THESIS.

Fibro-Vascular Bundles of Graminae.

For Degree of B.S.

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Preparation of Material: Portions of roots, stems, or leaves to be prepared for cutting cross sections are mounted in hard paraffin. After this becomes hard around the pieces, they are ready to be cut. A very sharp razor is essential for cutting good thin sections. After the sections are cut the next thing to be done is staining. I used red and blue aniline stain altogether. The sections were first heated in red aniline washed thoroughly, and then heated in blue aniline. Then they are again washed in water, transferred to alcohol several times until all the water is replaced, then transferred to alcohol over night, then in turpentine, and mounted on glass slides in Canada Balsam. The double staining brings out the different tissues excellently.

In order to examine the vessels longitudinally, parts of the
stems are boiled in strong potash, so that the tissue can be easily teased apart. The material teased out is stained and mounted as above.

*Triticum vulgare.* (Wheat)

Wheat is taken as the typical grass, and all other descriptions will be compared with it.

**Transverse Section:** The bundles are arranged in two quite regular rows, the larger bundles are placed near the inner surface, and the smaller ones near the epidermis. All the bundles are closed, the sheath being composed of strongly thickened sclerenchyma cells. These take a purple color from the mixing of the two stains.

In the center of the larger bundle, the pylem has arranged itself in the form of a V, containing four large vessels, which are also stained purple. The cusps of the V are toward the epidermis, and are formed by large pitted vessels, one on either cusp. At the angle of the V are two
large vessels one just above the other. The one at the very apex is an annular vessel, the other is a spiral vessel. Both of these are stained purple. The thick walled purple cells between the two large fitted vessels are a continuation, or a turning in of the sheath. These are arranged in from two to four straight rows, which run in the direction of the fitted vessels. The tissue below the annular vessel is composed of parenchyma cells. The tissue in the opening of the V is composed of thin walled cambium and xylem cells. These two tissues are light blue.

In the smaller bundles the gylox has arranged itself in the form of a V as in the larger bundles, but they only contain three large vessels, the two fitted vessels, and the annular vessel. The different tissues stain just as in the larger forms.

It must not be understood that each of the two different forms of bundles are always exactly alike. Imperfections occur, but they are comparatively rare. However diversified the
bundles may be in the number of their vessels, or in arrangement, this one thing is true, the apex of the V is always turned toward the center of the stem. If a bundle contains only two vessels, they are fleshy vessels; if it contains three, two are the fleshy vessels and the other one an annular vessel. The inner lying continuation of the sheath is always present, though sometimes there is much more than at other times. It occasionally happens that the larger type of bundles occur near the outer margin, and the smaller ones in the center of the stem. In one or two cases I found that one of the fleshy vessels had divided thus forming two vessels at one of the cusps of the V. Occasionally may be found either two spiral or two annular vessels.

In the roots the bundles are not arranged in two rows as in the stem, but are all placed in one row. They are so close together in many parts of the root, that the sheath of the bundle touches each other. The same elements are present,
but they are much more diversified. In these bundles I found only two rows of the thick-walled sclerenchyma cells lying between the pitted vessels. In almost all the bundles there was some change in the pith, as two annular vessels, or two spiral. Sometimes two of both. Sometimes three or four pitted vessels. In many there were only two vessels. The bundles are quite numerous, having an average of ten in a stem one sixteenth of an inch in diameter.

In the leaves, the bundles are all placed in the center of them. The same kind of cells that form the sheath, form a group of cells on either side of the bundles except the epidermis, and extend to the epidermis. That at the upper surface is larger, and more compact. Some of the bundles have one of the larger vessels present, consisting merely of sclerenchyma cells. When the pith is present, it is arranged quite regular. The apex is turned toward the upper epidermis. The three vesselsd form, and also the five vesselsd forms are present.
By making a section through the node, the origin of the leaf bundle can be found. Near the margin of the section the vessels cut are all seen in transverse section, but near the center there is no regularity in the bundles, or the vessels. There is a perfect network of vessels, some in transverse section, some in longitudinal section, some diagonal, showing both the cross section and the vessels longitudinally. Those seen in longitudinal section show the character of the vessels, and by following them their entire length they are found to anastomose with others. This is supposed to be the origin of the leaf bundles from those of the stem. Around all the bundles and vessels of the nodal section is found thin walled parenchyma cells. The center of a section through the node is not hollow like that through the inter-node, neither is it filled with pith, but the same structures that are around the margin, or outer part, continue as far as the center.
Nature of vessels and tissues. The sheath cells are not thickened uniformly as seen by the transverse section. For there are dots here and there along the walls. The parenchyma cells of the ground tissue are very thin walled, appearing like a thin film of color. The annular vessels, as the name implies, are thickened in rings. In transverse section they appear uniformly dark, and not very different from the spiral vessels. In examining them longitudinally, the rings are often found detached, when they appear like a ring shifted in its position, lying across the other part of the vessel, and in many places the walls have become absorbed between these rings, so that there remains nothing but the cavity. The spiral vessels have the walls thickened in the form of spirals. The spiral winds both in the direction of the hands of a watch, and in the opposite direction. The coils are very close together, and give them the appearance of a series of crossees, extending the entire length of the vessel.
ted vessels, have the walls thickened, and with several rows of depressions or pits, or sometimes continuous rows of pits. In many cases, the wall in these pits has been absorbed and then there are holes in the vessel, so that there is communication between different cells. Occasionally are found remnants of septae, that have not been entirely absorbed, this shows the changing of tissues in growing plants, for a special purpose. Now all the tissues have been described but the sieve tissue. This is the group of cells, or some of the cells lying outside the opening of the V. The vessel of the sieve tissue, are their walled, and contain transverse septae. The septae are perforated with pits, forming a sort of sieve, whence the name. These also occur sometimes along the walls. In the sections made through the node several sections were found through these septae. Unless a section happens to pass through these septae, there is no way of distinguishing them from the soft tissue of which it is one of the forms.
Arrisa sativa. (Oats)

Section of Stem. The same elements are present in the bundle of oats, that are found in the bundle of wheat, and in the normal bundles the arrangement is the same. In wheat the annular, and spiral vessels are of the same size, in oats the spiral vessels are in most cases not more than one fourth as large as the annular vessel, and in many instances even much smaller. Here are more irregularities in the bundles of oats than in those of wheat. In one bundle, the xylem consisted of two fitted, two spiral, and two annular vessels; in another of three fitted vessels, and in another of one spiral, one annular, and one fitted vessel. In such cases the xylem no longer had the form of a V. In the same section all most all diversities of number and arrangement occurred. No was my observation confined to one section. There are never less than four rows of aerenchyma cells between
the two pitted vessels. The spiral vessel is placed so that the xylem cells surround it, and sometimes also the cambial vessel. There is very little if any walled tissue present. In a section across the peduncle, having the fruit, I found only the three vessels, or smaller variety of bundles to be present. This part of the stem is not hollow, the bundles however, only occupy a row around the margin, the center of the section being filled with pith. This portion of the stem is three sided. A bundle is placed in each of the angles of the stem, and one one to two on each side.

**Phleum-Pratense (Timothy)**

In timothy grass, the bundles are very small and not being more than one half as large as those in wheat, and oats. The two kinds of bundles are present, those containing the three, and those containing four vessels. In these, the spiral vessel is about one fourth the size of the annular vessel. Just below the annular vessel
is an air space, most always about the size of the annular vessel. The sclerenchyma is never in more than three rows, and occurs generally in two rows. It never extends farther than to the spiral vessel, so that there is a great deal of the thin-walled tissue, containing both cambium and xylem cells. There are very few irregularities. In three sections across a stem, each containing many bundles, only one irregularity occurred, and that was the division of one of the fitted vessels.

*Daedalea glomerata* (Orchard Grass)

In orchard grass the bundles are as large as those of wheat and oats. The same elements are present and they have the same arrangement. The rows of sclerenchyma cells number from two to five. It is hard to tell which number is the most common. Also about the comparative size of the annular and spiral vessels. Sometimes one is larger, sometimes the other, and sometimes both are of the same size. Air cavities occur sometimes in longitudinal.
section, the character of the vessels are found to be the same as those of wheat.

Poa pratensis (Blue Grass)

The bundles of bluegrass are quite small, about the size of rye and timothy. The two forms occur. The same elements, and the same arrangement, and also quite regular. The bundles of the leaves consist of the sclerenchyma cells, the thin walled tissue, and the zylem which contains only the pitless vessels, and sometimes an annular vessel. At each end of the oval bundle the sheath is prolonged, in a group of cells which extends to the epidermis of that side. A transverse section through the node shows the character of the vessel to be the same as those of wheat. At the margin of the section, one can see the vessels of the leaf bundles entering and anastomosing with the other vessels. In some parts of the section, vessels are seen in transverse section, in other parts they are seen longitudinally.
Hordeum jubatum (Squirrel tail Grass)

In this grass, the bundle are only arranged in one row and that quite near the epidermis. The two varieties of bundle are present, but the smaller variety is most common. Both contain the elements of the same kind of bundle in wheat, and are quite regular. The sclerenchyma cells are very minute, and are in either two or three rows.

Zea Mays (Indian Corn)

As this has always been described when ever grasses were spoken of to illustrate the typical grass bundle, little will be said of it. It is larger than those of the other grasses spoken of. The bundle contain the same elements, with the same arrangement. There is always a large air cavity just below the annular vessel.
Explanation of Plate.

Plate I. Fig. 1. A section of one of the larger bundle of a stem of wheat (Triticum vulgare). (B) are the large pitted vessels, (v) the spiral vessel (A) the annular vessel, (C) cambium cells (D) sieve tissue, (G) thickened sclerenchyma cells forming the sheath and the tissue between the pitted vessels.

Fig. 2. This is a section of a fibro-vascular bundle of the leaf of wheat. The same letters represent the same vessels. (A) the thin-walled parenchyma, some if it is in the bundles themselves, and the tissue surrounding the bundles.

Fig. 3. This represents the pitted vessels of wheat bundles they are seen in a section through the node. Those in shading are below the ones with no lines.

Fig. 4. This figure represents the annular vessels of wheat, also seen in a section through the node. By these we can see the ring on the upper side and also there on the lower side.
the section is cut so as to permit it.

Fig. 5: This figure represents three septae of the sieve tubes of wheat. The oval white spots represent the holes through the septae.

Fig. 6: This figure represents one of the spiral vessels of wheat. The spirals are thickened and wind in both directions around the walls.

Plate II.

Fig. 7: This figure represents a section through the root of wheat. The same letters represent the same vessel as in the section through the stem. As no regular bundles were found, a drawing is made of an irregular bundle. It is to be noticed that (g) the thickened sclerenchyma occupies a great part of the bundle.

Fig. 1: This represents the smaller variety of bundle in the stem of wheat. Notice that the spiral vessel is absent.

Plate III.

Fig. 1 is a section of a bundle through the stem of Timothy grass.
the smallness of the bundle and the air cavity (t) are to be noted. All drawings are magnified the same, x370.

Fig. 2. A fibro bundle of oats, all the elements are present, the annular, and spiral vessels about the same size.

Fig. 3. A fibro-vascular bundle of squirrel-tail grass. The bundle is quite small, with the same elements present as in other bundle described, but the spiral vessel is much smaller than the annular vessel, and the fitted vessels are placed with their greatest length transversely as we regard the bundle.

Plate IV

Fig. 1. Fibro bundle of blade of blue grass, in which there are two four fitted vessels, one annular, and one spiral vessel. The sheath forms a pyramidal group of cells at each epidermis of the leaf.

Fig. 2. Portion of a section through a node of blue grass, showing some vessels in cross section, and some longitudinally. (8) fitted vessels, (d) sinu septae, (C) parenchyma, (G) sclerenchyma.
Fig. 3. Fibrous vascular bundle of Orchard-grass. All the elements are present, but the annular vessel is smaller than the spiral vessel. A very small amount of schlerenchyma between the pitted vessels. This is larger than that of Timothy. It is still somewhat smaller than those of wheat and oats.