of rows of bast fibers in primary bast cylinder - hybrida 0-5, intermedia 0-6, Aria 0-12; cross-diameter of cavities of primary bast - hybrida .0025 mm., intermedia .0025 mm., Aria .001 mm. I was unable to obtain leaves of S. Aria for this study but the evidence shown by the stems makes me quite confident that S. intermedia, and not S. Aria, is a parent of S. hybrida.
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