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AN ANATOMICAL STUDY OF THE LEAVES OF THE GENUS *PINUS*

Tōhei Doi and Kin-ichi Morikawa

CONTENTS

I. INTRODUCTION

So far as the natural system of classification of the species of the genus *Pinus* is concerned, it is most complete and we have a wide literatures on this subject.

We believe that the natural system of classification of the genus *Pinus* was systematized perfectly in A. Engler and K. Prantl's "Die natürlichen Pflanzenfamilien 2-Auflage, 13-Band" published in 1926 (3). This represented a long step forward as compared with either their

first edition (1889) or A. Engler and E. Gilg's "Syllabus der Pflanzenfamilien 9 und 10-Auflage (1924)," and especially it takes into consideration the anatomical characters of the leaves as the basis of classification as Koehne (5), Master (10) and Shaw (14) had already attempted to do.

We, therefore, considered what elements of the anatomical characters of the pine leaves would be most important to the new natural system of classification of A. Engler and K. Prantl (3). And beginning with those elements which have the closest connection with a natural system of classification, and proceeding to those of less vital relation, we have worked to establish a practical artificial system of classification of the genus *Pinus*, which shall correspond as closed as possible to the natural system of classification.

The anatomical characters of the leaves used for this purpose show in each species some one definite peculiarity and these characters, such as are indicated below, are easily distinguishable in a transverse section of a leaf:—

1. Whether the fibro-vascular bundle is single or double.
2. Are there in the stelar tissue surrounding the fibro-vascular bundle the sclerenchyma strengthing cells, which show the chemical reaction of hypoderm cells? If so, what degree of development do they show?
3. The shape of the endoderm.
4. (a). Are the walls of the endoderm-cells uniform or otherwise?
   (b). Are the outer walls thick, or not?
   (c). Are there both thick and thin outer walled cells?
5. Are the endoderm-cells of equal, or very unequal size, some of them large?
6. The position, number and sometimes the size of the resin canals.
7. Are the cells which surround the resin canal thin or thick walled?
8. When resin canals are situated close to the hypoderm, do the sclerenchyma cells, which encircle the resin canal, surround it perfectly on all its circumference? Are they wanting in the part touching the hypoderm?
9. The degree of development of the hypoderm.
10. The thickness of the epiderm, and the situation, sometimes the number of the stomata.

But it must be considered as an inevitable consequence of the artificial classification that there are a few points inconsistent with the natural system of classification (3).

For the arrangement of Subgenus, Section and Subsection etc. of the natural system of classification we are indebted to A. ENGLER and K. PRANTL (3), but in regard to the scientific names, there are not a few we owe to other botanists.

Since the anatomical characters formed in a transverse section taken from the middle part of leaf shows most clearly the characteristic structure of a given species (12, 15), the species were distinguished on the basis of such transverse sections.

In the case of species for which green leaves were not available, a section of about 2 cm. in length was cut from the middle part of withered leaves of dried specimens. And after expelling the air from the dried leaves by boiling, they were put to soak in a mixture of equal parts of glycerin and aether for from 6 months to one year, after which the leaves became normally expanded. Then they were made into transverse sections for the examination.

Concerning the number of the species of the genus *Pinus* the botanists have many different opinions. A. ENGLER and K. PRANTL (3) say there are 80-90 species. However, while accepting the conclusions of other students, we have made some corrections in the species.

T. DOI collected the leaves of most of the species of the genus *Pinus*. K. MORIKAWA has been collecting the leaves of the remaining species and has made a comparative examination of the anatomical characters of various kind of leaves and has distinguished all species as much as possible.

We must be very much obliged to Prof. Dr. R. KANEHIRA, Prof. Dr. M. FUJIOKA of the Department of Agriculture of Tokyo University, and Prof. Dr. S. KAWAGOE of the Agricultural and Forestry College Kagoshima for their useful books of reference and precious materials.

II. FIBRO-VASCULAR BUNDLE

It is already known that the fibro-vascular bundle which runs through the leaf is single in Soft Pine and constantly or irregularly double in Hard Pine (2, 3, 4, 5, 10, 11, 13, 14, 15). This distinction is employed by KOEHNE (5) as the basis of his two Sections, Haploxylon and Diploxylon.

Shaw (14) has accordingly divided the genus *Pinus* into two main Sections, Haploxylon and Diploxylon, and further into Subsections or Groups.

And also in the new natural system of classification A. Engler and K. Prantl (3) have divided it into "Untergattung I. Haploxylon Koehne" and "Untergattung II. Diploxylon Koehne" and further into "Sektion" or "Untersektion" etc. .

Thus the fibro-vascular bundle has been regarded as a more important basis for the classification of *Pinus* than the flowers, cones, seeds etc. . The double bundles are usually obvious even when they are contiguous, but they are sometimes completely merged into what appears to be a single bundle. This condition, however, is never constant in Hard Pine, and a little investigation will find a leaf with true double bundles.

In the stelar tissue some cells about the fibro-vascular bundle acquire thick walls with the appearance and chemical reaction of hypoderm cells (5, 11, 12, 13, 14). Among the Haploxylon this condition is most obvious in *Pinus monophylla*, *P. cembroides*, *P. edulis*, *P. quadrifolia*, *P. flexilis*, *P. parviflora*, *P. pentaphylla*, *P. Balfouriana* and *P. formosana*. Among the Diploxylon it appears in all degrees of development. The Diploxylon, therefore, falls under the following five cases according to the sclerenchyma cells in the stelar tissue :—

1. deficient. (*P. radiata* etc.)
2. Several sclerenchyma cells lie scattered below the fibro-vascular bundles, often below and above. (Fig. 1-A) (*P. Massoniana* etc.)
3. Sclerenchyma cells form an irregular line below the fibro-vascular bundles, occasionally several of them lie scattered above the bundles. (Fig. 1-B) (P. *densiflora*, *P. montana*, *P. palustris*, *P. silvestris*, *P. Thunbergii* etc.)
4. Sclerenchyma cells form irregular lines below and above the fibro-vascular bundles. (Fig. 1-C) (*P. Montezumae*, *P. oocarpa*, *P. Torreyana* etc.)
5. Sclerenchyma cells not only form irregular lines below and above the fibro-vascular bundles, but also lie scattered between the two bundles forming "I" shape. (Fig. 1-D) (*P. occidentalis*, *P. Sabiniana*, *P. tropicalis* etc.)

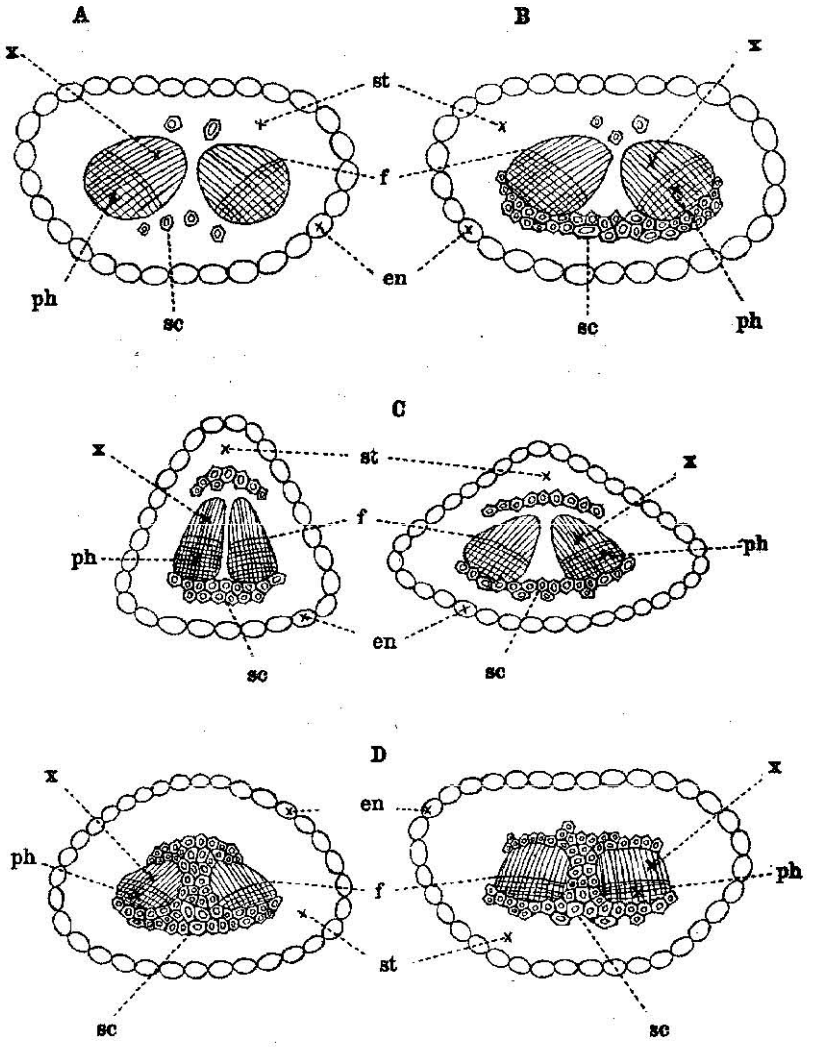

Fig. 1. Sclerenchyma cells about the fibro-vascular bundle. en=endoderm, st=stelar tissue, f=fibro-vascular bundle, x=xylem, ph=phloem, sc=sclerenchyma cells.

III. ENDODERM

Endoderm is the boundary tissue between the stelar tissue surrounding the fibro-vascular bundle and the green tissue, and its shape

is of the greatest importance in the classification of the species. Its shape can not be descided only by the shape of the transverse section of a leaf, for among the Diploxylon it varies much according as the space between two fibro-vascular bundles is wide, contiguous or approximately merged into one. The endoderm of the species with 5 leaves in fascicles among the Haploxylon is always circular in shape, but those among the Diploxylon are triangular. It is short-based triangular even in such a species as have 6 to 8 leaves in fascicles, since they belong to the Diploxylon. In the species with 3 leaves in fascicles it is circular or broad-elliptical in the Haploxylon, but in the Diploxylon long-based triangular or elliptical. In the species with 2 leaves in fascicles, however, it is elliptical in the Haploxylon such as *P. edulis* as in the Diploxylon. Only in such species as *P. Banksiana, P. contorta, P. silvestris* is it strangled-cocoon-like in shape.

The following classifications were worked out on the basis of the shape of the endoderm.

I. Haploxylon.

1. Endoderm circular. (Fig. 2-A).
   All species of the Haploxylon except *P. edulis*. All species belonging to the following group (2), excepting the species *P. edulis*, were changed to both case (1) and case (2).
2. Endoderm broad-elliptical. (Fig. 2-B).
   P. Bungeana, P. cembroides, P. edulis, P. Gerardiana, P. monophylla, P. Nelsonii, P. Pinceana.

II. Diploxylon.

3. Endoderm triangular.
   (a) Endoderm short-based triangular. (Fig. 2-C).
   P. Montezumae, P. Montezumae var. Lindleyi, P. Montezumae var. rudis.
   (b) Endoderm regular-triangular. (Fig. 2-D).
   P. arizonica, P. leiophylla, P. Montezumae, P. Montezumae var. Hartwegii, P. Montezumae var. Lindleyi, P. Montezumae var rudis, P. occidentalis, P. oocarpa, P. pseudostrobus, P. pseudostrobus var. tenuifolia, P. teocote, P. Torreyana.
   (c) Endoderm long-based triangular. (Fig. 2-E).
   P. attenuata, P. canariensis, P. caribaea, P. chihuahuana, P. Coulteri, P. echinata, P. Engelmannii, P. Gregii, P. insularis,

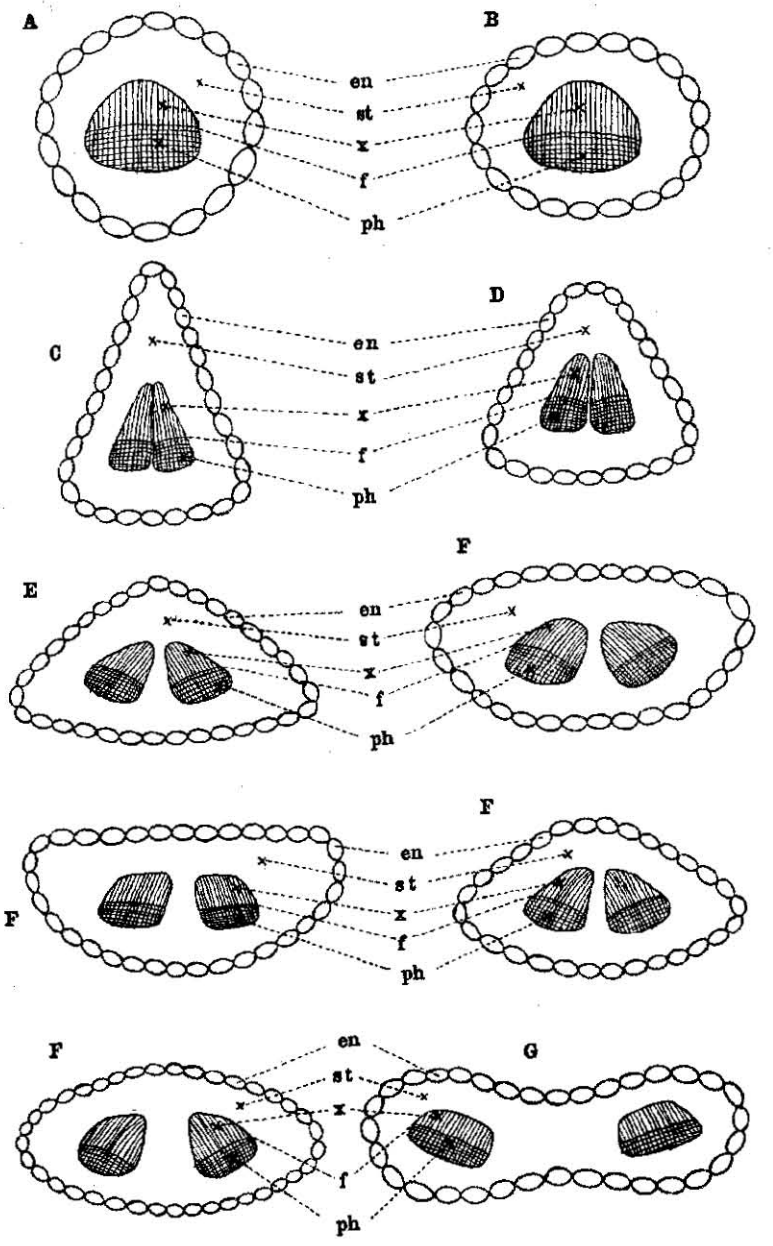

Fig. 2. Shape of the endoderm. A=circular, B=broad-elliptical, C=short-based triangular, D=regular-triangular, E=long-based triangular, F=elliptical, G=strangled-cocoon like. en=endoderm, st=stelar tissue, f=fibro-vascular bundle, x=xylem, ph=phloem.

P. Jeffreyi, *P. longifolia*, *P. Lawsonii*, *P. Lumholtzii*, *P. Montezumae*, *P. Montezumae var. Hartwegii*, *P. Montezumae var. Lindleyi*, *P. oocarpa*, *P. palustris*, *P. patula*, *P. ponderosa*, *P. Pringlei*, *P. radiata*, *P. rigida*, *P. Sabiniana*, *P. serotina*, *P. taeda*, *P. teocote*.

4. Endoderm elliptical. (Fig. 2-F).
P. attenuata, *P. brevispica*, *P. canariensis*, *P. caribaea*, *P. chihuahuana*, *P. clausa*, *P. Coulteri*, *P. densiflora*, *P. densiflora* X *P. Thunbergii*, *P. Thunbergii* X *P. densiflora*, *P. echinata*, *P. Engelmannii*, *P. glabra*, *P. Gregii*, *P. halepensis*, *P. insularis*, *P. Jeffreyi*, *P. Lawsonii*, *P. leucodermis*, *P. longifolia*, *P. luchuensis*, *P. Lumholtzii*, *P. Massoniana*, *P. Merkusii*, *P. montana*, *P. muricata*, *P. nigra*, *P. occidentalis*, *P. palustris*, *P. patula*, *P. pinaster*, *P. pinea*, *P. ponderosa*, *P. Pringlei*, *P. pungens*, *P. radiata*, *P. resinosa*, *P. rigida*, *P. Sabiniana*, *P. serotina*, *P. tabulaeformis*, *P. taeda*, *P. taiwanensis*, *P. teocote*, *P. Thunbergii*, *P. tropicalis*, *P. virginiana*.

5. Endoderm strangled-cocoon like. (Fig. 2-G).
P. Banksiana, *P. contorta*, *P. silvestris*.

It has been admitted that in many species the walls of the endoderm-cells are uniform, but in some species the outer walls of the endoderm-cells are conspicuously thick (10, 13, 14, 15) and in others the endoderm-cells are very unequal in size, some being large and some small (14).

Supplemented with the results of our observation, the characters of the endoderm are as follows:—

1. Endoderm-cells are approximately equal in their size and have walls of uniform thickness. (Fig. 3-A).
Most species of *Pinus*.

2. The outer walls of the endoderm-cells are conspicuously thick. (Fig. 3-B).
P. albicaulis, *P. Banksiana*, *P. contorta*, *P. Montezumae*, *P. ponderosa*, *P. teocote*, etc.

3. Endoderm-cells with both thick and thin outer walls. (Fig. 3-C).
P. Coulteri, *P. longifolia*, *P. Torreyana*, etc.

4. Endoderm-cells are very unequal in size, some being large and some small. (Fig. 3-D).
P. Merkusii.

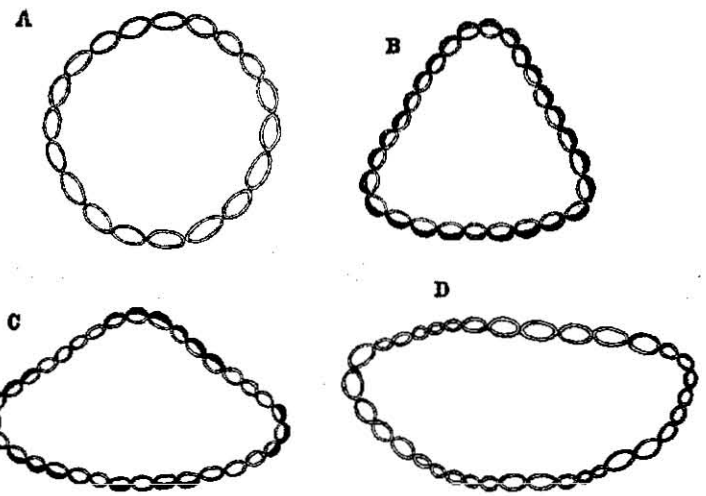

Fig. 3. Characters of the endoderm-cells.

IV. RESIN CANAL

The positions of resin canals can be divided into four types as follows; namely, (1) close to the endoderm, i.e. internal; (2) in the green tissue between the endoderm and hypoderm, i.e. medial; (3) close to the hypoderm, i.e. external; (4) across the green tissue, touching both the endoderm and hypoderm, i.e. septal. One of these positions is constant or any two of these are combined in the same species. So various are the positions of resin canals according to species. And along with the fibro-vascular bundle, the position of the resin canal is the most characteristic among the anatomical characters of a leaf. Thus many botanists of the past employed these positions in the leaves as the basis of the natural system of classification (1, 2, 3, 5, 7, 10, 11, 13, 14, 15).

The number of resin canals of a leaf is variable or constant according to the species, and this also aided us much in the classification of species (1, 7, 15). In such species as *P. aristata*, *P. Neisonii* and *P. pumila*, there are generally two resin canals, rarely only one, but in the other species there are always more than two.

As a rule, the species which are always constant in the number of resin canals in a leaf have only two or three resin canals. But it must be admitted that there are a few exceptional case. Species such as *P. Banksiana*, *P. cembra*, *P. contorta*, *P. strobus*, *P. Torreyana*, etc. all

belong to this type. The species, which have more than four resin canals, are always variable in the number of their resin canals. In many species the number of resin canals in a leaf varies from two to eight, and rarely from two to fifteen, in such species as *P. densiflora*, *P. nigra*, *P. pinaster*, *P. silvestris*, *P. Thunbergii*, etc. .

Either in the Haploxylon or in the Diploxylon, the cells surrounding and protecting the resin canals are different according to the species. Some of them are thin-walled cells and others are thick-walled, and shiny white in appearance.

Concerning the sclerenchyma cells surrounding and protecting the resin canals, the following seven types have been observed :—

1. Both the cells surrounding the resin canals and the hypoderm cells are thin-walled and weak. *P. albicaulis*, *P. Bungeana*, *P. koraiensis*, *P. monticola*, *P. parviflora*, *etc.*
2. The cells surrounding the resin canals are thin-walled, but the hypoderm cells are thick-walled. *P. contorta*, *P. palustris*, *P. Torreyana*, etc.
3. The cells surrounding the resin canals are thick-walled, but the hypoderm cells are thin-walled. *P. densiflora*, *P. Massoniana*, *P. silvestris*, etc.
4. Both the cells surrounding the resin canals and the hypoderm cells are thick-walled. *P. monophylla*, *P. nigra*, *P. Thunbergii*, etc.
5. Resin canals lie externally, and the sclerenchyma cells surrounding them are continuous. (Fig. 4-J) *P. Balfouriana*, *P. monticola*, *P. silvestris*, etc.
6. Resin canals lie externally, and the sclerenchyma cells surrounding them are wanting at the point touching the hypoderm and 2 to 4 secreting cells are close to the hypoderm. (Fig. 4-K) *P. densiflora*, *P. Massoniana*, *P. quadrifolia*, etc.
7. Resin canals lie externally, and the sclerenchyma cells surrounding them are continuous and surround the total circumference of some canals, but about others they are wanting at the parts touching the hypoderm, and secreting cells are close to the hypoderm. (Fig. 4-J, K) *P. densiflora* X *P. Thunbergii*, *P. Thunbergii* X *P. densiflora*, *P. tabulaeformis*.

Resin canals which lie externally are buried in the hypoderm, in which case they are very small (*P. Nelsonii* etc.). But the canals of

some species are so large that they touch both the endoderm and the hypoderm and thus form a septum (*P. tropicalis*).

In the case of the species in which the number of resin canals in a leaf is constantly two or three, the canals are almost the same in size; but in the case the many species in which the number of resin canals is variable, large and small canals are mixed (*P. densiflora*, *P. echinata*, *P. nigra*, *P. silvestris*, *P. Thunbergii*, etc.).

The following classifications were worked out on the basis of the positions of resin canals :—

I. Haploxylon.

1. Resin canals medial, i.e. situated in the green tissue, touching neither the endoderm nor hypoderm. (Fig. 4-G).
   P. cembra, *P. koraiensis*.
2. Resin canals medial and external, i.e. some of the resin canals in the green tissue, but some of them touching the hypoderm. (Fig. 4-H).
   P. Armandi, *P. Lambertiana*.
3. Resin canals external, i.e. situated close to the hypoderm. (Fig. 4-I).
   P. albicaulis, *P. amamiana*, *P. aristata*, *P. ayacahuite*, *P. Balfouriana*, *P. Bungeana*, *P. cembroides*, *P. edulis*, *P excelsa*, *P. flexilis*, *P. formosana*, *P. Gerardiana*, *P. Lambertiana*, *P. monophylla*, *P. monticola*, *P. Nelsonii*, *P. parviflora*, *P. pentaphylla*, *P. peuce*, *P. Pinceana*, *P. pumila*, *P. quadrifolia*, *P. strobus*, *P. Uyematsui*.

II. Diploxylon.

1. Resin canals internal, i.e. situated close to the endoderm. (Fig. 4-A).
   P. caribaea, *P. Lawsonii*, *P. occidentalis*, *P. palustris*, *P. Pringlei*.
2. Resin canals internal and medial, i.e. some of the resin canals touching the endoderm, but others in the green tissue. (Fig. 4-B).
   P. attenuata, *P. clausa*, *P. Coulteri*, *P. echinata*, *P. Lawsonii*, *P. leiophylla*, *P. Lumholtzii*, *P. Merkusii*, *P. patula*, *P. pungens*, *P. radiata*, *P. rigida*, *P. serotina*, *P. taeda*, *P. tecocote*, *P. virginiana*.
3. Resin canals internal and septal, i.e. some of resin canals touching the endoderm, but others touching both the endoderm and hypoderm, forming a septum. (Fig. 4-C).

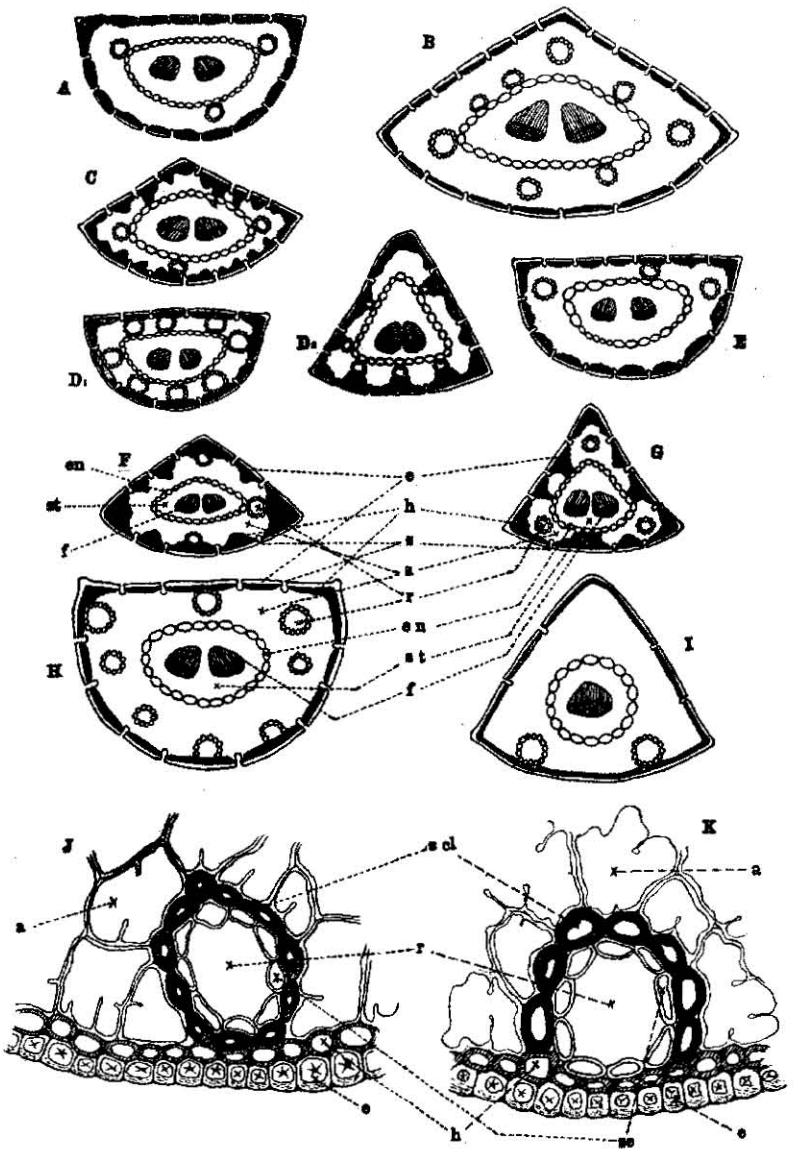

Fig. 4. Positions of the resin canals. A=internal, B=internal and medial, C=internal and septal, $D_1=D_2$=septal, E=septal and medial, F=septal and technically external, G=medial, H=medial and external, I=external, J=resin canals lie externally, and the sclerenchyma cells surrounding them are continuous, K=resin canals lie externally, and the sclerenchyma cells surrounding them are wanting at the point touching the hypoderm and 2 to 4 secreting cells are close to the hypoderm. e=epiderm, s=stomata, h=hypoderm, a=assimilative tissue (green tissue), r=resin canal, en=endoderm, st=stelar tissue, f=fibro-vascular bundle, scl=sclerenchyma cells surrounding the resin canal, sc=secreting cells.

P. oocarpa, P. Pringlei.

4. Resin canals septal, i.e. situated close to both the endoderm and hypoderm, forming a septum. (Fig. 4-D_1, D_2).
P. oocarpa, P. tropicalis.

5. Resin canals septal and medial, i.e. some of the resin canals touching both the endoderm and hypoderm, forming a septum, but others in the green tissue, touching neither the endoderm nor hypoderm. (Fig. 4-E).
P. Merkusii.

6. Resin canals septal and technically external, i.e. some of the resin canals touching both the endoderm and hypoderm, forming a septum, but others situated close to a remarkably developed hypoderm. (Fig. 4-F).
P. canariensis, P. tropicalis.

7. Resin canals medial, i.e. situated in the green tissue. (Fig. 4-G).
P. arizonica, P. attenuata, P. Banksiana, P. brevispica, P. chihuahuana, P. clausa, P. contorta, P. Coulteri, P. echinata, P. Engelmannii, P. glabra, P. Gregii, P. Jeffreyi, P. leiophylla, P. leucodermis, P. luchuensis, P. Merkusii, P. Montezumae, P. Montezumae var. Hartwegii, P. Montezumae var. Lindleyi, P. Montezumae var. rudis, P. muricata, P. nigra, P. patula, P. pinaster, P. ponderosa, P. pseudostrobus, P. pseudostrobus var. tenuifolia, P. pungens, P. radiata, P. rigida, P. Sabiniana, P. serotina, P. taeda, P. taiwanensis, P. teocote, P. Thunbergii, P. Torreyana, P. virginiana.

8. Resin canals medial and external, i.e. some of resin canals in the green tissue, but others touching the hypoderm. (Fig. 4-H).
P. brevispica, P. densiflora X *P. Thunbergii, P. Thunbergii* X *P. densiflora, P. insularis, P. luchuensis, P. resinosa, P. silvestris, P. taiwanensis.*

9. Resin canals external, i.e. situated close to the hypoderm. (Fig. 4-I).
P. canariensis, P. densiflora, P. halepensis, P. insularis, P. longifolia, P. Massoniana, P. montana, P. pinea, P. resinosa, P. silvestris, P. tabulaeformis, P. tropicalis.

As illustrated above, some species are constant in the position of resin canals in all their leaves, and others are variable in the number or the position in their various leaves. Some species, especially such

as *P. attenuata*, *P. rigida*, *P. teocote*, etc. have the resin canals medial, or medial and internal; and again there are a great number of species, such as *P. insularis*, *P. Lambertiana*, *P. luchuensis*, *P. resinosa*, *P. taiwanensis*, etc., which have the resin canals medial, medial and external, or external.

V. HYPODERM

Among the Haploxylon there are many species which show a very weak hypoderm. But among Diploxylon a very different tendency is manifest. That is to say, many species among the Haploxylon have but one layer of hypoderm cell, and are thin-walled and inconspicuous. But a few species show two or three layers of cells.

However, among the Diploxylon there are wide variations, so that while in some species the hypoderm is very weak and inconspicuous, others have one layer, two or three layers, and in some species five to seven layers, while the hypoderm pushes its way into the green tissue. One outstanding instance was where the hypoderm was so much developed as to cross the green tissue and touch the endoderm, forming a septum.

In these varying forms of hypoderm, there were those with thin cell walls, and yet others with very thick walls of silvery which contrasted remarkably with the green tissue. (2, 4, 8, 10, 11, 13, 14, 15).

By Shaw's study (14), as well as by the observations of the present authors, it is possible to classify the species according to the structure of the hypoderm.

I. Haploxylon.

1. Hypoderm consisting of one layer of thin-walled, inconspicuous cells. (Fig. 5-A).
   P. albicaulis, *P. cembra*, *P. koraiensis*, *P. parviflora*, *P. strobus*, etc.
2. Hypoderm, some parts consisting of one layer of thin-walled cells and others of two layers. (Fig. 5-A).
   P. monticola.
3. Hypoderm, some parts consisting of one layer of thick-walled cells, and others of two layers. (Fig. 5-B).
   P. flexilis.
4. Hypoderm consisting of 2 or 3 layers of thick-walled cells. (Fig. 5-B). *P. aristata*, *P. cembroides*, *P. Lambertiana*, etc.

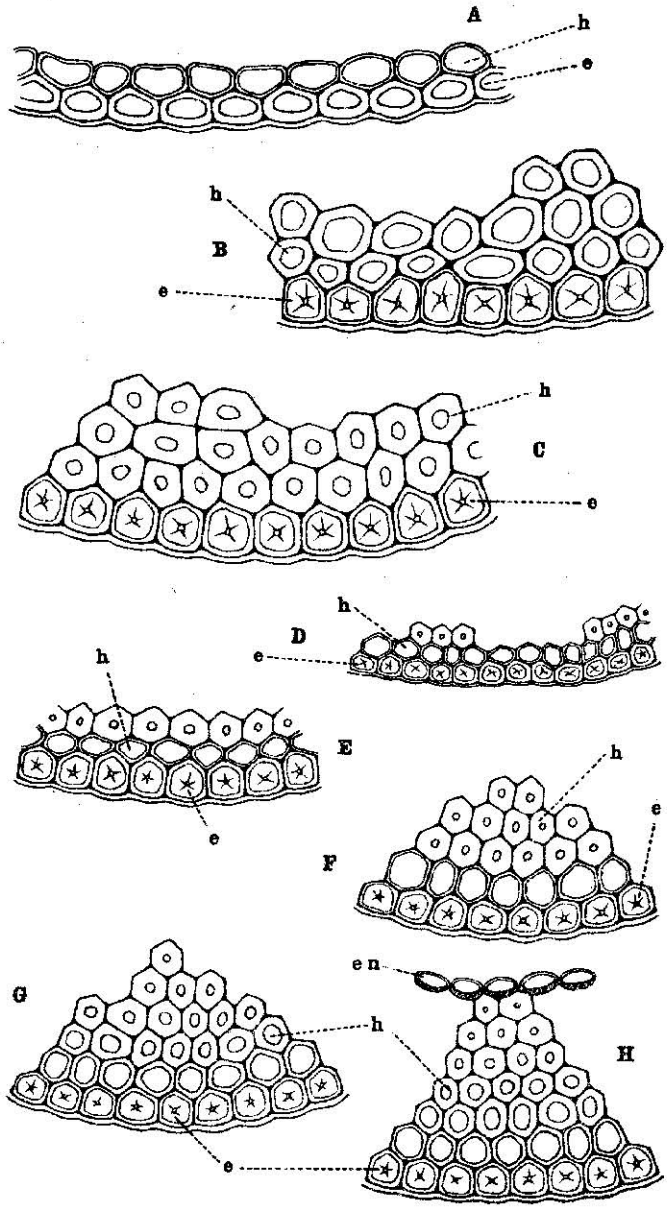

Fig. 5. Structure of the hypoderm. A=B=C=uniform, D=E=F=biform, G=H=multiform. e=epiderm, h=hypoderm, en=endoderm.

5. Hypoderm consisting of 2 or 3 layers of strong, thick-walled cells of shiny white color. (Fig. 5-c).
P. Balfouriana, P. monophylla.

II. Diploxylon.

1. Hypoderm of uniform thin-walled cells. (Fig. 3-A).

(a) Hypoderm consisting of one layer of thin-walled cells, occasionally having parts which consist of two layers of cells.
P. densiflora, P. Lumholtzii, P. patula, P. silvestris, P. taiwanensis, etc.

(b) Hypoderm consisting of 2 or 3 layers of thin-walled cells.
P. Gregii.

2. Hypoderm of uniform thick-walled cells. (Fig. 5-B).

(a) Hypoderm consisting of 2 or 3 layers of cells.
P. halepensis, P. Merkusii, P. nigra, P. Thunbergii, P. tropicalis, etc.

(b) Hypoderm in large masses, projecting far in to the green tissue.
P. canariensis, P. longifolia, P. Torreyana, etc. (Fig. 5-C, G).

(c) Hypoderm remarkably developed, extending from the epiderm to the endoderm and forming a septum across the green tissue. (Fig. 5-C, H).
P. pseudostrobus var. tenuifolia.

3. Hipoderm biform, i.e. very thin walls situated in the outer layer of cells and very thick walls in the inner layer or layers of cells.

(a) Hypoderm, some parts consisting of one layer of cells and others of two layers, biform in the parts of two layers of cells. (Fig. 5-D).
P. clausa, P. echinata, P. glabra, etc.

(b) Hypoderm consisting of 2 or 3 layers of cells. (Fig. 5-E).
P. contorta, P. palustris, P. pungens, P. radiata, P. taeda, etc.

(c) Hypoderm in large masses, projecting far into the green tissue and sometimes touching the endoderm. (Fig. 5-F).
P. Pringlei.

4. Hypoderm multiform, i.e. cell walls being gradually thicker toward the centre of the leaf.

(a) Hypoderm projecting far in to the green tissue, but not extending to the endoderm. (Fig. 5-G).
P. Coulteri, P. Montezumae, P. oocarpa, P. pinaster, P. ponderosa, etc.

(b) Hypoderm remarkably developed, extending from the epiderm to the endoderm and forming a septum across the green tissue. (Fig. 5-H).
P. pseudostrobus var. tenuifolia.

There are the following four types in the case where either the hypoderm or the connected tissue of the resin canal and the hypoderm forms a septum across the green tissue.

1. Hypoderm extending from the epiderm to the endoderm independently of the resin canal and forming a septum across the green tissue, owing to its own development. (Fig. 4-G).
P. pseudostrobus var. tenuifolia.
2. The septums are formed of remarkably large resin canals and a hypoderm which consists of only two or three layers of cells. (Fig. 4-D_1, E).
P. tropicalis.
3. Notwithstanding that resin canal is small, a distinct septum is formed across the green tissue owing to the considerable development of the hypoderm. (Fig. 4-D_2, F).
P. oocarpa.
4. In a same leaf, the septums are formed by the hypoderm only at some parts, and by the connected tissue of the hypoderm and the resin canal at other parts. (Fig. 4-C).
P. Pringlei.

VI. EPIDERM AND STOMATA

The epiderm of the Haploxylon is very thin, while that of the Diploxylon is generally thicker. But in each of these two Subgenus (Haploxylon and Diploxylon), the many species have approximately the same thickness, so that the epiderm is of small value for classification. However *P. contorta, P. luchuensis* and *P. montana* have a marked thickness of the epiderm.

In the Haploxylon there are two groups of species, one with stomata on the ventral side only, and the other with stomata on both the ventral and dorsal sides (1, 2, 4, 8, 10, 11, 13, 14, 15).

Although fundamentally, the Haploxylon is poor in variations as compared with the Diploxylon, the fact that in stomata only the Haploxylon shows great variation is of value in classification, for even in the Diploxylon species with 5 leaves in fascicles the stomata are always found on both dorsal and ventral sides. Further our attention was drawn to the unusual size and visibility of the stomata in *P. albicaulis* and *P. luchuensis*.

The following classifications were worked out on the basis of the position and the number of the stomata.

I. Haploxylon.

1. Stomata lie on the ventral side only.
   Most species except group (2). But *P. cembroides*, *P. monticola* and *P. Pinceana* are occasionally included in this group.
2. Stomata lie on both dorsal and ventral sides.
   (a) Stomata on the ventral side is only one. *P. Nelsonii*.
   (b) Stomata on the ventral side are 3 to 6 in number.
   P. albicaulis, *P. Bungeana*, *P. cembroides*, *P. edulis*, *P. flexilis*, *P. Gerardiana*, *P. Lambertiana*, *P. monophylla*, *P. monticola*, *P. Pinceana*.

II. Diploxylon.
Stomata lie on both dorsal and ventral sides.

VII. THE RELATION BETWEEN THE NATURAL SYSTEM OF CLASSIFICATION OF THE GENUS PINUS AND THE ANATOMICAL CHARACTERS OF LEAVES

The authors have worked out a practical system of classification of the species of *Pinus* on the basis of the anatomical characteristics of leaves. But our thought was to determine what elements of the anatomical characters of leaves have the most vital relation to a natural system of classification; and beginning with those elements which have the most vital relation to the natural system of classification, and proceeding to those of less intimate relation; we have worked to establish a most easy and practical system of classification of the genus *Pinus*, which shall correspond as closly as possible to the natural system of classification.

For this purpose, the authors have distinguished Subgenus, Section and Subsection divisions of *Pinus* in the new natural system of classification of A. Engler and K. Prantl (3) on the basis of the anatomical characters of pine leaves.

(A) Subgenus I. *Haploxylon* KOEHNE
Fibro-vascular bundle single.
(a) Section 1. *Cembra* SPACH
(α) Resin canals medial.
(β) Resin canals medial and external.
(γ) Resin canals external, stomata on both dorsal and ventral sides, endoderm circular. (except *P. pumila*).
(b) Section 2. *Strobus* SWEET ex SPACH
Resin canals mostly external, stomata on the ventral side only, hypoderm cells thin-walled and inconspicuous. (except *P. Lambertiana*).
(c) Section 3. *Paracembra* KOEHNE
(α) Subsection 1. *Gerardianae*.
Resin canals external, stomata on both dorsal and ventral sides, endoderm broad-elliptical. (except *P. quadrifolia*).
(β) Subsection 2. *Balfourianae*.
Resin canals external, stomata on the ventral side only, hypoderm cells thick-walled and shiny white.

(B) Subgenus II. *Diploxylon* KOEHNE
Fibro-vascular bundles double.
(d) Section 4. *Sula* MAYR
Resin canals technically external, endoderm triangular, hypoderm in large masses, projecting far in to the green tissue.
(e) Section 5. *Eupitys* SPACH
(α) Resin canals external, endoderm elliptical, number of resin canal 2 to 8, often to 15.
(β) Resin canals medial, endoderm elliptical, hypoderm uniform thick-walled cells.
(f) Section 6. *Banksia* MAYR
Resin canals medial, rarely medial and internal, endoderm elliptical, hypoderm mostly biform.
(g) Section 7. *Pinea* ENDL.
Resin canals external, endoderm elliptical, number of resin canal usually two.
(h) Section 8. *Australes* PILGER
Resin canals internal, sometimes internal and medial, endoderm mostly triangular, hypoderm biform.
(i) Section 9. *Khasia* MAYR

Resin canals external, rarely external and medial, endoderm triangular, hypoderm not projecting far in to the green tissue.

(j) Section 10. *Pseudostrobus* Endl.
Resin canals medial, rarely medial and internal, endoderm triangular, hypoderm mostly in large masses, projecting far in to the green tissue, outer walls of the endoderm mostly thick.

(k) Section 11. *Taeda* Spach
Resin canals medial, rarely medial and internal, endoderm triangular, hypoderm not projecting far in to the green tissue, outer walls of the endoderm mostly thin.

It will be seen from the above that the most important point to the natural system of classification is whether the fibro-vascular bundle is single or double (3, 5, 10, 14, 15). Then come, among the Haploxylon, in the order of their importance, the position of the resin canal and stomata, the shape of the endoderm and the degree of development of the hypoderm, and among the Diploxylon the position of the resin canal, the shape of the endoderm, the degree of development of the hypoderm, the number of the resin canals and the characters of the endoderm-cells.

Hence if we classify the species, on the basis of the anatomical characters of leaves, in the order above, (also considering many additional points), the practical artificial system of classification would come close to the natural system.

And such the Practical Analytical Key to the Species of the Genus *Pinus* is mentioned in the following Chapter VIII.

Resin canals of most species are external among the Haploxylon, but the position of the stomata is variable. This helps us much to classify the species. Among the Diploxylon, on the other hand, all stomata are situated on both dorsal and ventral sides. But the shape of the endoderm and the structure of the hypoderm have in each species some one definite peculiarity. We can, therefore, classify the species of the Diploxylon.

VIII. Analytical Key to the Species of the Genus Pinus, Based on the Anatomical Characters of Leaves

(The figure in parenthesis following the scientific name indicates the number of leaves in one fascicle.)

[I] Fibro-vascular bundle single . . . Subgenus I. *Haploxylon* KOEHNE

(A) Resin canals medial, i.e. situated in the green tissue, touching neither hypoderm nor endoderm. Endoderm circular. Stomata on the ventral side only.

(a_0) Resin canals 2, in the green tissue nearer to the hypoderm of the dorsal side. Stomata on each ventral side 3, 4 or 5. . . . . *P. cembra* L. (5).

(b_0) Resin canals 3, often 5, 3 of them confined to each edge. Stomata on each ventral side 4 to 13. Hypoderm consisting of one layer of thin-walled cells. . . . . *P. koraiensis* SIEB. et ZUCC. (5).

(B) Resin canals medial and external, i.e. some of resin canals situated in the green tissue, touching neither endoderm nor hopoderm, but others close to the hypoderm. Endoderm circular.

(a_0) Stomata on the ventral side only. Resin canals 3, dorsal 2 of them external and ventral one medial. . . *P. Armandi* FRANCH. (5).

(b_0) Stomata on both dorsal and ventral sides. Resin canals 3 to 5. Hypoderm 2 or 3 layers of thick-walled cells, though occasionally consisting of one layer of cells. . . *P. Lambertiana* DOUGLAS (5).

(C) Resin canals external, i.e. situated close to the hypoderm.

(a_0) Stomata on the ventral side only.

(a_1) Endoderm circular.

(a_2) External resin canals dorsal and ventral.

(a_3) Total number of resin canals 3.

(a_4) Hypoderm mostly one layer of thin-walled cells.

(a_5) Sclerenchyma cell deficient above and below the fibro-vascular bundle. Stomata on each ventral side 2, rarely 3 or 4. . . . . *P. strobus* L. (5).

(b_5) Several sclerenchyma cells lie scattered below the fibrovascular bundle, rarely below and above. Stomata 4 to 6 on each ventral side. . . . . *P. formosana* HAYATA (5), *P. Uyematsui* HAYATA (5).

(b_4) Hypoderm, some parts consisting of one layer of cells and others of 2 layers, especially 2-3 layers in the edge.

(a_5) Hypoderm cells thin-walled, not shiny white. Sclerenchyma cells surrounding the resin canals always continuous. Stomata 3 or 4 on each ventral side. . . *P. monticola* DOUGLAS (5).

(b_5) Hypoderm cells thick-walled, somewhat shiny white. The Sclerenchyma cells surrounding the resin canals are wanting

at the point touching the hypoderm and the secreting cells are close to the hypoderm. Stomata 3 to 5 on each ventral side. . . . . *P. quadrifolia* Sudworth (4).

(b_3) Total number of resin canals 4 to 8. . . . . *P. ayacahuite* Ehrenberg (5).

(b_2) External resin canals in the dorsal side only, one or two.

(a_3) Resin canal one or two, situated nearer to the middle part of the dorsal side, namely underneath the endoderm.

(a_4) Hypoderm consisting of one layer of thin-walled cells, weak. . . . . *P. pumila* Regel (5).

(b_4) Hypoderm, some parts consisting of one layer of thick-walled cells and others of two layers, especially 2-3 layers at the edge, shiny white. . . . . *P. aristata* Engelm. (5).

(b_3) Two resin canals separated from each other, situated on the dorsal side of the hypoderm.

(a_4) The angle formed between the two ventral sides larger than a right angle, approximately 120°. Hypoderm cells thick-walled. Stomata 3 to 5 on each ventral side. . . . . *P. cembroides* Zuccar. (3), *P. Pinceana* Gordon (3). (*P. Pinceana* is easily distinguished from *P. cembroides* by the greater length of its leaf.)

(b_4) The angle formed between the two ventral sides smaller than a right angle, approximately 72°.

(a_5) Hypoderm consisting of one layer of cells. Stomata 4, 5 or 6 on each ventral side.

(a_6) Several sclerenchyma cells lie scattered below the fibro-vascular bundle, often below and above.

(a_7) Hypoderm cells very thin-walled, uniform. . . . . *P. parviflora* Sieb. et Zucc. (5), *P. pentaphylla* Mayr (5).

(b_7) Hypoderm cells with both thick and thin walls. . . . . *P. amamiana* Koidz. (5), *P. formosana* Hayata (5), *P. Uyematsui* Hayata (5).

(b_6) The sclerenchyma cells are wanting above and below the fibro-vascular bundle.

(a_7) Hypoderm one layer of cells, weak.

(a_8) Stomata 2, often 3 or 4 on each ventral side. Leaves 6 to 14 cm. long. . . . . *P. strobus* L. (5).

(b_8) Stomata 4 to 6 on each ventral side. Leaves 10 to 18 cm. long. . . . . *P. excelsa* Wallich (5).

(b_7) Hypoderm for the most part consisting of one layer of cells, and others of two layers. Leaves 7 to 10 cm. long. . . . . *P. peuce* GRISEB. (5).

(b_5) Hypoderm, some parts consisting of one layer of cells and others of two or three layers, especially 2-3 layers at the edge.

(a_6) The sclerenchyma cells surrounding the resin canals are wanting at the point touching the hypoderm and the secreting cells are close to the hypoderm. Hypoderm for the most part consisting of 2 or 3 layers of thick-walled cells. Stomata 3 to 5 on each ventral side. . . . . *P. quadrifolia* SUDWORTH (4).

(b_6) The sclerechyma cells surrounding the resin canals are continuous.

(a_7) Hypoderm cells thin-walled, not shiny white. The cells surrounding the resin canals thin-walled. The sclerenchyma cells are wanting below and above the fibro-vascular bundle. Stomata 3 or 4 on each ventral side. . . . . *P. monticola* DOUGLAS (5).

(b_7) Hypoderm cells very thick-walled, shiny white. Several sclerenchyma cells lie scattered below the fibro-vascular bundle. The cells surrounding the resin canals thick-walled. Stomata 4 to 6 on each ventral side. . . . . *P. Balfouriana* MURRAY (5).

(b_1) Endoderm small, broad-elliptical.

Resin canals 2. Hypoderm cells thick-walled. Stomata 3 to 5 on each ventral side. . *P. cembroides* ZUCC. (3), *P. Pinceana* CORDON (3). (*P. Pinceana* are easily distinguished from *P. cembroides* by the greater length of their leaves.)

(b_0) Stomata on both dorsal and ventral sides.

(a_1) Endoderm circular.

(a_2) Transverse section of the leaf circular.

Many sclerenchyma cells form irregular lines below and above the fibro-vascular bundle, silvery. Resin canals 4 to 9. Hypoderm 1-3 layers of very thick-walled cells, silvery. . *P. monophylla* TORREY (1).

(b_2) Transverse section of the leaf triangular.

(a_3) Resin canals two, rarely one.

(a_4) The angle formed between the two ventral sides larger than a right angle, approximately 120°.

(a_5) Stomata one on each ventral side, often two. Resin canals one or two, very small, almost buried in the hypoderm. . . . . *P. Nelsonii* SHAW (3).

(b_5) Stomata 3 to 5 on each ventral side. Resin canals 2. . . . *P. cembroides* Zuccar. (3), *P. Pinceana* Gordon (3). (*P. Pinceana* are easily distinguished from *P. cembroides* by the greater length of their leaves.)

(b_4) The angle formed between the two ventral sides smaller than a right angle, approximately 72°. Stomata 3, 4 or 5 on each ventral side.

(a_5) The outer walls of the endoderm thick. Hypoderm one layer of thin-walled cells, inconspicuous. Stomata very obvious. Resin canal large. . . . . *P. albicaulis* Engelm. (5).

(b_5) The outer walls of the endoderm cells not thick.

(a_6) Hypoderm, some parts consisting of one layer of cells and others of two layers.

(a_7) Hypoderm cells thin-walled. The cells surrounding the resin canals thin-walled. Stomata 3 or 4 on each ventral side, sometimes on dorsal side. The sclerenchyma cells are wanting below and above the fibro-vascular bundle. . . . . *P. monticola* Douglas (5) (rare case).

(b_7) Hypoderm cells thick-walled, shiny white. Stomata usually on both dorsal and ventral sides, on each ventral side 3, often 4. Several sclerenchyma cells lie scattered below and above the fibro-vascular bundle. . . . . *P. flexilis* James (5).

(b_6) Hypoderm for the most part consisting of 2 or 3 layers of thick-walled cells, others of one layer. . . . . *P. Lambertiana* Douglas (5).

(b_3) Resin canals 3 to 7.

(a_4) Hypoderm for the most part consisting of one layer of thin-walled cells, others of two layers. The cells surrounding the resin canals very thin-walled. The angle formed between the two ventral sides larger than a right angle, approximately 120°. . . . . *P. Bungeana* Zuccar. (3), *P. Gerardiana* Wall. (3). (*P. Gerardiana* is distinguished from *P. Bungeana* by its denser, longer, and more slender leaves.)

(b_4) Hypoderm for the most part consisting of 2 or 3 layers of thick-walled cells, others of one layer. The angle formed between the two ventral sides smaller than a right angle, approximately 72°. . . . . *P. Lambertiana* Douglas (5).

(b_1) Endoderm small, broad-elliptical.

(a_2) Resin canals in dorsal side two, sometimes one.

(a_3) Stomata one, often two on each ventral side. Resin canals one or two, very small, almost buried in the hypoderm. . . . . *P. Nelsonii* SHAW (3).

(b_3) Stomata 3 to 5 on each ventral side. Resin canals usually two. Hypoderm one or two layers of cells.

(a_4) Transverse section of a leaf semicircular. . . . . *P. edulis* ENGELM. (2).

(b_4) Transverse section of a leaf triangular. Hypoderm cells thick-walled. . . . . *P. cembroides* ZUCCAR. (3), *P. Pinceana* GORDON (3). (*P. Pinceana* are easily distinguished from *P. cembroides* by the greater length of their leaves.)

(b_2) Resin canals in the dorsal and ventral sides, 3 to 7, often 9.

(a_3) The many sclerenchyma cells forming irregular lines below and above the fibro-vascular bundle, silvery. Transverse section of a leaf circular. Resin canals 4 to 9. Hypoderm 1-3 layers of very thick-walled cells, silvery. . . . . *P. monophylla* TORREY (1).

(b_3) The sclerenchyma cells deficient below and above the fibro-vascular bundle. Transverse section of a leaf triangular. Resin canals 3 to 6. Stomata 4 or 5, rarely 6 on each ventral side. Hypoderm for the most part consisting of one layer of cells, others of 2 or 3 layers. . . . . *P. Bungeana* ZUCC. (3), *P. Gerardiana* WALL. (3). (*P. Gerardiana* is distinguished from *P. Bungeana* by its denser, longer, and more slender leaves.)

[II] Fibro-vascular bundles double. . . . Subgenus II. *Diploxoylon* KOEHNE.

(A) Resin canals internal, i.e. situated close to the endoderm. Stomata on both dorsal and ventral sides. Hypoderm biform, namely very thin walls situated in the outer layer of cells and very thick walls in the inner layer or layers of cells. Resin canals 2 to 5.

(a_1) Hypoderm in thick masses, projecting far in to the green tissue and sometimes touching the endoderm. The sclerenchyma cells forming irregular lines below and above the fibro-vascular bundles. Resin canals 2 or 3. . . . . *P. Pringlei* SHAW (3).

(b_0) Hypoderm not projecting far in to the green tissue, not touching the endoderm. Endoderm with thin outer walls.

(a_1) The sclerenchyma cells developing distinctly, forming irregular lines below and above the fibro-vascular bundles, sometimes lying between the two bundles forming "I" shape. Resin canals 3 or 4 Endoderm triangular or elliptical Hypoderm 3 or 4 layers of cells. . . . . *P. occidentalis* Swartz (2-5).

(b_1) The sclerenchyma cells form an irregular line below the fibro-vascular bundles, but are wanting above the bundles Endoderm long-based triangular or elliptical. Resin canals 2 to 5.

(a_2) Hypoderm, some parts consisting of one layer of cells and others of two layers, biform when of 2 layers. . . . . *P. caribaea* Morelet (2 or 3).

(b_2) Hypoderm consisting of 3 layers of cells, occasionally of 2 or 4 layers of cells. Several sclerenchyma cells lie scattered below the fibro-vascular bundles. (Leaves not exceeding 24 cm. in length) . . . . . *P. Lawsonii* Roezl (3, 4 or 5).

(c_2) Hypoderm 3 to 6 layers of cells. The sclerenchyma cells continuous and forming an irregular line below the fibro-vascular bundles (Leaves 24-45 cm. in length). . . *P. palustris* Miller (3).

(B) Resin canals internal and medial, i.e. some of the resin canals situated close to the endoderm, but others in the green tissue, touching neither endoderm nor hypoderm. Stomata on both dorsal and ventral sides.

(a_0) Endoderm triangular. Transverse section of a leaf triangular.

(a_1) Hypoderm uniform, weak.

(a_2) Resin canals 3.

(a_3) Endoderm regular-triangular. The angle formed between the two ventral sides smaller than a right angle, approximately 72°. . . . . *P. leiophylla* Schlecht. et Cham. (5).

(b_3) Endoderm long-based triangular. The angle formed between the two ventral sides larger than a right angle, approximately 120°. Hypoderm consisting of one layer of thin-walled cells, occasionally of two layers of cells. . . *P. patula* Schlecht. et Cham. (3, or 4, 5).

(b_2) Resin canals 4 to 10.
Hypoderm one or two layers of cells. . . . . *P. Lumholtzii* Robins. et Fern. (3).

(b_1) Hypoderm biform, i.e. very thin walls situated in the

outer layer of cells and very thick walls in the inner layer or layers of cells.

(a_2) The outer walls of the endoderm-cells thick. Hypoderm consisting of 2 or 3 layers of cells. Two or three resin canals medial and with one internal canal. . . . . *P. teocote* SCHLECHT. et CHAM. (3-5).

(b_2) The outer walls of the endoderm-cells not thick.

(a_3) Hypoderm, some parts consisting of one layer of cells and others of two layers, biform when of two layers. Endoderm with thin outer walls.

(a_4) Two resin canals in the lateral edges always medial, and very large. Outer cells of the hypoderm very small and inconspicuous. Total number of resin canals 3 to 5. . . . . *P. echinata* MILLER (2 or 3, case of 3).

(b_4) Two resin canals in the lateral edges internal, occasionally internal and medial or medial, nearer to the endoderm, and small. Outer cells of the hypoderm not small Total number of resin canals 3 to 5. . . . *P. caribaea* MORELET (2 or 3, case of 3)

(b_3) Hypoderm for the most part consisting of 2 layers of cells, occasionally of 3 layers of cells. Resin canals 2 to 6. . . . . *P attenuata* LEMMON (3), *P. serotina* MICHAUX (3), *P. taeda* L. (3).

(c_3) Hypoderm for the most part consisting of 3 layers of cells, occasionally of 2 or 4 layers of cells. Endoderm with thin outer walls. Resin canals 3 or 4. . . *P. Lawsonii* ROEZL (3, often 5).

(d_3) Hypoderm 2 to 6 layers of cells. Resin canals 2 to 8. . . . . *P. rigida* MILLER (3).

(c_1) Hypoderm multiform, i.e. cell walls being gradually thicker toward the centre of the leaf. Endoderm-cells with both thick and thin outer walls. Resin canals 2 to 10. . . *P. Coulteri* D. DON (3).

(b_0) Endoderm elliptical. Transverse section of a leaf semi-circular.

(Reference 174 p. (B-a_0) on the species which the transverse section of a leaf are triangular.)

(a_1) Hypoderm uniform.

Two resin canals medial and with an internal canal. Hypoderm 2-3 layers of thick-walled cells. Endoderm-cells very unequal in size, some of them large. . . . . *P. Merkusii* JUNGH. et DE VRIESE (2).

(b_1) Hypoderm biform, i.e. very thin walls situated in the

outer layer of cells and very thick walls in the inner layer or layers of cells.

(a_2) Hypoderm, some parts consisting of one layer of cells and others of two layers, biform when of two layers of cells. Endoderm with thin outer walls.

(a_3) Two resin canals in the lateral edges internal, occasionally internal and medial or medial, nearer to the endoderm. Resin canals 3 to 5. (Leaves 12 to 25 cm. long.) . . . . . *P. caribaea* Morelet (2 or 3, case of 2).

(b_3) Two resin canals in the lateral edges always medial.

(a_4) Medial resin canals 3 or more, 2 of them in the lateral edges and very large. Outer cells of the hypoderm very small and inconspicuous. Total number of resin canals 4 to 7. (Leaves 7 to 12 cm. long). . . . . *P. echinata* Miller (2 or 3, case of 2)

(b_4) Medial resin canals 2, confined to lateral edges. Total number of resin canals 3. Outer cells of the hypoderm not small. (Leaves 5 to 9 cm. long.) . . . . . *P. clausa* Vasey (2).

(b_2) Hypoderm consisting of 2 layers of cells, occasionally of 3 layers of cells.

(a_5) Medial resin canals 2 or 3, occasionally with an internal canal.

(a_4) Resin canals 3. Leaves 4 to 8 cm. long. . . . . *P. virginiana* Miller (2).

(b_4) Resin canals 4. Leaves 10 to 15 cm. long . . . . . *P. radiata* D. Don (2 or 3).

(b_3) Medial resin canals 4 to 6, occasionally with an internal canal. Leaves 3 to 7 cm. long. . *P. pungens* Lambert (2).

(C) Resin canals internal and septal, i.e. some of the resin canals situated close to the endoderm, and others touching both the endoderm and hypoderm, forming a septum. Stomata on both dorsal and ventral sides.

(a_5) Endoderm regular-triangular or short-based triangular. Resin canals one to six, mostly septal. Hypoderm biform or multiform, projecting far in to the green tissue, but not touching the endoderm. The sclerenchyma cells forming irregular lines below and above the fibro-vascular bundles. . . *P. oocarpa* Schiede (3, 4 or 5) (rare case).

(b_5) Endoderm long-based triangular or elliptical Resin canals 3, mostly internal. Hypoderm biform, in thick masses, projecting far in to the green tissue and sometimes touching the endo-

derm. The sclerenchyma cells forming irregular lines below and above the fibro-vascular bundles . . . . . *P. Pringlei* SHAW (3).

(D) Resin canals septal, i.e. situated close to both the endoderm and hypoderm, forming a septum. Stomata on both dorsal and ventral sides.

(a_0) Endoderm triangular. Hypoderm biform or multiform, projecting far in to the green tissue, but not touching the endoderm. Resin canals one to six. The sclerenchyma cells forming irregular lines below and above the fibro-vascular bundles. . . . . *P. oocarpa* SCHIEDE (3, 4 or 5).

(b_0) Endoderm elliptical. Hypoderm cells uniform thick-walled. Resin canals of remarkable size, 2 to 9. The sclerenchyma cells not only form irregular lines below and above the fibro-vascular bundles, but also lie scattered between the 2 bundles forming "T" shape. . . . . *P. tropicalis* MORELET (2).

(E) Resin canals septal and medial, i.e. some of the resin canals situated close to both the endoderm and hypoderm, forming a septum, but others in the green tissue, touching neither the endoderm nor hypoderm. Stomata on both dorsal and ventral sides. Endoderm elliptical. Medial resin canals 2 and with a septal canal. Endoderm-cells very unequal in size, some of them large. Hypoderm cells uniform thick-walled. . . . *P. Merkusii* JUNGH. et DE VRIESE (2).

(F) Resin canals septal and technically external, i.e. some of the resin canals situated close to both the endoderm and hypoderm, forming a septum, but others touching a remarkably developed hypoderm. Stomata on both dorsal and ventral sides.

(a_0) Resin canals 2 to 4, small. Hypoderm in large masses, projecting far in to the green tissue. Endoderm long-based triangular, with thin outer walls. . . . . *P. canariensis* SMITH (3).

(b_0) Resin canals of remarkable size, 2 to 9. Hypoderm not projecting far in to the green tissue, with uniform thick-walled cells. Endoderm elliptical. The sclerenchyma cells not only form irregular lines below and above fibro-vascular bundles, but also lie scattered between the 2 bundles forming "T" shape. . . . . *P. tropicalis* MORELET (2).

(G) Resin canals medial, i.e. situated in the green tissue, touching neither the endoderm nor hypoderm. Stomata on both dorsal and ventral sides.

(a_0) Endoderm triangular.

(a_1) Hypoderm uniform.

(a_2) The outer walls of the endoderm thick.

(a_3) Hypoderm 2 to 4 layers of thick-walled cells, not extending to the endoderm.

(a_4) The sclerenchyma cells form irregular lines below and above the fibro-vascular bundles.
Endoderm regular-triangular. Resin canals 3 or 4, 3 of them confined to 3 edges. The angle formed between the two ventral sides smaller than a right angle, approximately 72°. . . *P. pseudostrobus* Lindl. (5).

(b_4) The sclerenchyma cells form an irregular line below the fibro-vascular bundles.

(a_5) Leaves 30-40 cm. in length. . . . . *P. Engelmannii* Carrière (3-5).

(b_5) Leaves 7-25 cm. in length.

(a_6) Endoderm long-based triangular. The angle formed between the two ventral sides larger than a right angle, approximately 120°. Leaves 12-25 cm. long.

(a_7) The sclerenchyma cells form an irregular line below the fibro-vascular bundles, but are wanting above the bundles. Leaves deep yellowish green. . *P. ponderosa* Douglas (3).

(b_7) The many sclerenchyma cells form an irregular line below the fibro-vascular bundles and several of them are scattered above the bundles. Leaves grayish green. . . . . *P. Jeffreyi* Balfour (3-5).

(b_6) Endoderm regular-triangular. The angle formed between the two ventral sides smaller than a right angle, approximately 72°.

(a_7) Leaves deep green, fine serrated, 7-17 cm. long. . . . . *P. arizonica* Engelm. (5).

(b_7) Leaves grayish green, 12-25 cm. long. . . . . *P. Jeffreyi* Balfour (3-5).

(b_2) Hypoderm remarkably developed, extending from the epiderm to the endoderm and forming a septum across the green tissue. Resin canals 2 or 3, confined to the edges. The sclerenchyma cells forming irregular lines below and above the fibro-vascular bundles . . . . . *P. pseudostrobus var. tenuifolia* Shaw (5)

(b_2) The outer walls of the endoderm not thick.

(a_3) Resin canals 2.

(a_4) Fibro-vascular bundles distinct. The angle formed between the two ventral sides larger than a right angle, approximately 120°.

(a_5) Hypoderm one layer of thin-walled cells, inconspicuous. Medial resin canals two, occasionally with an internal canal. . . . . *P. patula* SCHLECHT. et CHAM. (3).

(b_5) Hypoderm 2 to 3 layers of thin-walled cells. Resin canals always medial. . . . . *P. Greggii* ENGELM. (3).

(b_4) Fibro-vascular bundles contiguous or merged in one. The angle formed between the two ventral sides smaller than a right angle, approximately 72°. Hypoderm one or two layers of cells. . . . . *P. leiophylla* SCHLECHT. et CHAM. (5).

(b_3) Resin canals 3 to 6. Hypoderm 2 or 3 layers of cells. Fibro-vascular bundles distinct or contiguous. The angle formed between the two ventral sides larger than a right angle, approximately 120°. . . . . *P. chihuahuana* ENGELM. (3).

(c_2) The leaf-section is notable for the presence of both thick and thin outer walls of the endoderm-cells and for the large amount of the hypoderm, both forms appearing in the same leaf. Three resin canals confined to the 3 edges. . . . *P. Torreyana* PARRY (5).

(b_1) Hypoderm biform, i.e. very thin walls situated in the outer layer of cells and very thick walls in the inner layer or layers of cells. Transverse section of a leaf triangular.

(a_2) The outer walls of the endoderm-cells thick. Hypoderm 2 or 3 layers of cells. Resin canals 2 or 3, confined to the edges. . . . . *P. teocote* SCHLECHT. et CHAM. (3-5).

(b_2) The outer walls of the endoderm-cells not thick.

(a_3) Hypoderm in some parts consisting of one layer of cells, and in others of two layers, biform when of two layers of cells. Resin canals 2 to 6, 2 of them nearer to the edges, very large. Outer cells of the hypoderm very small, inconspicuous. Endoderm with thin outer walls . . . . . *P. echinata* MILLER (2 or 3, case of 3).

(b_3) Hypoderm consisting of 2 layers of cells, occasionally of 3 layers of cells.

(a_4) The cell walls of the stelar tissue thick. Resin canals 2 or 3 . . . . . *P. radiata* D. DON (2 or 3, case of 3).

(b_4) The cell walls of the stelar tissue thin. Resin canals 2 to 6. . . . . *P. attenuata* LEMMON (3), *P. serotina* MICHAUX (3), *P. taeda* L. (3).

(c_3) Hypoderm 2 to 6 layers of cells.
Resin canals 2 to 8 . . . . . *P. rigida* Miller (3).

(c_1) Hypoderm multiform, i.e. cell walls being gradually thicker toward the centre of the leaf.

(a_2) The outer walls of the endoderm thick. Hypoderm 4 or 5 layers of cells.

(a_3) Hypoderm projecting far in to the green tissue, but not extending to the endoderm. Resin canals 2 to 9.

(a_4) The sclerenchyma cells form irregular lines below and above the fibro-vascular bundles.

{(a_5) Number of the resin canals usually 3. . . . . *P. Montezumae* Lambert (3-8).

(b_5) Number of the resin canals 1 or 2, often 3. Leaves 15-25 cm. in length, often very slender and drooping. . . . . *P. Montezumae var. Lindleyi* Loudon (3-8).

(c_5) Number of the resin canals 4, 5 or more. Leaves short (7-15 cm. long), rigid, glaucous.

(a_6) Resin canals 4 or 5. Leaves are in fascicles of 5, occasionally more, 10-15 cm. in length. . . . . *P. montezumae var. rudis* Shaw (5-8).

(b_6) Resin canals numerous, 7-10. Leaves are in fascicles of 3 and 4 as well as 5, 7-15 cm. in length. . . . . *P. Montezumae var. Hartwegii* Engelm. (3-5).}

(b_4) The sclerenchyma cells forming an irregular line below the fibro-vascular bundles.

{(a_5) Leaves 30-40 cm. in length. . . . . *P. Engelmannii* Carrière (3-5).

(b_5) Leaves 7-25 cm. in length.

(a_6) Endoderm long-based triangular. The angle formed between the two ventral sides larger than a right angle, approximately 120°. Leaves 12-25 cm. long.

(a_7) The sclerenchyma cells form an irregular line below the fibro-vascular bundles, but are wanting above the bundles. Leaves deep yellowish green. . . . . *P. ponderosa* Douglas (3).

(b_7) The many sclerenchyma cells form an irregular line below the fibro-vascular bundles and several of them are scattered above the bundles. Leaves grayish green . . . . . *P. Jeffreyi* Balfour (3-5).

(b_6) Endoderm regular-triangular. The angle formed between the two ventral sides smaller than a right angle, approximately 72°.

(a_7) Leaves deep green, fine serrated, 7-17 cm. long. . . . . *P. arizonica* ENGELM. (5).

(b_7) Leaves grayish green, 12-25 cm. long. . . . . *P. Jeffreyi* BALFOUR (3-5).

(b_3) Hypoderm remarkably developed, extending from the epiderm to the endoderm and forming a septum across the green tissue. Resin canals 2 or 3, confined to the edges. The sclerenchyma cells forming irregular lines below and above the fibro-vascular bundles . . . . . *P. pseudostrobus var. tenuifolia* SHAW (5).

(b_2) The leaf-section is notable for the presence of both thick and thin outer walls of the endoderm-cells and for the large amount of the hypoderm, both forms appearing in the same leaf.

(a_3) Endoderm regular-triangular. Resin canals 3, confined to the 3 edges. Hypoderm 5 to 7 layers of cells. The many sclerenchyma cells forming irregular lines below and above the fibro-vascular bundles. The angle formed between the two ventral sides smaller than a right angle, approximately 72°. . . . . *P. Torreyana* PARRY (5).

(b_3) Endoderm long-based triangular. Resin canals 2 to 10, taking free portion. The angle formed between the two ventral sides larger than a right angle, approximately 120°.

(a_4) Hypoderm 2-4 layers of cells. Numerous resin canals always medial. The sclerenchyma cells not only form irregular lines below and above the fibro-vascular bundles, but also lie between the two bundles forming " H " shape. . . *P. Sabiniana* DOUGLAS (3).

(b_4) Hypoderm consisting of 5-7 layers of cells. Resin canals medial, or occasionally with one or two internal canals. . . . . *P. Coulteri* D. DON (3).

(b_5) Endoderm elliptical.

(a_1) Hypoderm cells uniform thick-walled.

(a_2) The outer walls of the endoderm thick. Resin canals 2 to 9. Hypoderm 2 or 3 layers of cells.

(a_3) Leaves 30-40 cm. in length . . . . . *P. Engelmannii* CARRIÈRE (3-5).

(b_3) Leaves 12-25 cm. in length.

(a_4) The sclerenchyma cells form an irregular line below the fibro-vascular bundles, but wanting above the bundles. Leaves deep yellowish green. . . . . *P. ponderosa* Douglas (3).

(b_4) The many sclerenchyma cells form an irregular line below the fibro-vascular bundles and several of them are scattered above the bundles. Leaves grayish green. . . . . *P. Jeffreyi* Balfour (3-5)

(b_2) The outer walls of the endoderm not thick.

(a_3) Endoderm-cells very unequal in size, some of them large. Two resin canals medial, but occasionally with an internal canal or a septal canal. Hypoderm 2 or 3 layers of cells. . . . . *P. Merkusii* Jungh. et De Vriese (2).

(b_3) Endoderm-cells approximately equal in size.

(a_4) Transverse section of a leaf triangular. Fibro-vascular bundles contiguous. Resin canals 3 to 6. . . . . *P. chihuahuana* Engem. (3).

(b_4) Transverse section of a leaf semicircular.

(a_5) The sclerenchyma cells not only form irregular lines below and above the fibro-vascular bundles, but also lie scattered between the 2 bundles forming "Ⅱ" shape. Hypoderm 2 to 3 layers of thick-walled cells. Resin canals 2 to 11, always medial . . . . *P. leucodermis* Antoine (2).

(b_5) The sclerenchyma cells form irregular lines below and above the fibro-vascular bundles, but not forming "Ⅱ" shape. Hypoderm consisting of one layer of cells, occasionally of two layers of cells. Resin canals 2 to 6, medial or medial and external. . . . . *P. taiwanensis* Hayata (2), *P. brevispica* Hayata (2).

(c_5) The sclerenchyma cells form a irregular line below the fibro-vascular bundles, occasionally several of them lie scattered above the bundles.

(a_6) Hypoderm, some parts consisting of one layer of cells and others of two layers. Resin canals 2 or 3. Epiderm very thick. The sclerenchyma cells lie scattered and form a irregular line below the fibro-vascular bundles, but are wanting above the bundles . . . . . *P. luchuensis* Mayr (2).

(b_6) Hypoderm consisting of 2 layers of very thick-walled cells, occasionally of 3 layers of cells. Resin canals 2 to 12, often to 15. The sclerenchyma cells forming an irregular line below

the fibro-vascular bundles, and several of them lie scattered above the bundles. . . . . *P. Thunbergii* PARL. (2), *P. nigra* ARNOLD (2).

(b_1) Hypoderm cells uniform thin-walled.

(a_2) Hypoderm consisting of one layer of thin-walled inconspicuous cells, occasionally of 2 layers of cells.

(a_3) The sclerenchyma cells forming irregular lines below and above the fibro-vascular bundles. Resin canals 2 to 6, medial or medial and external. Transverse section of a leaf semicircular. . . . . *P. taiwanensis* HAYATA (2), *P. brevispica* HAYATA (2).

(b_3) Several sclerenchyma cells lie scattered below the fibro-vascular bundles. Medial resin canals two, occasionally with an internal canal. Transverse section of a leaf triangular. . . . . *P. patula* SCHLECHT. et CHAM. (3, sometimes 4 or 5).

(b_2) Hypoderm consisting of 2 to 3 layers of cells. Resin canals 2, always medial . . . . . *P. Greggii* ENGELM. (3).

(c_1) Hypoderm biform, i.e. very thin walls situated in the outer layer of cells and very thick walls in the inner layer or layers of cells. Transverse section of a leaf semicircular.
(Reference p. 179 (b_1) on the species which the transverse section of a leaf are triangular.)

(a_2) Hypoderm, some parts consisting of one layer of cells and others of two layers, biform when of two layers of cells.

(a_3) Outer cells of the hypoderm very small, inconspicuous. Endoderm with thin outer walls.

(a_4) Resin canals 2 to 6, medial or medial and internal : 2 medial canals of them nearer to the edges, very large. . . . . *P. echinata* MILLER (2 or 3, case of 2).

(b_4) Resin canals always 2, medial, confined to the edges, not large. . . . . *P. glabra* WALTER (2).

(b_3) Outer cells of the hypoderm large, conspicuous. Medial resin canals two, or occasionally with an internal canal. . . . . *P. clausa* VASEY (2).

(b_2) Hypoderm consisting of 2 or 3 layers of cells.

(a_3) Resin canals 2.

(a_4) Hypoderm usually 2 layers of cells. Leaves 4 to 8 cm. long. . . . . *P. virginiana* MILLER (2).

(b_4) Hypoderm 2 layers of cells, but having parts

which consist of 3 layers of cells. Leaves 10 to 15 cm. long. . . . . *P. radiata* D. Don (2 or 3, case of 2).

{(b_3) Resin canals 3 to 6.

(a_4) Leaves from 3 to 7 cm. long. Resin canals 3 to 6, medial or medial and internal. . . . . *P. pungens* Lambert (2).

(b_4) Leaves from 10 to 15 cm. long.

(a_5) Resin canals 2 or 3, medial or medial and internal. . . . . *P. radiata* D. Don (2 or 3, case of 2).

(b_5) Resin canals 3 or 4, always medial. . . . . *P. muricata* D. Don (2).}

(d_1) Hypoderm multiform, i.e. cell walls being gradually thicker toward the centre of the leaf.

(a_2) The outer walls of the endoderm thick. Transverse section of a leaf triangular. Resin canals 2 to 9.

{(a_3) Leaves 30-40 cm. in length . . . . . *P. Engelmannii* Carrière (3-5).

(b_3) Leaves 12-25 cm. in length.

(a_4) The sclerenchyma cells form an irregular line below the fibro-vascular bundles, but are wanting above the bundles. Leaves deep yellowish green. . . . . *P. ponderosa* Douglas (3).

(b_4) The many sclerenchyma cells form an irregular line below the fibro-vascular bundles and several of them are scattered above the bundles. Leaves grayish green. . . . . *P. Jeffreyi* Balfour (3-5).}

(b_2) The outer walls of the endoderm not thick. Transverse section of a leaf semicircular. The inner cells of the hypoderm gradually larger, remarkably large in the edges. Resin canals 2 to 14. . . . . *P. pinaster* Solander (2).

(c_2) The leaf-section is notable for the presence of both thick and thin outer walls of the endoderm-cells and for the large amount of the hypoderm, both forms appearing in the same leaf. Resin canals 2 to 10.

(a_3) Hypoderm consisting of 2-4 layers of cells. Numerous resin canals always medial. The sclerenchyma cells not only form irregular lines below and above the fibro-vascular bundles, but also lie between the two bundles forming "T" shape . . . . . *P. Sabiniana* Douglas (3).

(b_3) Hypoderm consisting of 5-7 layers of cells. Resin canals medial, or occasionally with one or two internal canals. . . . . *P. Coulteri* D. DON (3).

(c_0) Endoderm strangled-cocoon like.

The space between the two fibro-vascular bundles very wide. Resin canals one or two. Hypoderm with very thin walls in the outer layer of cells and very thick walls in the inner layer or layers of cells, namely biform. The outer walls of the endoderm thick.

{(a_1) Epiderm cells thick, their thickness thicker than their width. Hypoderm 2 or 3 layers of cells. . . *P. contorta* DOUGLAS (2).

(b_1) Epiderm cells not thick, their thickness as long as their width. Hypoderm 2 or 3 layers of cells. . *P. Banksiana* LAMBERT (2).}

(H) Resin canals medial and external, i.e. some of the resin canals situated in the green tissue, touching neither endoderm nor hypoderm; but others close to the hypoderm. Stomata on both dorsal and ventral sides.

(a_0) Endoderm long-based triangular. Resin canals external, rarely with a medial canal in ventral side, 2 to 5. . . . . *P. insularis* ENDL. (3), (rare case).

(b_0) Endoderm elliptical.

(a_1) Resin canals 2 to 6; external canals usually 2 in the ventral side, medial canals in the dorsal side. Hypoderm consisting of one layer of cells. The sclerenchyma cells surrounding the resin canals thick. . . . . *P. resinosa* AITON (2).

(b_1) External resin canals in the dorsal side only or both the dorsal and ventral sides. Number of resin canals from 1 to 4, often to 11.

(a_2) Transverse section of a leaf triangular. Resin canals 2 to 5, external or external and medial. . . . . *P. insularis* ENDL. (3), (rare case).

(b_2). Transverse section of a leaf semicircular.

(a_3) The sclerenchyma cells forming irregular lines below and above the fibro-vascular bundles. Resin canals 2 to 6, medial or medial and external. Hypoderm consisting of one layer of cells, rarely of 2 layers of cells. . . . . *P. taiwanensis* HAYATA (2), *P. brevispica* HAYATA (2).

(b_3) The sclerenchyma cells scattered and forming a irregular line below the fibro-vascular bundles, occasionally several of

them scattered above the bundles. Hyopoderm, some parts consisting of one layer of cells and others of two layers.

(a_4) Resin canals 3; 2 of them medial, confined to the edges; other external in the dorsal side. Epiderm very thick. Hypoderm for the most part consisting of 2 layers of cells, others of one layer. . . . . *P. luchuensis* Mayr (2).

(b_4) Resin canals 2 to 12, among them the medial canals taking free portion. Epiderm not so thick as *P. luchuensis*. Hypoderm for the most part consisting of one layer of cells, others of two layers. . . . . *P. densiflora* X *P. Thunbergii*; *P. Thunbergii* X *P. densiflora* Mayr

(c_0) Endoderm strangled-cocoon like.

The space between the two fibro-vascular bundles very wide. The sclerenchyma cells forming a irregular line below the fibro-vascular bundles, occasionally several of them scattered above the bundles. The sclerenchyma cells surrounding the resin canals continuous at the part touching the hypoderm. Resin canals 2 to 15, external, occasionally with one or two medial canals. Hypoderm one layer of thin-walled cells, often having parts which consist of two layers of cells. . . . . *P. silvestris* L. (2).

(I) Resin canals external, i.e. situated close to the hypoderm. Stomata on both dorsal and ventral sides.

(a_0) Endoderm triangular.

(a_1) Hypoderm in large masses, projecting far into the green tissue.

(a_2) Some or all of the endoderm-cells with thick outer walls. Resin canals 2. . . . . *P. longifolia* Roxb. (3).

(b_2) Endoderm with thin outer walls. Resin canals 2 to 4 . . . . . *P. canariensis* Smith (3).

(b_1) Hypoderm not projecting far in to the green tissue. Resin eanals 2 to 5, external, rarely with a medial canal. . . . . *P. insularis* Endl. (3).

(b_0) Endoderm elliptical.

(a_1) Hypoderm consisting of one layer of cells, occasional having parts consisting of two layers of cells.

(a_2) External resin canals 2. in the ventral side only. . . . . *P. resinosa* Aiton (2).

(b_2) External resin canals in the dorsal side or both the dorsal and ventral sides.

(a_3) Epiderm remarkably thick.

The sclerenchyma cells forming an irregular line below the fibro-vascular bundles, occasionally several of them scattered above the bundles. Resin canals 2 to 7. . . . . *P. montana* MILLER (2).

(b_3) Epiderm not remarkably thick.

(a_4) Transverse section of a leaf triangular. Resin canals 2 to 5 . . . . . *P. insularis* ENDL. (3).

(b_4) Transverse section of a leaf semicircular.

(a_5) The sclerenchyma cells surrounding the resin canals are wanting at the part touching the hypoderm and several secreting cells are close to the hypoderm.

(a_6) The sclerenchyma cells forming an irregular line below the fibro-vascular bundles; occasionally several of them are scattered above the bundles.

(a_7) Hypoderm consisting of one layer of very thin-walled cells. Resin canals 2 to 12. Leaves 7-12 cm. long. . . . . *P. densiflora* SIEB. et ZUCC. (2).

(b_7) Hypoderm consisting of one layer of thick-walled cells, but having parts which consist of two layers of cells. Resin canals 2 to 10. . . . . *P. tabulaeformis* CARRIÈRE (2), (*P. funebris* KOMAROW pro parte). (rare case).

(b_6) The several sclerenchyma cells scattered below the fibro-vascular bundles, but not forming an irregular line, deficient above the bundles. Hypoderm with very thin-walled cells, inconspicuous. Resin canals 5 to 8. Leaves 12-20 cm. long. . . . . *P. Massoniana* LAMBERT (2, rarely 3).

(b_5) The sclerenchyma cells surrounding the resin canals always continuous at the part touching the hypoderm. Resin canals 2, confined to lateral edges, one of them in the dorsal side and the other in the ventral side. Several sclerenchyma cells lie scattered below the fibro-vascular bundles. . . . . *P. pinea* L. (2).

(c_5) The sclerenchyma cells surrounding the resin canals continuous and surround the total circumference of some of the resin canals, but in other canals they are wanting at the parts touching the hypoderm, and secreting cells are close to the hypoderm. The sclerenchyma cells form an irregular line below the fibro-vascular bundles. occasionally several of them lie scattered above the bundles. Hypoderm one layer of thick-walled cells, but having parts which

consist of two layers of cells. Resin canals 2 to 10. . . . . *P. tabulaeformis* Carrière (2), (*P. funebris* Komarow pro parte).

(b_1) Hypoderm consisting of 2 to 3, rarely to 5 layers of uniform thick-walled cells.

(a_2) Resin canals of remarkable size, not touching the endoderm, technically external, 2 to 9. The sclerenchyma cells forming irregular lines below and above the fibro-vascular bundles. Hypoderm 3 to 5 layers of cells. . . . . *P. tropicalis* Morelet (2).

(b_2) Resin canals not so large as *P. tropicalis*. The sclerenchyma cells forming an irregular line below the fibro-vascular bundles, occasionally several of them are scattered above the bundles.

(a_3) Resin canals 2, confined to lateral edges, one of them in the dorsal side and the other in the ventral side. The sclerenchyma cells surrounding the resin canals always continuous at the part touching the hypoderm. Several sclerenchyma cells lie scattered below the fibro-vascular bundles . . . . . *P. pinea* L. (2).

(b_3) Resin canals 3 to 7, taking free portion.

The sclerenchyma cells surrounding the resin canals are continuous and surround the total circumference of some of the resin canals, but in other canals they are wanting at the parts touching the hypoderm and secreting cells are close to the hypoderm . . . . . *P. halepensis* Millier (2).

(c_1) Hypoderm in large masses, projecting far into the green tissue.

(a_2) Some or all of the endoderm-cells with thick outer walls. Resin canals 2. . . . . *P. longifolia* Roxb. (3).

(b_2) Endoderm with thin outer walls. Resin canals 2 to 4 . . . . . *P. canariensis* Smith (3).

(c_2) Endoderm strangled-cocoon like.

The space between the 2 fibro-vascular bundles very wide. The sclerenchyma cells forming an irregular line below the fibro-vascular bundles, occasionally several of them are scattered above the bundles. The sclerenchyma cells surrounding the resin canals always continuous at the part touching the hypoderm. Resin canals 2 to 15, external, occasionally with one or two medial canals. Hypderm consisting of one layer of thin-walled cells, often having parts which consist of 2 layers of cells . . . . . *P. silvestris* L. (2).

Those species enclosed in parenthesis "{ . . . . . }" in this Analytical Key (Chapter VIII), are either such as fail to show some distinct peculiarity, or which, because of possible slight changes in their characters, are difficult of exact classification.

IX. LITERATURE CITED

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X. INDEX TO THE SPECIES, VARIETIES AND THEIR SYNONYMS IN THE ANALYTICAL KEY (CHAPTER VIII.)

The scientific names of the admitted Species or Varieties are in roman type, of Synonyms in italics.

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