LIV.—A REVISION OF THE SPECIES OF ABIES. By WILLIAM RAMSAY M'NAB, M. D., Edinburgh, Professor of Botany, Royal College of Science for Ireland. (With Plates 46, 47, 48 and 49.)

[Read June 26, 1876].

LAST year I presented to the Royal Irish Academy a paper (*antea*, p. 209), in which the anatomy of the leaves of the section Tsuga of the genus Pinus was described, and in the present paper I propose to continue the investigation of the anatomical structure of the leaves of the same great genus. The sections to which I shall now direct attention are Abies of Endlicher and Parlatore, and Pseudotsuga of Carrière and Bertrand, the former including a considerable number of species of which the common European silver fir may be taken as the type. Much confusion has been caused by Linnæus in 1753 falling into an error as to the application of the names Picea and Abies—an error which was corrected by Duroi in 1771; but in this paper I shall not follow Parlatore in calling the common silver fir (generally known by the name of Abies pectinata of De Candolle) Pinus (Abies) Abies of Duroi; but shall adopt the more commonly used A. pectinata.

Dr. C. E. Bertrand* enumerates and briefly describes the anatomical characters of twenty-two species of Abies. All Bertrand's forms, with a single exception, I believe I have been able to examine; and while we agree in many most important points, still in others I find considerable discrepancies in our results. Perhaps this may result from an examination of but few examples of each species, and this I have tried to avoid by examining as many specimens as I could obtain, both living and dried. A very large number of specimens have been examined, and many thousands of sections cut—the greater part of my spare time for twelve months past having been devoted to the work.

Great confusion exists in the nomenclature of this section; the synonymy is very complex, and the cultivated forms frequently do not agree with the species described by Botanical authors. It has, therefore, been difficult in many cases to discover what the true plant of the original describer was, but I have been very fortunate in obtaining a great deal of information regarding the cultivated species introduced into Britain within the last twenty-five years from my father, who has cultivated most of the species with the greatest success, and whose accurate and extensive knowledge of this genus is well known. All the forms introduced by Jeffrey have been raised from seed in the Royal Botanic Garden at Edinburgh, and I have thus been able to obtain, from the Museum, and from the Edinburgh Botanic Garden, authentic specimens of the different forms for examination. To Dr. Hooker and Professor Oliver I am very deeply indebted for permission

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* Anatomie Comparée des Tiges et des Feuilles chez les Gnétacées et les Conifères. Paris, 1874.

to examine authentic specimens from the Kew Herbarium, many difficulties having been removed by their kind assistance; while Professor Perceval Wright also helped me greatly by his kindness in enabling me to examine the authentic specimens in the Herbarium of Trinity College, Dublin. To many other friends—Dr. Moore, of Glasnevin; Mr. Fowler, of Castle Kennedy; Mr. Syme, Elvaston Nurseries; Messrs. Waterer, Low, and Veitch—my best thanks are also due.

Parlatore* enumerates and describes eighteen species and two varieties in his section Abies, but he seems in some instances to have mixed up two or more anatomically distinct forms under one name. Each form has been carefully described, and a figure of the section of the leaf given, so that this paper may, to a certain extent, be useful in identifying the cultivated species in our gardens and nurseries.

The species of Abies are generally separated into two groups by the bracts of the cones, which are either long or short. Bertrand separates two groups by the position of the resin-canals. In the present paper I have adopted a geographical arrangement, as I find that the forms most related anatomically are most connected geographically, the outlying forms being generally the most distinct. A great zone of species stretches from North America, by Japan and the Himalayas, to Asia Minor and Southern Europe.

The section Abies of Pinus is distinguished by having the leaves inserted singly into the stem, by their not being placed on cushions, and by the double fibro-vascular bundle. The second section mentioned in this paper is Pseudotsuga, which differs in having a single fibro-vascular bundle.

I. Abies, Endl., Parlatore. Genus Abies, Link. Abies, Bertrand.

1. *Pinus* (*Abies*) *bracteata*, Don, Trans. Linn. Soc. xvii. 443; Parlatore, D. C. Prod., vol. xvi., pars 2, p. 419, No. 88. *Pinus venusta*, Dougl. *Abies venusta*, Koch, Dendrologie, vol. ii. part 2, p. 210.

Shoots hairy or smooth. Leaves inserted singly all round the stem, but bent so as to form two lateral rows; occasionally a few directed upwards. Leaf rigid, linear, twisted above the base, which is slightly narrowed towards the orbicular insertion, widest above the twisted part, then gradually tapering, contracting suddenly near the sharp-pointed apex; upper surface bright green with no stomata, beneath with a band of stomata on each side of the midrib, there being from 10 to 12 rows of stomata in each band. Leaves from $1\frac{1}{2}$ to 2 inches in length, and about $\frac{1}{10}$ of an inch wide. Buds covered with pale yellow scales, which are not resinous.

Transverse section of leaf.—Leaf flattened, $3\frac{1}{2}$ times broader than thick, sides rounded, upper surface gently curved inwards, below with

* De Candolle, Prodromus, vol. xvi., sect. 2, pp. 419, *et seq.*

a prominent midrib. Hypoderma well developed, a continuous band of thickened cells running underneath the epidermis of the upper surface, from the external margin of the one resin-canal to the external margin of the other. At the rounded margins of the leaf the hypoderma consists of two rows of cells. The hypoderma is also developed under the epidermis covering the prominent midrib below, the layer of cells being double in the middle. The resin-canals are placed one at each side of the leaf, close to the under side, and separated from the epidermis by a single layer of cells. The pallisade parenchyma is well developed on the upper side, and below there is parenchyma with well-marked intercellular spaces communicating with the stomata.

Fibro-vascular bundle double, the parts placed close together, and having a few thick liber-like cells above and in the middle. The whole is surrounded by a sheath.

The figure (Plate 46, fig. 1) is drawn from a specimen supplied to me by Mr. Syme, Elvaston Nurseries, Borrowash, Derby.

Bertrand* gives the following characters for A. bracteata:—Glands touching the inferior epidermis; no stomata on upper surface of leaf, more than 10 rows of stomata in each band; no pseudo-liber cells in parenchyma of leaf; zone of hypoderm continuous; leaf mucronate.—In the different specimens examined by me the same characters were found.

Gordon† describes this species, and directs attention to the buds, while Koch‡ gives a description of it under the name of Pinus (Abies) venusta. According to this author the name venusta, Douglas (1836), has the priority by one year of that of bracteata, D. Don (1837). It has also been described and figured by Mr. Andrew Murray, in the Transactions of the Botanical Society of Edinburgh, vol. vi., p. 211, with plates. Koch states that the young shoots are hairy, while Parlatore says: "Ramuli glabri:" both states occur among the specimens examined by me.

P. (Abies) bracteata is one of the most distinct species of the whole section. Five different specimens have been examined by me—three from their natural habitats, the others cultivated.

I am indebted to my valued correspondent, Mr. Syme, of Elvaston Nurseries, Borrowash, Derby, for a fine cultivated specimen for examination, a section of the leaf of this plant being the one figured. The other cultivated specimen examined was from a very small plant in Glasnevin Garden, kindly given to me by Dr. Moore, and in it the hypoderm was not so well developed, there being 2 or 3 cells omitted in 3 or 4 places, but it agreed in all other characters.

I am indebted to Dr. Hooker, C.B., P.R.S., and to Prof. Oliver, F.R.S., for permission to examine two specimens in Kew Herbarium. One is a specimen collected by D. Douglas in "America boreali-occi-

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* *Op. cit.*, p. 89. † The Pinetum (1858), p. 145.
‡ Dendrologie, vol. ii., part 2, p. 210.

dentalis;" the other was marked "119, Picea bracteata, W. Lobb, California." These specimens of Douglas and Lobb have in every respect the same anatomical characters as the specimen from Elvaston Nurseries, figured in the paper.

There is a specimen with cones in the Museum, Royal Botanic Garden, Edinburgh, presented by Mr. Andrew Murray in 1859. The leaves of this specimen do not differ anatomically from those already described.

2. *Pinus* (*Abies*) *religiosa*, Humb., Bonpl. and Kunth, Nov. Gen. et Sp. 2, p. 5; Parlatore, D. C. Prod. vol. xvi., pars 2, p. 420, No. 91.

Shoots hairy or smooth. Leaves inserted singly, and not very closely, all round the stem, but bent so as to form two lateral rows. Upper side of shoot with leaves directed outwards at a small angle. Leaf linear, straight or curved, slightly twisted above the base, contracting at apex into a point, upper surface deep green with no stomata, below with a band of stomata on each side of the midrib, there being from 8 to 10 rows in each band. Leaves from 1 to 1½ inch in length, and about $\frac{1}{12}$ inch wide. Buds pale-coloured, and very resinous.

Transverse section of leaf.—Leaf flattened, nearly three times broader than thick, sides rounded, upper surface with a central longitudinal furrow, below with a slightly prominent midrib. Hypoderma conspicuous, forming a continuous, or only very slightly interrupted, band, extending from the resin-canal of one side underneath the epidermis of the upper surface to the resin-canal of the other side: below the epidermis of the midrib a series of hypoderm cells also exists. The resin-canals are two in number, placed close to the epidermis of the under side of the leaf, and rather near the margin. The pallisade parenchyma is well developed on whole upper part of leaf; below, the parenchyma, with intercellular spaces communicating with the stomata, is well seen.

Fibro-vascular bundle double, surrounded by a well-developed sheath; the parts of the bundle are not widely separated, and a few thick liber-like cells are placed superiorly.

The figure (Plate 46, fig. 2) is drawn from a specimen kindly supplied to me by Mr. Fowler, gardener, Castle Kennedy, N. B.

Pinus (Abies) religiosa is very closely related to P. bracteata, and Bertrand says that the two do not differ anatomically. The shape of the leaf in section is, however, different, and the thick hypoderm cells are larger and more interrupted than in P. bracteata. I have seen two specimens from Castle Kennedy, one figured above, the other in the Museum, Royal Botanic Garden, Edinburgh. It has a cone, ripened in 1867, about 4 inches long by 2 wide, with projecting bracts. The specimen from Glasnevin was in an unhealthy condition when examined, and has the hypoderm less developed than in the Castle Kennedy specimens. In Kew Herbarium is a specimen, marked "Abies religiosa, Guatemala, Skinner;" and on the label also, "Abies hirtella. Differt ab Ab. religiosa foliis obtusissimis emarginatis, nec acutissimis." This seems to me only to differ from religiosa in having the hypoderm cells more scattered, and it resembles in every way the young leaves on the plant of religiosa from Glasnevin Garden. Some of the leaves on the Castle Kennedy specimens are rather obtuse, so that there may be a little variation in this interesting form.

I place religiosa next bracteata, which it resembles much in its leaves, but it differs in its cone.

3. *Pinus* (*Abies*) *amabilis*, Douglas, Bot. Mag. Comp. 2, p. 93 (not Parlatore). *Abies grandis*, A. Murray, Syn. Var. Conif., p. 18 (not Douglas). *A. grandis*, Lambert (?). *Picea lasiocarpa*, Balf. in Jeff. seeds, p. 1, t. 4, f. 1 (not Hook.). *Abies spectabilis*, Herpin de Fremont, Bertrand, Anat. Gnét. et Conif. p. 91 (not Don).

Shoots densely covered with small dark hairs. Leaves inserted singly all round the stem, and placed very close together, the leaves on the under side of the stem and the lateral ones forming two lateral rows spreading outwards, those on the upper side of the branch twisted round so as to bring the upper surfaces of the leaves superiorly: these upper leaves all point to the apex of the shoot, nearly parallel to its long axis, and give the branches a very peculiar appearance. Leaf linear, more or less twisted at the base, which narrows towards the orbicular insertion, width nearly uniform, apex rounded and emarginate, upper surface very bright green with no stomata, beneath with a band of stomata on each side of the midrib, there being from 8 to 10 rows of small stomata in each band. Leaves 1 to $1\frac{1}{4}$ inch long by about $\frac{1}{15}$ inch wide. Buds covered with brown scales, and resinous.

Transverse section of leaf.—Leaf flattened, three times broader than thick, sides rounded, upper surface with a faint longitudinal furrow, the midrib not prominent. Hypoderma well developed, forming a continuous, or nearly continuous, layer running from the resin-canal of one side, under the upper epidermis, to the resin-canal of the other; the hypoderm is also developed in the middle line below. The resin-canals are placed, one at each side of the leaf, close to the inferior epidermis, but sometimes having a layer of hypoderm separating the canal from the epidermis. The pallisade parenchyma is well developed on the upper side, and below is parenchyma, with intercellular spaces communicating with the stomata.

Fibro-vascular bundle double, the whole surrounded by a well-marked sheath.

The figure (Plate 46, fig. 3) is drawn from a specimen supplied to me by my father, from the Royal Botanic Garden, Edinburgh.

The peculiar appearance of the foliage of this plant is well shown in Mr. Murray's figure (Syn. Var. Conif. p. 19, fig. 20), an appearance which is considered characteristic of amabilis of Douglas. It seems probable that this is not the plant meant by Douglas to be called amabilis, but that the form he really wished to bear this name is now known as Pseudotsuga magnifica.

I have examined in all eleven specimens of this plant. It has been sent to me from the Royal Botanic Garden in Edinburgh as the true amabilis of Douglas, grafts and layers from Douglas' plants being there cultivated. I have also received it from Mr. Syme, of Elvaston Nurseries, as the true amabilis of Douglas, as well as from Mr. Waterer, of Knap Hill Nursery. A plant of it was noticed last September by Dr. Moore, of Glasnevin, growing near Ambleside, in the Lake District. I have also examined five native specimens—three in Kew Herbarium, from the Oregon Boundary Commission: one collected in St. Juan Island, by Dr. Lyell, in 1858; another, near Lake Chilukweyak, B. C., Cascade Mountains, 49° N. L., Dr. Lyell, 1859; and the third, Cascade Mountains to Fort Colville, about 49° N. L., Dr. Lyell, July, 1860. A section of the leaf of one of these is figured (Plate 46, fig. 3, a.)

In the Museum at the Royal Botanic Garden, Edinburgh, there is a cone, about 4 inches long, with a few leaves, marked "Pinus lasiocarpa, 409. California, Mr. Jeffrey, 1853." In the Herbarium is a specimen of the same, marked "Picea sp., No. 409. Mountains east of the Falls of Fraser's River, Sept. 27, 1851, Jeffrey." This No. 409, Jeff., is A. lasiocarpa of Balfour and Oregon Committee, as shown by the figure given by Mr. A. Murray, Syn. Var. Conif. p. 25, fig. 34. From an examination of both the cone and leaves, I have no difficulty in identifying this plant as being lasiocarpa of Balfour, grandis of Murray, and probably of Lambert, and amabilis of Douglas, as represented in our gardens. No plants of this, Balfour's lasiocarpa, seem to have grown from Jeffrey's seeds.

From the great development of hypoderm, I place this species next to bracteata and religiosa. The cone is unlike that of the two species, and has large bracts, which do not project beyond the scales.

4. *Pinus* (*Abies*) *grandis*, Douglas, Bot. Mag. Comp. 2, p. 147; Parlatore, D. C. Prod. xvi. p. 427, No. 104 (excl. of syn.). *Abies amabilis*, Murray, Syn. Var. Conif. p. 20; Koch, Dendrologie, vol. ii. pt. 2, p. 211. *Abies Gordoniana*, Carr. Conif. ed. 2, p. 298; Bertrand, Anat. Comp. Gnét. et Conif. p. 91.

Shoots smooth. Leaves inserted singly all round the stem, but bent so as to form two lateral rows; occasionally a few are directed upwards. Leaf linear, twisted at the base, which is slightly narrowed towards the orbicular insertion; width of leaf nearly uniform, with a rounded emarginate apex, upper surface bright green, with no stomata, or very rarely with a small cluster of 3 or 4 near the apex, beneath with a band of stomata on each side of the midrib, there being from 7 to 8 rows of stomata in each band. Leaves from 1 to $1\frac{1}{4}$ inch long, and about $\frac{1}{12}$ inch wide. Buds covered with resinous brown-coloured scales.

Transverse section of leaf.—Leaf flattened, about three times broader than thick, sides rounded, upper surface with a faint longitudinal furrow, the midrib not prominent. Hypoderma consisting of a few scattered cells under the upper epidermis, one or two at the sides of the resin-canals, and a few inferiorly in the middle line. The resin-canals are placed, one at each side of the leaf, close to the epidermis of the under surface. The pallisade parenchyma is well developed on the upper side, and below is parenchyma with well-marked intercellular spaces communicating with the stomata.

Fibro-vascular bundle double, the parts placed close together, the whole surrounded by a well-marked sheath.

The figure (Plate 46, fig. 4) is drawn from a specimen supplied to me by my father, while Pl. 46, fig. 4, a, is from a specimen sent under the name of A. lasiocarpa.

Much confusion exists in regard to this species, a confusion which seems to have begun at the very beginning, and to have been made still worse by the Oregon Association distributing several plants under one name. I have been able to examine many specimens, and shall briefly give the result of my investigations.

Specimens of grandis have reached me from three different sources, all purporting to be grandis of Douglas. The first comes from the Royal Botanic Garden, Edinburgh, where it has been long cultivated, and my father sends it to me with the note that it is a layer from one of Douglas's original plants. The same plant is cultivated in the Botanic Garden, Glasnevin, and is marked as the true grandis of Douglas. The third specimen comes from Mr. Barron, of Elvaston Nurseries, and was sent to me by Dr. Masters. All these have the same foliage, and the same peculiar anatomical structure of the leaf, and the peculiar scattered hypoderm cells. Assuming, then, that this plant is probably the true grandis of Douglas, an examination of recently introduced specimens will show a great deal of confusion.

In the Museum and Herbarium of the Royal Botanic Garden, Edinburgh, Jeffrey's original specimens are preserved, and I have been enabled to examine them carefully, through the kindness of Professor Balfour, F.R.S. In the Museum there is a cone in a net, and lying beside the cone is a shoot with leaves, bearing a label in Jeffrey's handwriting. The cone is 5 inches long, by 2½ inches wide, and shows the short pointed bract. There seems little doubt that the cone belongs to the shoot, as shown by the examination of other specimens. On the label is the following—

*Picea.* No. 393.

Along the banks of Fraser's River, from the Falls to the Ocean.

Sept. 30, 1851.

There is another cone in the collection, marked "P. lasiocarpa? Jeffrey, 393." The cone is in pieces, and seems to have measured about 4 inches by 2. No leaves are attached to this specimen. The scale and bract is the same as that figured by Mr. Murray, Syn. Var. Conif. p. 25, figure 32.

In the Herbarium there are two specimens, one with part of an immature cone, the other with the whole of a small one, also immature. Both are marked "No. 393, Jeffrey, Picea, sp." One bears a long printed label; the other, with the entire cone, is marked by my father, "P. Lowii."

In Kew Herbarium there is a specimen from the Oregon Association, No. 393, with the printed label, and erroneous date, 1852. Jeffrey's No. 393 is, undoubtedly, the same as grandis, Douglas; but it is extensively cultivated as Picea lasiocarpa. My father has sent me two specimens of it for examination, one marked "Picea lasiocarpa. Introduced by Jeffrey, and described by Mr. Murray," meaning that it is the lasiocarpa of the Oregon Committee. (See Trans. Ed. Bot. Soc., vol. xi. p. 326). Mr. Murray (Syn. Var. Conif. p. 24) is quite correct in stating that Jeffrey's No. 393 is Douglas's grandis, and not lasiocarpa. A specimen of lasiocarpa, received from Mr. Barron of Elvaston, through Dr. Masters, is also grandis; hence Mr. Barron's conclusion that lasiocarpa only equals grandis.

Lasiocarpa of the Oregon Committee, Jeffrey, No. 409, is a different plant, already noticed as amabilis.

I have examined sixteen specimens—ten cultivated, and six native—of Picea grandis, Douglas, and have received it under three different names:

A. grandis, Hort. Edin., Hort. Glasnevin., Hort. Barron.
P. lasiocarpa, Hort. Edin.
P. amabilis, Hort. Glasnevin.

There is a specimen in Kew Herbarium from Dr. Lyell, marked "Abies grandis, Dgl. ?," from the Columbia River, lat. 46°–49° N.

A specimen in the Edinburgh Museum, marked "grandis," from Mr. Andrew Murray, is Lowiana.

5. *Pinus* (*Abies*) *Lowiana*, Gordon, Supp. to Pinetum, p. 53; A. Murray, Syn. of Var. Conif. p. 27. *A. Parsonsiana*, Hort. *A. lasiocarpa*, Hort.

Shoots hairy. Leaves inserted singly all round the stem, but bent so as to form two lateral rows; occasionally a few are directed upwards. Leaf linear, twisted at the base, some only slightly, others twisted through half a turn, width nearly uniform, apex rounded and emarginate, upper surface bright green, with 6 or 7 (or fewer,) rows of stomata in a central band, beneath with a band of stomata on each side of the midrib, there being from 9 to 10 rows in each band. Leaves 1 to 2 inches in length, and about $\frac{1}{12}$ inch wide. Buds covered with resinous brownish scales.

Transverse section of leaf.—Leaf flattened, about three times as broad as thick, sides rounded, upper surface with a faint longitudinal furrow, below without a prominent midrib. Hypoderma well developed at the margins of the leaf; scattered cells under the upper epidermis, and a few cells below, under the fibro-vascular bundle. The resin-canals are placed, one at each side of the leaf, close to the under side. The pallisade tissue is interrupted above by the presence of stomata.

The fibro-vascular bundle is double, the parts not placed very close together, the whole surrounded by a well-marked sheath.

The figure (Plate 46, fig. 5) is drawn from a specimen grown in the Royal Botanic Garden, Edinburgh, from seed sent by Jeffrey.

I have examined nine specimens of this plant, six of them being cultivated, and three native specimens. In the Museum, Royal Botanic Garden, Edinburgh, is a cone with a shoot having leaves tied to it, which is marked "Picea Lowii (P. grandis). Oregon, Mr. Jeffrey, 1854." The cone is 4 inches long by 2½ inches wide. The scale and seed are both large, the bract being very short. The part that is free from the scale is broader than long; the margin is toothed, with a sharp-pointed apex, indeed, agreeing very well with Mr. Gordon's description. The number in Jeffrey's list is not given, and I failed to find more than the one specimen of Jeffrey's. I have little doubt that the seeds were mixed with those of Jeffrey's 393 and 409, and the three things all sent out as P. lasiocarpa, Oregon Committee; hence the name it receives in certain gardens. Lowiana was sent home by Mr. William Murray, as there is a shoot of it, without a cone, in the Museum, in the Royal Botanic Garden, Edinburgh, marked "Picea grandis. California, W. Murray, Esq. Presented by A. Murray, Esq., 1860." In Kew Herbarium is a specimen marked, "No. 3. California, — Low, Esq., Clapton." It is also cultivated as Parsonsiana, and I have received it as such from Edinburgh, and from Mr. Barron, Elvaston Nurseries, per Dr. Masters.

6. *Pinus* (*Abies*) *concolor*, Engelm. Herb.; Parlatore, D. C. Prod., xvi., pars 2, p. 426, No. 103. *Picea concolor*, Gordon, Pinetum, p. 155.

Leaves about 1½ inch long, and $\frac{1}{12}$ inch broad, linear, curved, twisted at base, rather obtuse at apex, stomata on both sides—about 15 rows on the upper side, and two bands below, each with about 8 or 10 rows of stomata.

Transverse section of leaf.—Leaf about 2½ times as broad as thick, rather tetragonous in form although much flattened, sides rounded, upper surface convex with no furrow, below with a rather prominent midrib. Hypoderma developed at the sides of the leaf, and below the epidermis of the midrib, occasionally a few scattered cells in other parts of the leaf between the rows of stomata. The resin-canals are placed, one at each side of the leaf, close to the lower epidermis. The pallisade tissue is not developed, owing to the presence of stomata on both sides of the leaf.

Fibro-vascular bundle double, the two parts rather widely separated, and with a well-marked sheath surrounding the whole.

The figure (Plate 46, fig. 6) is drawn from the specimen in Kew Herbarium from Fendler, "Pl. Novo-Mexicano," No. 828, 1847.

This species is very distinct anatomically, and as far as I know is not yet in cultivation, not having received it from any of our gardens and nurseries.

M. Bertrand (*loc. cit.* p. 89) gives Abies concolor as a synonym of Abies grandis, Lindl., but gives the characters of concolor for the species.

7. *Pinus lasiocarpa*, Hooker, Fl. Bor. Amer. ii., p. 163, (not Balfour.) *Abies bifolia*, A. Murray, Proc. of Royal Hort. Soc. London, iii., p. 320. *P. amabilis*, Parlatore, D. C. Prod., vol. xvi., p. 426, No. 102 (in part). ? *Picea amabilis*, Newberry.

Leaves of two forms, those on ordinary branches from $\frac{1}{2}$ to $1\frac{1}{2}$ inch long, and grooved on the upper side, those on the cone-bearing shoots shorter, and without the groove. Stomata on both sides of the leaf, above with many rows especially near the apex, below with two bands on each side of the rather prominent midrib, there being from 6 to 8 rows in each band. Leaves either pointed, or blunt, or slightly emarginate, from $\frac{1}{14}$ to $\frac{1}{12}$ inch wide.

Transverse section of leaf.—Leaf (ordinary branch) flattened, about three times as broad as thick, sides rounded, upper surface with a central longitudinal furrow, below with a prominent midrib. Leaf (cone-bearing branch) tetragonal, more than half as thick as wide, with no furrow. Hypoderma developed at edges of leaf below epidermis of midrib, and generally superiorly. Resin-canals in the parenchyma of the leaf, and remote from the inferior epidermis.

Fibro-vascular bundle double, and surrounded by a well-marked sheath.

I have examined nine dried specimens, all of which I refer to this species. The first is a specimen in Kew Herbarium: the leaves were sent to me by Prof. Oliver, and labelled "P. lasiocarpa, Hook. (sp. typica). Coll. Douglas." This specimen first showed me that P. lasiocarpa, Hooker, was not P. lasiocarpa of Balfour, or of our gardens. A transverse section of the leaf is figured in Plate 46, fig. 7. My valued correspondent, Mr. Syme, of Elvaston Nurseries, sent me leaves of P. bifolia, A. Murray, got from M. Roezl. These on examination proved to be the same as P. lasiocarpa, Hooker. The two forms of leaves were sent by Mr. Syme—both the grooved and quadrangular forms. One of the leaves is figured in section (Plate 47, fig. 8). Mr. Syme adds on the label of the specimen sent to me the note: "M. Roezl informs me that it is not very handsome." Young plants sent by Mr. Syme were also examined, but they did not present the distinctive features of the species. Five specimens from Kew Herbarium were then examined, collected by Dr. Lyell in 1860 and 1861, and in the collection of the Oregon Boundary Commission. These specimens were collected in the Cascade Mountains, Galton range of Rocky Mountains, and along the Columbia River, through 10° of latitude, viz., from 39°N. to 49°N.; and on the Galton range, at an elevation of 7000 feet. These are, in fact, the types of Mr. Murray's "bifolia," and one of the specimens is marked "Ab. amabilis, Douglas, fid. Parlatore." An unnamed specimen from Douglas also exists in Kew Herbarium (Plate 46, fig. 7, a.)

When examining the specimens in the Royal Botanic Garden, Edinburgh, I found a specimen marked "Picea magnifica robusta. Oregon, Mr. Jeffrey, 1853." Two cones and a few leaves were preserved in the Museum, and I was able at once to refer the specimen to P. bifolia of Murray, or P. lasiocarpa, Hooker.

The section of the leaf from the cone-bearing branch in Kew Herbarium with the label, "Colville, Indian name 'Marcilp.' Hab. East side of Cascade Mountains, latitude 49°N. Not uncommon up to 6000 feet above the sea. Aug., 1860," is figured (Plate 47 fig. 9).

After the most careful examination of these specimens I am compelled to come to the conclusion that P. lasiocarpa of Hooker is a good species which has been confounded with other forms by subsequent botanists. I further conclude that bifolia of Murray is a synonym of P. lasiocarpa, Hooker. From an examination of the cones of grandis, magnifica, and bifolia, I find that it is very difficult to separate them by external characters, all being hairy or "lasiocarpous;" and as magnifica and bifolia are mixed in the Museum in Edinburgh, it shows that thoroughly competent botanists may confound them. By an examination of the bract, the two can be readily separated: the bract of magnifica is large, while that of bifolia is very small. If we bear in mind that amabilis, Douglas, and lasiocarpa, Hooker, were described within a comparatively short time of each other, I feel constrained to consider that the two things are and were distinct. Further, when we consider M. Roezl's note, mentioned above, that it is not a handsome plant, I think we could hardly agree with Parlatore in calling it amabilis, Douglas. The scale, but not the bract, of amabilis, Douglas, is figured in Loudon's "Arboretum," and he mentions that the bract is very short and pointed; in fact, the cone he figured was bifolia, Murray. I feel quite confident that the plant Douglas meant to call amabilis is magnifica of Murray, and not bifolia of Murray, but in the absence of authentic specimens, I think we should retain the name amabilis for the plant long cultivated under that name, and retain the name of lasiocarpa, Hook., for this species, while we use A. Murray's name, magnifica, for the species which Douglas undoubtedly meant should be called amabilis.

The scale and bract of Jeffrey's specimen in the Museum of the Royal Botanic Garden, Edinburgh, were examined. The cones, two in number, are 6 inches long, by about 2½ inches wide. Another one in the same collection, 7½ inches long, and 2 inches wide, marked "P. Pinsapo, from Ronda in Spain," belongs to the same species, viz., lasiocarpa, Hook.

This species is probably A. amabilis (Forbes), Bertrand, which Bertrand says does not differ anatomically from A. Fraseri.

8. *Pinus* (*Abies*) *Fraseri*, Pursh, Fl. Bor. Amer. 2, p. 639; Parlatore, D. C. Prod., xvi., pars 2, p. 419, No. 90.

Shoots hairy, the surface broken and uneven from the presence of resin-canals. Leaves inserted singly all round the stem, bent at base so as to be irregularly two-rowed, a few of the leaves directed upwards. Leaf linear, bent at the base or straight, short, leathery, apex obtuse or emarginate, upper surface deep green with several rows of stomata in the central furrow, beneath with a band of stomata on each side of the midrib, there being from 8 to 9 rows of stomata in each band. Leaves about ½ inch in length, and about $\frac{1}{12}$ inch wide. Buds large, covered with yellowish-brown resinous scales.

Transverse section of leaf.—Leaf flattened, three times broader than thick, sides rounded, upper surface with a well-marked central groove, below with a distinct but not very prominent midrib. Hypoderma moderately developed, irregularly scattered below superior epidermis and forming a very much interrupted layer, the layer continuous at the rounded margins, one, rarely two, cells thick; a layer of hypoderm below at the midrib forming a single layer of cells with a few scattered here and there forming a double row. The resin-canals are placed in the parenchyma of the leaf, and separated from the inferior epidermis by many layers of chlorophyll-bearing cells. The pallisade parenchyma is developed at each side of the groove above, but is defective where the stomata are present.

Fibro-vascular bundle double, surrounded by a well-marked sheath.

The figure (Plate 47, fig. 10) is drawn from a specimen supplied to me by Mr. Fowler, gardener, Castle Kennedy, N. B.

I have examined four specimens of this species, only one of which is from a cultivated specimen. There is a cone 2¼ inches long by 1 broad, in the Museum, Royal Botanic Garden, Edinburgh, ripened at Castle Kennedy, but it has no leaves. The other three specimens I have examined are from Kew Herbarium. The first is from the summit of the Hoosack Mountains, Massachusetts—Pinus Fraseri, Pursh. The second is marked "P. balsamea. Canada, P. Fraseri;" the third, "Pinus americanus, Newfoundland. Herb. Forsyth." About the two last I am rather doubtful, as I find it very difficult to separate Fraseri and balsamea by anatomical characters only.

9. *Pinus* (*Abies*) *balsamea*, Linn. Sp. Pl. p. 1421; Parlatore, D. C. Prod. vol. xvi. pars 2, p. 423, No. 95.

Shoots hairy, the surface broken and uneven from the presence of resin-canals. Leaves inserted singly all round the stem, but bent so as to form two lateral rows, a few being directed upwards. Leaf linear, twisted at the base, which is narrowed towards the orbicular insertion, apex emarginate, upper surface dark green, with two or more rows of stomata in the middle line near the apex, beneath with a band of stomata on each side of the midrib, there being about ten rows of stomata in each band. Leaves from ½ to ¾ inch long, and about

$\frac{1}{12}$ inch wide. Buds covered with brownish scales, which are very resinous.

Transverse section of leaf.—Leaf flattened, about three times broader than thick, sides rounded, upper surface with a faint longitudinal furrow, below with a slightly prominent midrib. Hypoderma wanting; very rarely there are one or two cells at the rounded margin, and one or two below the fibro-vascular bundles. The resin-canals are placed in the parenchyma of the leaf, and although sometimes running very near the lower surface, are always separated from the epidermis by chlorophyll-bearing cells. The pallisade parenchyma is well developed on the upper side, as the stomata rarely extend down the leaf for any distance, although occasionally a single row may run for about two-thirds of the length; below, the parenchyma has intercellular spaces communicating with the stomata.

The fibro-vascular bundle is double, the whole surrounded by a well-marked sheath.

The figure (Plate 47, fig. 11) is drawn from a specimen grown in the Royal Botanic Garden, Edinburgh.

I have examined five specimens of this species: one specimen grown in the Royal Botanic Garden, Edinburgh; one from Mr. Syme, Elvaston Nurseries; two specimens are from Kew Herbarium—one marked "P. balsamea. Canada, Mr. Perceval;" the other, "P. balsamea, L. Gonan;" the fifth specimen is from the Museum, Royal Botanic Garden, Edinburgh. The leaves examined are from the base of a cluster of cones, and are very interesting, as having a considerable quantity of hypoderm developed. Like P. lasiocarpa, this species is bifolious, and the leaves resemble those of P. Fraseri. Indeed, I find it very difficult to separate the two forms, viz., Fraseri and balsamea, by characters derived from the structure of the leaf.

10. *Pinus* (*Abies*) *sibirica*, Turcz., Cat. Baekal, No. 1067; Parlatore, D. C. Prod. vol. xvi. pars 2, p. 425, No. 101. *Abies sibirica*, Ledeb. Fl. Alt. 4, p. 202. *Picea Pichta*, Loud. Arbor. Brit. 4, 2338. *Abies Pichta*, Forbes, Pin. Wob. 109, t. 37.

Shoots hairy or smooth. Leaves inserted singly and close together all round the shoot, those on the under side bent to form two lateral rows, those on the upper side directed with their points upwards and forwards towards apex of the shoot. Leaf linear, twisted above the base, which is slightly narrowed towards the orbicular insertion, width nearly uniform throughout the entire length, apex rounded or slightly truncate, upper surface dark green, with no stomata, beneath with a band of stomata on each side of the midrib, there being from 4 to 5 rows in each band. Leaves from $\frac{1}{2}$ to $1\frac{1}{2}$ inch long, and about $\frac{1}{12}$ inch wide. Buds brownish, and very resinous.

Transverse section of leaf.—Leaf flattened, about three times as broad as thick, sides rounded, upper surface with a slight longitudinal furrow, below with a very faintly prominent midrib. Hypoderma entirely absent. The resin-canals are placed in the parenchyma of the leaf, sometimes, however, rather low, but always separated by chlorophyll-bearing cells from the lower epidermis. Pallisade tissue well developed under superior epidermis, the parenchyma with intercellular spaces communicating with the stomata, well developed below.

Fibro-vascular bundle double, with one or two thickened cells above and below, the whole surrounded by a well-marked sheath.

The figure (Plate 47, fig. 12) is drawn from a plant cultivated in Glasnevin Garden, and kindly supplied to me by Dr. Moore.

This species is cultivated in the Botanic Garden, Glasnevin, and in the Royal Botanic Garden, Edinburgh, under the name of Pichta. I have also received it from Mr. Syme, of Elvaston Nurseries, correctly named sibirica. In Mr. Syme's specimen a single thick hypoderm cell was noticed in one leaf under the epidermis covering the midrib below.

11. (*Pinus Abies*) *Veitchii*. *Picea Veitchii*, Lindley, Gard. Chron., Jan. 1861. *Abies Veitchii*, A. Murray, Sketch of Conif. of Japan, p. 39. *Pinus selenolepis*, Parlatore, D. C. Prod. xvi., p. 427, No. 105.

Shoots and arrangement of leaves not observed. Leaf flat, linear, grooved on upper side, apex obtuse and emarginate, above glaucous green, with no stomata, below with two bands of stomata on each side of the midrib, there being from 6 to 7 rows of stomata in each band. Leaf from ½ to 1 inch long, and about $\frac{1}{16}$ inch broad.

Transverse section of leaf.—Leaf flattened, about three times as broad as thick, sides rounded, upper surface with a longitudinal furrow, below with a slightly prominent midrib. Hypoderma only slightly developed, a few cells being placed above and below, touching the epidermis in the middle line. No hypoderm, or rarely a single thickened cell, at the rounded margin of the leaf. The resin-canals are placed in the middle of the parenchyma. The pallisade parenchyma is well developed above, and the parenchyma with intercellular spaces below.

The fibro-vascular bundle is double, the tissue between the bundles and the well-developed sheath being thickened.

The figure (Plate 47, fig. 13) is drawn from a dried specimen in Kew Herbarium.

This species does not seem to be in cultivation, and the only specimen known to me is that in Kew Herbarium. The single specimen has two labels, viz.:—"No. 946. Abies microsperma. From Fusi Yami. 2/63. Yokohama;" and "813. Picea Veitchii, Ldl. Oldham legit."

It is undoubtedly the Abies Veitchii of description, and is perfectly distinct from Abies Veitchii of gardens.

12. *Pinus* (*Abies*) *firma*, Antoine, Conif. 70, tab. 27, *bis*. *Abies firma*, Siebold and Zuccarini, Flora Japon. ii., 15, tab. 107 (not Parlatore). *Abies homolepis* (?), Sieb. and Zucc., Flora Jap., ii., 17, t. 108. *Abies brachyphylla*, Maxim. Pl. exsicc. *Pinus brachyphylla*, Parl., D. C. Prod. xvi., 2., p. 424.

Shoots hairy or smooth. Leaves inserted singly all round the stem, but bent so as to form two lateral rows. Leaf linear, twisted above the base, which is slightly narrowed towards the orbicular insertion, width tolerably uniform, or slightly greater towards the apex, which is rounded and emarginate, upper surface green, occasionally with a few stomata in a patch near the apex, but generally without stomata, beneath with a band of stomata on each side of the prominent midrib, there being from 10 to 11 rows of stomata in each band. Leaf from ½ to 1¼ inch in length, and about $\frac{1}{10}$ inch wide. Buds ?

Transverse section of leaf.—Leaf flattened, three times as broad as thick, sides rounded, upper surface convex, with a well-marked central furrow, below with a prominent midrib. Hypoderma well developed, forming a continuous layer extending all round the leaf, except where the two bands of stomata occur on the lower surface on each side of the midrib. The resin-canals are placed, one at each side of the leaf, in the parenchyma of the leaf, and separated from the lower epidermis by many chlorophyll-bearing cells. The pallisade parenchyma is well developed on the upper side, and below is the parenchyma with well-marked intercellular spaces communicating with the stomata.

Fibro-vascular bundle double, the two parts placed rather close together, and having a number of very thick liber-like cells below. The whole is surrounded by a well-marked sheath.

The figure (Plate 47, fig. 14) is drawn from a specimen from Kew Herbarium, and is not yet in cultivation as far as I can learn.

I have only seen three specimens of this species, all of which are in the Kew Herbarium, and I am indebted to Dr. Hooker and Prof. Oliver for leave to examine them. The first is marked "812. Abies firma, S. & Z. Nagasaki, Japan, 1862. Oldham." The second, from which the figure is drawn, has the label, "Ex herb. Hort. Bot. Petropol. Maximiowicz, iter secundum. Abies firma, S. & Z. Japonia, Nippon, 1864." The third specimen is that with the label, "Ex herb. Hort. Bot. Petropol. Maximiowicz, iter secundum. Abies brachyphylla, Maxim. Japonia, Yokohama, 1862."

Very much confusion exists regarding this and the next species (P. bifida). All the examples cultivated under the name of firma that I have yet seen are bifida. As the specimen marked "brachyphylla" in Kew Herbarium is authentic, it will be seen that the species described by Maximiowicz, and adopted by Parlatore, must sink as a synonym of firma, Sieb. and Zucc., if the plant here noticed be Siebold and Zuccarini's species. Bertrand correctly gives the characters of Abies firma as here defined. Mr. Andrew Murray (Conifers of Japan, p. 53) mixes up firma and bifida; but his figures 98 and 99 would certainly apply very well to firma, and fig. 108 to bifida.

Koch (Dendrologie, vol. 2, pt. 2, page 227) adopts Mr. Murray's view of the identity of firma and bifida, but adopts the name of Abies Momi, Sieb., for the united forms. As the species are markedly distinct, anatomically, I have no hesitation in separating them; and at the same time, as I cannot find the slightest difference to exist between firma and brachyphylla, I have as little hesitation in uniting them.

13. *Pinus* (*Abies*) *bifida*, Ant. Conif. p. 79, t. 31, f. 2. *Abies bifida*, Sieb. and Zucc., Flor. Japon., 2, p. 18, t. 109. *Abies firma*, A. Murray, Conif. of Japan, p. 53.

Shoots hairy or smooth. Leaves inserted singly all round the stem, but bent so as to form two lateral rows, rarely a few pointing downwards or upwards. Leaf linear, twisted above the base which is slightly narrowed towards the orbicular insertion, then gradually tapering, with a bifid apex, the two portions being very acute; upper surface bright green, with no stomata, beneath with a band of stomata on each side of the midrib, there being from 10 to 12 rows in each band. Leaves varying in length from $\frac{1}{2}$ to $1\frac{1}{2}$ inch, about $\frac{1}{10}$ inch wide at widest part. Buds covered with brownish scales, which are resinous.

Transverse section of leaf.—Leaf flattened, $3\frac{1}{2}$ times as broad as thick, sides with a rather acute lateral margin; upper surface convex, with a central longitudinal furrow, midrib not prominent below. Hypoderma well developed, forming a slightly interrupted row of cells running from the margin of the resin-canal of one side to the margin of the resin-canal of the other side; the hypoderm is also developed under the epidermis covering the midrib. The resin-canals are placed, one at each side of the leaf, generally quite close to the epidermis of the under side of the leaf, but in the same leaf the resin-canal may become small, and be separated from the epidermis by one or two chlorophyll-bearing cells. The ground parenchyma of the leaf is distinguished by the occurrence of numerous large thickened prosenchymatous cells or idioblasts, which are unbranched, and have their long axes parallel to the long axis of the leaf. These idioblasts are a special peculiarity of this species, and are called pseudo-liber fibres by Bertrand. The pallisade tissue is well developed on the upper side, and below is the parenchyma with well-marked intercellular spaces communicating with the stomata.

Fibro-vascular bundle double, the parts placed close together, with several thickened liber-like cells, sometimes above and always below the bundles, the whole surrounded by a sheath.

The figure (Plate 47, fig. 15) is drawn from a specimen supplied to me by Messrs. Veitch & Sons, Chelsea, under the name of Abies firma.

I have examined five specimens of this, all presenting the marked characteristics of the species. There is a specimen in Kew Herbarium, marked A. bifida, Sieb. and Zucc., which is the same as this, but I have not examined it microscopically. It is cultivated in the Royal Botanic Garden, Edinburgh, under the correct name of P. bifida, and there is another plant, differing only in the smaller size of the leaves, which my father sent as P. sp., Japan. It is the species cultivated in gardens and nurseries as Abies firma, and under that name I have received it from Messrs. Veitch, and Mr. Fowler of Castle Kennedy. Mr. Fowler sends two forms—one marked by him as a late variety; anatomically they are the same, except that the late variety shows great irregularity in the size and position of the resin-canals, being normal, in the lower half of the leaf, but in the parenchyma, near the apex.

This species can at once be separated from firma by the presence of the remarkable idioblasts as well as by the margin and apex of the leaf.

Abies homolepis, Sieb. and Zucc., I have not seen, but from Bertrand's description of the leaf I would consider it a synonym of A. firma.

Pinus holophylla, Parlatore; Abies holophylla, Maxim., is also unknown to me except by Parlatore's description in D. C. Prod., vol. xvi., pt. 2, p. 424. It is from Mandschuria.

14. *Pinus* (*Abies*) *Harryana*, n. sp. *Abies Veitchii*, Hort, *not* descr.

Shoots smooth. Leaves inserted singly all round the stem, but bent so as to form two lateral rows, a few projecting upwards and downwards. Leaf linear, twisted above the base, widest above the twist, getting gradually narrower, then suddenly contracting near the apex into a sharp, simple, or bifid point; upper surface bright green, without stomata except in a few rare cases where a small cluster of three or four occur near the apex, beneath with a band of stomata on each side of the midrib, there being from 7 to 8 rows of stomata in each band. Leaves from $\frac{1}{2}$ to $1\frac{1}{4}$ inch long, and about $\frac{1}{12}$ inch wide. Buds covered with pale brown very resinous scales.

Transverse section of leaf.—Leaf flattened, about $3\frac{1}{2}$ times as broad as thick, sides rounded, upper surface with a longitudinal furrow, below with a slightly prominent midrib. Hypoderma well developed, forming a slightly interrupted band, extending from the anterior side of the resin-canal of the one side, under the epidermis of the upper side of the leaf, to the side of the resin-canal of the other side; the hypoderma is also developed under the epidermis of the midrib. The resin-canals are placed, one at each side of the leaf, close to the lower epidermis. The pallisade tissue is well developed on the upper side, and below is parenchyma with well-marked intercellular spaces communicating with the stomata.

Fibro-vascular bundle double, the parts placed very close together, and having a large number of bast fibres below; the fibro-vascular bundles and the bast fibres surrounded by a well-marked sheath.

The figure (Plate 47, fig. 16) is drawn from a specimen kindly supplied to me by Messrs. Veitch and Sons, Royal Exotic Nursery, Chelsea, London.

This sharp-leaved form can be at once distinguished from the obtuse emarginate-leaved A. Veitchii. Then their anatomical characters are remarkably distinct. Veitchii in the Kew Herbarium has the resin-canals in the parenchyma of the leaf, and possesses very little hypoderm. The same characters are given by Bertrand for Veitchii, so that there can be no doubt that we have both had the same plant under examination. The Veitchii from Veitch's Nursery; Royal Botanic Garden, Edinburgh; Mr. Syme, Elvaston Nurseries; and the Lawson Nursery Co. (Limited), Edinburgh, is quite distinct, having the resin-canals, close to the lower epidermis, and the hypoderm well developed. In the absence of sufficient materials for description, as the cone remains unknown, I would provisionally name it Pinus Harryana, after Mr. Harry Veitch, the head of the firm of Veitch & Sons.

The leaves of this species rather closely resemble in general form and appearance those of Pinus (Pseudotsuga) Fortunei, Murray, and it seems not improbable that it may have been confounded with that plant under the name of Jezoensis. It is a Japanese species, but is not A. Jezoensis, Sieb. et Zucc., to judge from the figure.

15. *Pinus* (*Abies*) *Pindrow*, Royle, Himal. p. 354, t. 86; Parlatore, D. C. Prod. vol. xvi. pars 2, p. 424, No. 99. *Abies Pindrow*, Spach, Hist. Nat. d. Veg. Phan. xi. p. 423. *Picea Pindrow*, Loud., Arb. Brit. iv., 2346.

Shoots hairy or smooth. Leaves inserted singly all round the stem, but bent so as to form two lateral rows, a few directed upwards and downwards. Leaf long and linear, twisted above the base, narrowed towards the orbicular insertion, width uniform, the apex bifid, with two narrow sharp points, upper surface deep green with no stomata, beneath with a more or less conspicuous band of stomata on each side of the midrib, there being from 7 to 8 rows in each band. Leaves from 1 to 2½ inches long, and about $\frac{1}{12}$ inch wide. Buds resinous, covered with brownish scales.

Transverse section of leaf.—Leaf flattened, four times as broad as thick, sides rounded, upper surface with a slightly marked longitudinal furrow, midrib not prominent below. Hypoderma well developed, forming a continuous, or very nearly continuous, band from the resin-canal of one side, under the epidermis of the upper surface, to the resin-canal of the other side; the hypoderma is also developed below the fibro-vascular bundles. The resin-canals are placed, one at each side of the leaf, close to the epidermis of the under side. The pallisade parenchyma is well developed on the upper side, and below is the parenchyma with well-marked intercellular spaces communicating with the stomata.

Fibro-vascular bundle double, the parts rather widely separated, a few thick cells developed both above and below; the whole surrounded by a well-marked sheath.

The figure (Plate 47, fig. 17) is drawn from a specimen kindly supplied to me by Dr. Moore, and cultivated in Glasnevin Garden.

Mr. Syme, of Elvaston Nurseries, has directed my attention to the fact that this species has the shoots either hairy or smooth, both in young and old plants.

Bertrand (*loc. cit.* p. 89) says that Pindrow has "Très-peu d'hypoderma;" this I have only found in exceedingly young leaves, all others examined by me having abundance of hypoderm. He seems to have confused the species from the Himalayas, because he says, p. 91, "A. Webbiana, Lind., ne diffère pas anatomiquement de l'A. Pindrow, Spach," in which statement I cannot concur.

16. *Pinus* (*Abies*) *Webbiana*, Wall, MSS.; Parlatore, D. C. Prod. xvi. pars 2, p. 425, No. 100. *Pinus spectabilis*, Lamb., Pin. ed. 2, vol. 2, p. 3, t. 2. *Abies Webbiana*, Spach. *Picea Webbiana*, Loudon, Arb. Brit. iv. p. 2346.

Shoots hairy or smooth. Leaves inserted singly all round the stem, but directed chiefly towards the two sides, those on the upper side with their points directed towards the apex of the shoot, and nearly parallel to its axis. Leaf long, linear, twisted more or less according to its position on the shoot, base narrowed towards the orbicular insertion. Breadth of leaf uniform through most of its length, slightly contracted near the bifid apex, the two portions being small and very sharp, or slightly rounded; upper surface dark green, with no stomata, beneath with a band of stomata on each side of the midrib, there being from 8 to 10 rows in each band. Leaves from 1 to 2½ inches long, and about $\frac{1}{10}$ inch wide. Buds brownish and resinous.

Transverse section of leaf.—Leaf about four times as broad as thick, sides with a well-marked lateral line, upper surface convex, with a well-marked longitudinal furrow, below with a slightly prominent midrib. Hypoderma rather well developed, forming an interrupted band running from the resin-canal of one side, under epidermis of upper surface, to the resin-canal of the other side; the hypoderm is also developed under the epidermis of the slightly prominent midrib. The resin-canals are placed, one at each side of the leaf, close to the epidermis of the under surface. The pallisade tissue is well developed on the upper side, and below is the parenchyma with well-marked intercellular spaces communicating with the stomata.

Fibro-vascular bundle double, with thick cells above and below, the whole surrounded by a well-marked sheath.

The figure (Plate 48, fig. 18) is drawn from a specimen cultivated at Glasnevin Garden, and kindly supplied to me by Dr. Moore.

This species, like A. Pindrow, has the shoots either glabrous or hairy when young or old, and I am again indebted to Mr. Syme, of Elvaston, for specimens showing this. In young plants the hypoderm is only very feebly developed, but the form of the section of the leaf at once separates it from Pindrow.

Mr. Syme sent a specimen under the name of Picea Webbiana ovata, which I cannot separate anatomically from the type.

There is a specimen in the Museum, Royal Botanic Garden, Edinburgh, of cone and leaves from Castle Martyr, Co. Cork. The cone is about 6 inches long by 2½ inches broad. On examining the leaves attached to the shoot, they are found to have the same anatomical characters as those already described. In the same Museum are two other cones without leaves—one from Castle Martyr measuring 7 inches by 2½ inches, and the other from Holkam Hall, which only measures 5½ inches in length by 2½ inches in breadth.

17. *Pinus* (*Abies*), sp. nov. (?)

I have met with two specimens of a pine closely related to Pindrow and Webbiana, which on further investigation may turn out to be new. The first specimen was noticed while examining the specimens in the Herbarium of Trinity College, Dublin. It was marked, "Abies Webbiana, Himalaya occid., 9,000 to 12,000, Hook. fil. et Thomson." The leaves are 1½ to 2 inches in length, and only very slightly notched at the apex. The second specimen was met with in the Museum, Royal Botanic Garden, Edinburgh. It was a fine cone-bearing shoot, with leaves, and had been grown at Castle Kennedy, in Scotland. The cone measures 2½ inches by 2, and the leaves are long and narrow, 2 inches long in most cases, from $\frac{1}{15}$ to $\frac{1}{10}$ inch wide, and only slightly notched at the apex.

Transverse section of leaf.—Leaf flattened, about four times as broad as thick, sides rounded, upper surface with a slightly-marked longitudinal furrow, below with a scarcely prominent midrib. Hypoderma well developed, forming a continuous (Castle Kennedy specimen) or slightly interrupted (Himalayan specimen) band running all round the leaf, except where the stomata are developed in a band on each side of the midrib. The resin-canals are in the parenchyma of the leaf, and separated from the lower epidermis by several chlorophyll-bearing cells. The pallisade parenchyma is well developed on the upper side, there being no stomata on the upper epidermis, and below is the parenchyma with intercellular spaces communicating with the stomata, of which there are about 10 rows in each of the bands.

Fibro-vascular bundle double, with thickened cells above and below, the whole surrounded by a well-marked sheath.

The figure (Pl. 48, fig. 19) is drawn from the Himalayan specimen, which is smaller, and possesses less hypoderm than the specimen from Castle Kennedy.

The cone is small, in this resembling Pindrow, but as it was unbroken the bracts could not be described.

Although I have examined eleven different cultivated specimens of Webbiana and Pindrow, I have only met with this one new form from Castle Kennedy, so that it must be very rare in our gardens and nurseries.

I abstain from giving this a name, as the synonymy of the group is obscure, and already several different names have been given to supposed species.

18. *Pinus* (*Abies*) *pectinata*, Lam. Fl. Franç., ii., 202 (1778). *Pinus Abies*, Duroi, Obs. Bot., p. 39; Parlatore, D.C. Prod. vol. xvi. p. 420, No. 92 (in part). *Pinus Picea*, Linn. Sp. Plant. ii., 1001 (1753). *Abies Picea*, Koch, Dendrologie, vol. ii., pt. ii., p. 217.

Shoots hairy. Leaves inserted singly all round the stem, the lower ones bent to form two lateral rows, those on the upper side more or less spreading, and bent at the base so as to bring the superior surface upwards, the inferior surface being next the axis. Leaf linear, more or less twisted above the base according to the position on the stem, apex rounded or emarginate, upper surface shining dark green with no stomata, below with a band of stomata on each side of the slightly prominent midrib, there being 7 or 8 rows of stomata in each band. Leaves about $\frac{3}{4}$ to 1 inch in length, and $\frac{1}{12}$ inch wide. Buds covered with slightly resinous brown scales.

Transverse section of leaf.—Leaf flattened, about $2\frac{1}{2}$ times broader than thick, sides rounded, the leaf becoming markedly thinner towards the margins, upper surface with a longitudinal furrow, below with a slightly prominent midrib. Hypoderma well developed, a slightly interrupted row of cells running from near the resin-canal of one side to near the resin-canal of the other side. The hypoderm is also developed below the epidermis of the midrib. Resin-canals placed, one on each side of the leaf in the parenchyma, and separated from the lower epidermis by layers of chlorophyll-bearing cells. Pallisade tissue well developed on upper side, the parenchyma below with intercellular spaces communicating with the stomata.

Fibro-vascular bundle double, the parts placed rather close together, the whole surrounded by a sheath.

The figure (Plate 48, fig. 20) is drawn from a specimen from Glasnevin Garden, kindly given to me by Dr. Moore.

Bertrand (*op. cit.* p. 90) places A. pectinata in the group with the resin-canals touching the lower epidermis, and adds that Nordmanniana appears to be little different from A. pectinata. All the specimens of A. pectinata that I have examined have the resin-canals in the parenchyma of the leaf, so that I conclude that the A. pectinata examined by Bertrand was a variety of A. Nordmanniana.

All the specimens examined by me have the resin-canals in the parenchyma of the leaf, and have the hypoderm well developed; the quantity of hypoderm varies, and is least developed in the plant growing in the Botanic Garden, Glasnevin. This very interesting tree was raised from seed by Dr. Moore, the seed having been received from the Himalayas, and transmitted to Dr. Moore by the East India Company. The leaves of this plant are wider, and have a sharper or less rounded margin than the typical form; and this, taken along with the feebler development of the hypoderm, might warrant the separation of the plant under the name of variety Mooreana. (Pl. 48, fig. 21).

The leaves from a cone-bearing shoot in the Museum, Royal Botanic Garden, Edinburgh, were examined, and found to have a more tetragonal form, there being no longitudinal furrow visible. The leaves, therefore, seem to me inclined to be of two shapes, thus resembling bifolia, Murray (lasiocarpa, Hooker).

Specimens from Edinburgh, Glasnevin, and Cirencester, have been examined, but no dried specimens from native habitats.

19. *Pinus* (*Abies*) *Nordmanniana*, Stev., Bull. de la Soc. d. Nat. de Mosc., xi. 45 (1838). *Pinus Abies*, Duroi; Parlatore, D.C. Prod. vol. xvi., p. 421, No. 92 (in part).

Shoots hairy or smooth. Leaves inserted singly all round the stem, those below bent so as to form two lateral rows, those above directed more or less upwards, and twisted at the base so as to bring the upper surface of the leaf superiorly. Leaf linear, more or less twisted at base, apex emarginate, upper surface yellowish green, with no stomata, beneath with a band of stomata on each side of the slightly prominent midrib, there being from 8 to 9 rows of stomata in each band. Leaves from 1 inch to $1\frac{1}{4}$ inch in length, and about $\frac{1}{12}$ inch wide. Buds covered with reddish-brown resinous scales.

Transverse section of leaf.—Leaf flattened, three times broader than thick, sides rounded, upper surface only faintly grooved, below with a scarcely prominent midrib. Hypoderma well developed, forming a slightly interrupted band, running from the resin-canal of one side, under the upper epidermis, to the resin-canal of the other side. The hypoderm is also developed under the epidermis covering the midrib. The resin-canals are placed at each side of the leaf, close to the under surface, and separated from the epidermis by a single layer of cells. The pallisade tissue is well developed above, and below is the parenchyma with intercellular spaces.

Fibro-vascular bundle double; parts placed close together, and having a well-marked sheath.

The figure (Plate 48, fig. 22) is drawn from a specimen from Glasnevin, given to me by Dr. Moore.

The difference in the position of the resin-canals at once separates Nordmanniana from pectinata; the shape of the leaf and the arrangement of the hypoderma being similar. Plants from Edinburgh, Glasnevin, and Cirencester have been examined, but none from native habitats. The leaves on the cone-bearing shoot differ from those on the ordinary branches only in having the midrib slightly more prominent.

20. *Pinus* (*Abies*) *cilicica*, Kotschy, in Osterr. Bot. Wochenblatt, iii., 409 (1853); Parlatore, D. C. Prod. xvi., p. 422, No. 93.

Shoots hairy or smooth. Leaves inserted singly all round the stem, but bent so as to form two lateral rows; several point upwards, and very few are directed downwards. Leaves linear, twisted above the base, especially in those leaves on the upper part of the shoot which are turned so as to have the superior surface upwards, apex obtuse and emarginate, upper surface green, with no stomata, beneath with a band of stomata on each side of the midrib, there being from 7 to 8 rows of stomata in each band. Leaves from 1 to 1¼ inch in length, and about $\frac{1}{12}$ inch wide. Buds covered with yellowish-brown resinous scales.

Transverse section of leaf.—Leaf flattened, about 3½ times as broad as thick, sides rounded, upper surface with a very slightly marked longitudinal furrow, below without a prominent midrib. Hypoderma conspicuous, forming a single, more or less interrupted layer, running from the resin-canal of one side, under the epidermis of the upper side of the leaf, to the resin-canal of the other side; there is also a small row beneath the epidermis in the middle line below. The resin-canals are placed, one on each side of the leaf, near the margin and close to the epidermis of the under side of the leaf. The pallisade tissue is well developed on the upper side of the leaf, while below is the parenchyma, with intercellular spaces communicating with the stomata.

Fibro-vascular bundle double, the whole surrounded by a well-marked sheath.

The figure (Plate 48, fig. 23) is drawn from an original specimen of Kotschy's, No. 370, in the Herbarium of Trinity College, Dublin, kindly given to me for examination by Professor Perceval Wright, M.D.

I have only examined three specimens of this pine—one from Mr. Syme, of Elvaston Nurseries; one from Glasnevin; and the third from Trinity College, Dublin, Herbarium, collected by Kotschy in Syria: "in regionibus Daniæ, supra Eden, alt. 5000. Die 28 Jul. 1855." Anatomically it is the same as P. Nordmanniana; but I have not seen the cones, and so cannot give any definite opinion as to its distinctness. Bertrand * says of this species: "Pas d'hypoderm sous l'épiderme supérieur." In all my specimens the hypoderm is well developed, so that probably Bertrand has made some mistake.

There is a cone in the Museum, Royal Botanic Garden, Edinburgh, measuring 6 inches by 2 inches, and marked "Abies cilicica. Crimea, P. Lawson & Sons, 1856." It has no leaves, but after most careful examination I have no hesitation in referring the cone to Abies bifolia, Murray,—the P. lasiocarpa, Hooker.

21. *Pinus* (*Abies*) *cephalonica*. Endl., Cat. Hort. Acad. Vindob. i., 218. *Pinus* (*Abies*) *β. cephalonica*, Parl., D. C. Prod. xvi., 2, p. 422, No. 92. *Abies cephalonica*, Link., Linnæa, 15, p. 529. *Picea cephalonica*, Loudon, Encyc. Trees, 1039.

Shoots smooth. Leaves inserted singly all round the stem, but bent so as to form two lateral rows, many pointing upwards, very few projecting downwards; the leaves at the sides of the shoot are twisted at the base; those above and below are not, or only very

* Anat. Comp. des Gnét. et Conif. p. 89.

slightly, twisted. Leaf linear, narrow at base, widest above base, contracting gradually towards the apex, and then suddenly narrowing with a sharp point; upper surface dark shining green, generally with no stomata, but occasionally with a partial row near the apex of the leaf in the middle line, below with a band of stomata on each side of the midrib, there being from 6 to 7 rows in each band. Leaves about 1 inch in length, and about $\frac{1}{12}$ inch wide. Buds covered with yellowish-brown resinous scales.

Transverse section of leaf.—Leaf flattened, about three times broader than thick, sides rounded, upper surface nearly flat or gently curved inwards, below with a slightly prominent midrib. Hypoderma well developed, forming a continuous layer from the resin-canal of one side, under the upper epidermis, to the resin-canal of the other side; at the margins the hypoderm is greatly developed, being generally three cells thick, a double layer of hypoderm below the double fibro-vascular bundle. The resin-canals are placed at each side of the leaf, close to the epidermis of the under side. The pallisade parenchyma is well developed on the upper side, while below is the parenchyma with intercellular spaces communicating with the stomata.

Fibro-vascular bundle double, the whole surrounded by a well-marked sheath.

The figure (Plate 48, fig. 24) is drawn from a specimen grown in Glasnevin Garden, and kindly given to me by Dr. Moore.

A plant growing in the Botanic Garden, at the Agricultural College, Cirencester, had an incomplete row of stomata on the upper side of the leaf.

Specimens from Glasnevin, Edinburgh, and Cirencester have been examined. One from the Museum, Royal Botanic Garden, Edinburgh, has cones; and the leaves from the cone-bearing shoots do not differ from those on the ordinary branches, except that the leaf is, at the apex, slightly bevelled off from behind, and there are a few stomata near the apex.

The forms described as Abies Reginæ Ameliæ, Heldr., and Abies Apollinis, Link., have been examined. According to Mr. Andrew Murray (Lawson's "Pinetum," part v.), Reginæ Ameliæ is a variety of Abies Apollinis, which he makes a species distinct from A. cephalonica. Mr. Murray says of Reginæ Ameliæ, "foliis crassis, sub-acuminatis;" but I cannot observe any difference between the leaves of this form and P. cephalonica except that the hypoderma is less developed. The leaves of a cone-bearing shoot of cephalonica are like those figured by Mr. Murray (Lawson, "Pinetum," part v., fig. 1) for Apollinis, while the leaves of the plant cultivated in the Royal Botanic Garden, Edinburgh, differ only in having the margin less rounded, and having a slightly developed longitudinal furrow above.

Mr. Murray (Pinet. Brit., part iii.) gives figures of P. Panachaica, Heldr., and reduces that species to P. cephalonica. From an examination of Mr. Murray's figures, and of recent specimens, I have no hesitation in reducing A. Reginæ Ameliæ, Heldr., and A. Panachaica, Heldr., to cephalonica, while Apollinis may rank as a variety, bridging over the space between P. cephalonica and P. Nordmanniana. A section of the leaf of A. Apollinis is figured (Plate 48, fig. 25).

22. *Pinus* (*Abies*) *Pinsapo*, Boiss.; Parlatore, D. C. Prod. xvi., p. 422, No. 94 (in part). *Abies Pinsapo*, Boissier, Elench. Pl. Nov. Hisp. p. 84. *Picea Pinsapo*, Loud. Encycl. of Trees, 1041.

Shoots smooth. Leaves inserted singly all round the stem, and projecting nearly straight out in all directions from the shoot, but fewer below than on the upper surface. Leaf linear, short, rigid, scarcely twisted above the large orbicular base. Leaf narrowed above insertion, then widening to its full extent and gradually narrowing towards the elongated sharp-pointed apex; upper surface green, with rows of stomata generally about 6 or 8 in number, and placed rather distantly over the whole upper surface, below with a band of stomata on each side of the midrib, there being about 6 or 7 rows in each band. Leaf from $\frac{1}{2}$ to $\frac{3}{4}$ inch long, and about $\frac{1}{10}$ inch wide. Buds covered with brownish scales, and very resinous.

Transverse section of leaf.—Leaf flattened, but rather tetragonal, only about twice as broad as thick, sides rounded, upper surface convex, below with a prominent midrib. Hypoderma chiefly developed at the margins of the leaf, and above and below the midrib; very much interrupted by the arrangement of the stomata. The resin-canals are placed, one at each side of the leaf, near the margin close to the lower epidermis, but separated from it by a single layer of hypoderm cells. The pallisade tissue is much interrupted on the upper side, and below is the parenchyma with intercellular spaces communicating with the stomata.

Fibro-vascular bundle double, the whole surrounded by a well-marked sheath.

The figure (Plate 48, fig. 26) is drawn from a specimen supplied to me by Dr. Moore, and grown at Glasnevin.

I have only examined three plants of this species—two from Glasnevin and one from Cirencester. Bertrand places this species in his second section, but I have never found the resin-canals in the parenchyma of the leaf. In the Museum, Royal Botanic Garden, Edinburgh, there is a cone measuring $7\frac{1}{2}$ inches by 2 inches, and to which one or two leaves were attached. It is marked "Picea Pinsapo. From Ronda, in Spain. Mr. Robertson, Trinity, 1859." After the most careful examination, I refer it to Abies bifolia, Murray—the P. lasiocarpa of Hooker.

23. *Pinus* (*Abies*) *Baborensis*, Cosson. *Abies Pinsapo Baborensis*, Cosson, Bull. de la Soc. Bot. de France, viii. 607. *Abies numidica*, De Lannoy, Rev. Hort. (1866), 106 and 168. *Pinus Pinsapo*, Parlatore, in part.

Shoots hairy. Leaves inserted singly all round the stem, but bent so as to form two lateral rows, a few projecting upwards, the base of the leaves on the upper side of the shoot twisted. Leaf linear, base much smaller than in Pinsapo, rapidly widening to its full extent, then contracting rapidly near the blunt or emarginate apex; upper surface dark green, with a few stomata in one or two short rows near the apex of the leaf in the middle line, below with two bands of stomata on each side of the midrib, there being from 7 to 8 rows in each band. Leaves $\frac{1}{2}$ to $\frac{3}{4}$ inch in length, and about $\frac{1}{12}$ inch wide. Buds covered with yellowish-brown resinous scales.

Transverse section of leaf.—Leaf flattened, about $3\frac{1}{2}$ times as broad as thick, sides rather sharp, upper surface slightly convex, with a faint longitudinal furrow, below with a slightly marked midrib. Hypoderma chiefly developed at the margins of the leaf, there being only about a dozen thickened cells placed externally to the resin-canal, and a few scattered hypoderm cells under the upper epidermis, and a few in the middle line below resin-canals, near the margins of the leaf and placed close to the epidermis of the lower surface. The pallisade tissue is well developed on the upper side where not interrupted by the presence of stomata, and below is the parenchyma with intercellular spaces communicating with the stomata.

Fibro-vascular bundle double, the whole surrounded by a well-marked sheath.

The figure (Plate 48, fig. 27) is drawn from a specimen supplied by Mr. Syme, Elvaston Nurseries.

I have only examined four specimens of this plant, which differs so strikingly from A. Pinsapo in anatomical characters. Not having seen the cone, I cannot describe it. This species is cultivated in the Royal Botanic Garden, Edinburgh, and at Glasnevin Botanic Garden, under the name of Abies numidica, and is sent to me by Mr. Syme, with both the names "numidica," and "Baborensis."

24. *Pinus* (*Abies*), sp.: Rocky Mountains, Drummond.

Shoots hairy. Leaves inserted singly, and very close together, all round the stem, but bent to form two lateral rows, those on the upper side of the shoot chiefly directed upwards. Leaf linear, twisted at the base, especially on upper side where the leaf is twisted half a turn, base orbicular, width of leaf rather uniform, apex blunt, the margin of the leaf sharp, upper surface dull green, with no stomata, below with a band of stomata on each side of the hardly prominent midrib, there being from 5 to 7 rows in each band. Leaves from $\frac{1}{4}$ to $\frac{3}{4}$ inch long, and about $\frac{1}{12}$ inch wide. Buds covered with yellowish-brown resinous scales.

Transverse section of leaf.—Leaf flattened, about $3\frac{1}{2}$ times as wide as thick, sides not rounded, but with a sharp transparent margin, upper surface with a longitudinal furrow, below with the midrib not prominent. Hypoderma well developed, forming an interrupted band from the outer margin of the resin-canal of one side, under the epidermis of the upper surface, to the resin-canal of the other side; the hypoderma is also developed under the fibro-vascular bundle. The resin-canals are placed at each side of the leaf, close to the lower epidermis. The pallisade tissue is well developed on the upper side, and below is the parenchyma with well-marked intercellular spaces communicating with the stomata.

Fibro-vascular bundle double, the parts placed close together, with a few thick liber-like cells above and in the middle. The whole is surrounded by a well-marked sheath.

The resin-canal has a double wall—the inner cells smaller and with thin walls, the outer larger and with thick walls; this thick-walled layer being in contact with the lower epidermis.

Only one plant of this species has come under my notice. It has been long cultivated in the Royal Botanic Garden, Edinburgh, and was sent to me by my father, marked "Picea sp., California, old tree." The unique plant in the Edinburgh Garden was raised from seed sent from the Rocky Mountains by Drummond. The cone being unknown, I have not attempted to name it.

The figure (Plate 49, fig. 28) is drawn from the plant in the Edinburgh Garden.

The leaf is somewhat like that of P. pectinata, but the plant is not a handsome one.

II. PSEUDOTSUGA, Bertrand; Carrière (in part). Abies, Auct. Tsuga, Carrière. Keteleeria, Carrière.

1. *Pinus* (*Pseudotsuga*) *nobilis*, Douglas, MSS.; Parlatore, in D. C. Prod. xvi., pt. ii., p. 419, No. 89.

Shoots covered with fine hairs. Leaves inserted singly all round the stem, very close together, the leaves on the lower side of the shoot directed laterally by being curved outwards, but not twisted at the base; those on the upper side of the shoot all directed upwards. Leaf rigid, linear, more or less falcate, with an obtuse apex, upper surface variable, sometimes with numerous stomata, the whole surface being pale in colour, at other times stomata less numerous, or even wanting, and the colour darker; beneath with a band of stomata on each side of the midrib, between the midrib and the resin-canal, sometimes with stomata between the external margin of the resin-canal and the edge of the leaf, there being 5 to 7 rows of stomata in each of the bands between the midrib and resin-canal. Leaves about 1 to 1½ inch in length, and about $\frac{1}{12}$ inch wide. Buds small, dark-coloured, and covered with resin.

Transverse section of leaf.—Leaf broadly triangular, three times broader than thick, sides rounded, upper surface with a central longitudinal furrow, below with a prominent midrib. Hypoderma conspicuous, a single layer, rarely a double layer, at the rounded margin of the leaf; a number of hypoderm cells above, under the longitudinal furrow, and a considerable mass two or more cells thick at the prominent midrib below; the hypoderma is interrupted above between the central furrow and the margin by the presence of stomata. The resin-canals are two in number, placed close to the under side of the leaf, and generally about half-way between the midrib and the margin of the leaf, a small cluster of hypoderm cells often placed below the resin-canal. Between the midrib and the resin-canal, on each side, inferiorly, the stomata are developed and the hypoderma is wanting. Between the resin-canal and the margin of the leaf the hypoderma is either continuous or interrupted by the presence of a few stomata. The pallisade parenchyma is scarcely developed at all, owing to the presence of stomata on the upper surface of the leaf.

Fibro-vascular bundle single, and surrounded by a well-marked sheath.

The figure (Plate 49, fig. 29) is drawn from a specimen supplied to me by my father, and cultivated in the Royal Botanic Garden, Edinburgh. Another specimen is figured (Plate 49, fig. 29 a) which was sent to me by my father as Picea amabilis, Douglas.

Pseudotsuga nobilis is a bifolious species, the leaves on the cone-bearing shoots being very like those of magnifica. Indeed it is very difficult, even in cone-bearing specimens, to separate the one from the other anatomically.

I have examined many specimens of nobilis from Glasnevin, Edinburgh, and from Mr. Syme of Elvaston, both of old and young plants. Many native specimens have also been examined, one from Douglas, in Kew Herbarium, "P. nobilis, Sabine. On the high mountains at the Grand Rapids, on the Columbia River, and near the base of Mount Hood, 1825;" several specimens from Jeffrey; one in Kew Herbarium, and two in the Edinburgh collection. One of these is No. 398, "Chastey Bull, U. California, Lat. 41°, elevation 9,000 feet, Oct. 12, 1852." The leaves on the cone-bearing shoots of this specimen are remarkably like those of P. magnifica, but the long projecting scales of the cone show that it is not magnifica. There is also a specimen of nobilis from the Cascades of Columbia, Dr. Gardener.

The leaves of the type specimen of P. amabilis, Sab., Douglas, sent to me by Professor Oliver are those of P. nobilis (Plate 49, fig. 29 b), but may be those of magnifica.

2. *Pinus* (*Pseudotsuga*) *magnifica*. *Abies magnifica*, A. Murray, Proc. Royal Hort. Soc. London, iii. p. 318.

Shoots covered with fine hairs. Leaves inserted singly all round the stem, very close together, leaves on the lower side of the shoot directed laterally by being curved outwards, but not twisted at the base, those on the upper side of the shoot rather closely appressed, not twisted; upper side of leaf towards the branch, and directed towards the apex of the branch, almost covering the shoot. Leaf rigid, linear, more or less falcate, with an obtuse or rather bluntly-pointed apex, upper surface of leaf with numerous rows of stomata, often with 8 or more rows, and giving the leaf a whitish appearance; beneath with a band of stomata on each side of the midrib, there being from 4 to 6 rows of stomata in each band. Leaves about 1 to 1½ inch in length, and about $\frac{1}{12}$ inch wide. Buds small, dark-coloured, and covered with resin.

Transverse section of leaf.—Leaf slightly quadrangular, rather more than one-half as thick as broad, sides rounded, upper surface with a central ridge, below with a prominent midrib. Hypoderma well developed, a single or sometimes a double layer, at sides, below epidermis of midrib, and a few below the ridge on upper side. The hypoderma is interrupted above between the ridge and the margin, by the presence of the stomata. The resin-canals are two in number, placed close to the under side of the leaf, and generally about half-way between the midrib and the margin. Between the midrib and the resin-canal on each side inferiorly, the stomata are developed, and occasionally a row of stomata is seen between the resin-canal and the margin of the leaf. The pallisade parenchyma is scarcely developed, owing to the presence of the stomata.

The fibro-vascular bundle is single, and surrounded by a well-marked sheath.

The figure (Plate 49, fig. 30) is drawn from a specimen kindly supplied to me by Mr. Anthony Waterer, Knap Hill Nursery, near Woking, Surrey.

I have examined twelve specimens of this species—six living, and six dried. The living plants were from Edinburgh; from Mr. Syme, Elvaston Nurseries; from Mr. Anthony Waterer, Knap Hill Nursery; and from Glasnevin; while the dried specimens were from Kew Herbarium, and Edinburgh Museum. It is cultivated in Edinburgh under the names robusta and magnifica. The specimen marked "robusta" has the following note by my father: "The piece of P. robusta is from a layer taken from the original plant sent home by Douglas;" and he adds, "I think it likely that, in certain soils, P. nobilis, robusta, and magnifica, may all turn out to be the same, although distinct in the garden here." Two of the specimens were raised from seeds sent home by Jeffrey. The specimen in Glasnevin was a small very unhealthy plant from Perth Nurseries, and was cultivated under the name of Picea amabilis. The specimens from Mr. Syme and Mr. Waterer were correctly named magnifica. There are three specimens of this species in the Kew Herbarium, one marked "Sierra Nevada, L. California, W. Lobb;" figured (Plate 49, fig. 30 a), and two marked "California, H. Low, Esq., Clapton." These are, I believe, the types of Mr. Murray's magnifica. There are three specimens in the Edinburgh collection; one is marked "Picea robusta magnifica, 1480, Jeffrey." The cones are 6 inches long and 2 inches wide. The bract is long, but not projecting, and has an evident relationship to P. nobilis. The second specimen in the Edinburgh Museum is marked "Pinus, sp. nova, from California, P. Lawson & Son." The cone is 9 inches long by 2½ inches wide, and is bent slightly. The third is marked "P. magnifica robusta, 1480, Oregon, Mr. Jeffrey, 1853." The cone is 8½ inches long by 2½ inches wide, and is slightly bent. This is the species mentioned in the Trans. Bot. Soc., vol. vi., p. 370, by Mr. A. Murray under the name of campylocarpa.

It is certain that this species was sent home by Douglas, as it has long been cultivated in the Edinburgh Botanic Garden, under the name of robusta, the plant being a layer of Douglas's unique specimen. It was also sent by Jeffrey, who called it amabilis, Douglas, and I have no doubt whatever that Jeffrey was perfectly right in so naming it.* The cone is exactly like that of P. lasiocarpa, Hook. (bifolia, Murray); and one of the specimens named in the Edinburgh Museum "P. magnifica robusta, 1480, Oregon, Mr. Jeffrey, 1853," is bifolia of Murray. It has also been sent to Low by Mr. Lobb, and described by Mr. Murray under my father's MSS. name of magnifica.

3. *Pinus* (*Pseudotsuga*) *Davidiana*, Bertrand, Anat. Compar. des Gnét. et des Conif. p. 82.

This species is from Thibet, and is described by Bertrand, but I have not seen it. According to Bertrand it is allied to Pinus Fortunei, but has stomata on both sides of the leaf.

4. *Pinus* (*Pseudotsuga*) *Fortunei*, Parlatore, D. C. Prod. p. 430, No. 112. *Abies Fortunei*, A. Murray, Proc. Hort. Soc. Lond. iii. 421 (1862). *Pseudotsuga Jezoensis*, Bertrand, *op. cit.* p. 83. *Picea Jezoensis*, Carr. (?)

Shoots hairy. Leaves inserted singly all round the stem, scattered, forming two lateral rows. Leaf linear, twisted above the base, widest above the twist, remaining tolerably uniform until about $\frac{1}{3}$ of length from apex, then narrowing into a sharp projecting point; upper surface dark-green, with no stomata (rarely a few near the apex of certain leaves), beneath with a band of stomata on each side of the midrib, there being about 16 rows of stomata in each band. Leaves from $\frac{3}{4}$ to 1 inch in length, and about $\frac{1}{8}$ inch wide. Buds (?)

Transverse section of leaf.—Leaf flattened, about five times broader than thick, sides rounded, slightly angular near resin-canal, upper side nearly flat, or slightly concave, below with a slightly prominent midrib. Hypoderma well developed, forming an interrupted band running from the resin-canal of one side, under the epidermis of the upper surface, to the resin-canal of the other side: a cluster of hypoderm cells below the midrib. The resin-canals are placed, one at each side of the leaf, close to the epidermis of the under surface, but separated from it by a layer of thick hypoderm cells. The pallisade parenchyma is well developed on the upper side, and below is parenchyma with intercellular spaces communicating with the stomata.

Fibro-vascular bundle single, but sometimes divided into as many as six small portions. Bast cells developed below, and the whole surrounded by a tolerably evident sheath.

The figure (Plate 49, fig. 31) is drawn from a specimen kindly

* See Transactions Edinburgh Botanical Society, xi., p. 326.

supplied to me by Messrs. Veitch and Son, Royal Exotic Nursery, Chelsea.

I have only examined one specimen of this plant, received from Messrs. Veitch under the name of Abies Jezoensis. There is no difficulty in identifying the specimen with Mr. Murray's A. Fortunei, a Chinese species. It is, however, very like the plant sent out by Messrs. Veitch as Abies Veitchii, and I strongly suspect there is some confusion yet to be cleared up about these Japanese plants. Veitchii, of Hort. Veitch, is not Veitchii of Kew Herbarium, but resembles P. Fortunei, excepting that the leaves are smaller. Veitchii (Hort.) may, therefore, be Jezoensis, and thus P. Fortunei must stand as the name of this most interesting plant.

5. *Pinus* (*Pseudotsuga*) *Douglasii*, Sabine, Lamb., Gen. Pinus, 2 ed., vol. iii. tab. 21. *Picea Douglasii*, Link. in Linnæa, xv. 524. *Pseudotsuga Douglasii*, Carr., Trait. Général des Conif. 2 ed., p. 256.

Shoots smooth. Leaves inserted singly all round the stem, but bent so as to form two lateral rows, occasionally a few are directed upwards and downwards. Leaf linear, twisted near the base, which is narrowed to the small insertion, breadth uniform for greater part of length, apex rounded, upper surface bright green, with no stomata, beneath with a band of stomata on each side of the midrib, there being, from 5 to 6 rows of stomata in each band. Leaves from 1 to $1\frac{1}{4}$ inch long, and about $\frac{1}{15}$ inch wide. Buds covered with yellow resinous scales.

Transverse section of leaf.—Leaf flattened about $2\frac{1}{2}$ times as broad as thick, sides rounded, upper surface with a longitudinal groove, below with a slightly prominent midrib. Hypoderma very variable, in some leaves very well-developed, in others almost absent on upper side. The resin-canals are placed one at each side of the leaf, close to the epidermis of the under side. The pallisade parenchyma is well developed on the upper side, and below is parenchyma with well-marked intercellular spaces. In the parenchyma of the leaf are developed, in North American specimens only, peculiar stellate idioblasts, which ramify between the ordinary parenchymatous cells.

Fibro-vascular bundle single, surrounded by a well-marked sheath.

The figure (Plate 49, fig. 32) is drawn from a specimen supplied by Mr. Syme, which shows the absence of hypoderma in cultivated plants and agrees well with others from Edinburgh and Glasnevin. Plate 49, fig. 32a, represents a specimen of Douglasii from Kew Herbarium. It is marked "Abies sp. nova, Douglasii? Rocky Mountains. Independence Bluff, Nuttall." It has the cone of Douglasii, but the development of hypoderm and idioblasts separates it from all the cultivated specimens I have yet seen. It is the same as Wright's No. 1885, from New Mexico, which Parlatore refers to P. Douglasii. The third specimen figured (Plate 49, fig. 32b.) is Fendler's, No. 829, which Parlatore refers to amabilis. Either the species is variable, or else we have one species in cultivation and another known only by Herbarium specimens, viz., Fendler, No. 829; Wright, No. 1885; and Abies, sp. Douglasii? Rocky Mountains, Nuttall. I am indebted to Prof. Perceval Wright for the opportunity of examining the specimens of Fendler and Wright in the Herbarium of Trinity College. The leaves of the fine old plant of Douglasii, in the Royal Botanic Garden, Edinburgh, have neither hypoderm nor stellate idioblasts.

## LV.—A CONTRIBUTION TO THE HISTORY OF DOLOMITE.—THE DOLOMITES OF THE CARBONIFEROUS LIMESTONE OF IRELAND. By EDWARD T. HARDMAN, F. C. S., F. R. G. S. I., of the Geological Survey of Ireland. (With Plates 41 and 42.)

[Read May 8, 1876.]

As Bischof well remarks, "no rock has attracted greater attention than dolomite;" and very many theories as to its origin have been put forward; the principal of which are based on the idea of the metamorphism, in some way, of limestone rocks, varying the means of such changes according to the views of different authors.

(1). Von Buch's supposition involves the introduction of magnesia into limestone, as the result of the eruption of volcanic rocks in the neighbourhood, producing vapours of magnesic chloride.*

(2). Haidinger suggested that the effect was produced by the action of sulphate of magnesia on limestone, sulphate of lime and carbonate of magnesia being formed.† But as this cannot be effected in the ordinary way, it is assumed that under the influence of great heat and pressure it might take place. It will be remembered, however, that most dolomitic deposits of themselves utterly refute such an hypothesis.

(3). Von Morlot put forward a similar theory, having, as he supposed, found that when sulphate of magnesia and carbonate of lime were heated in a sealed tube to a temperature of 392° F., a double carbonate of lime and magnesia was formed, together with gypsum.‡ But Dr. Sterry Hunt has shown that in this case the so-called dolomite was really but a mixture of carbonate of lime with carbonate of magnesia,§ nor did he find that Marignac's‖ substitution of chloride of magnesium for the sulphate yielded any better results.

All these well-known theories not only presuppose in every case the action of igneous rocks, and a high temperature, but also the evolution of gaseous sulphuric and hydrochloric acids, in order to obtain the necessary supplies of magnesia from the eruptive rocks themselves. In our present state of chemical and geological knowledge, it will therefore be doing no violence to the scientific reputation of their originators, to say that they may now be looked upon rather as curiosities of geological literature.

(4). Forchammer appears to refer the formation of dolomite to

* See Bischof, Chem. Geol., vol. iii., 155 *et seq.* Also Chem. and Geol. Essays, T. Sterry Hunt, 44 D., &c., p. 81,—Ann. de Chem. and Phys., xxiii., 296.

† Bischof, *op. cit.*, p. 158.—Pogg. Ann., lxxiv., p. 591.

‡ Bischof, *loc. cit.*, also N. Jahrb. für Min., 1847, 862.

§ Chem. and Geol. Essays T. Sterry Hunt.

‖ For the experiment, see Bischof, vol. iii., p. 159.

the reaction of spring-water, containing a large percentage of carbonate of lime, with sea-water, at a very high temperature.* But this theory, which bears a slight degree of resemblance to that of Hunt (see *post*), will not answer, since many dolomites, e. g. those the carboniferous formation in Ireland, not only are interstratified with limestone, but actually the same bed may be highly fossiliferous limestone in one place, and pass into dolomite in another. Such instances are common, and it is clear that such a rock could not have been deposited from boiling sea-water.

(6). Dr. T. Sterry Hunt apparently endeavours to strike the happy medium between the Wernerists and the Plutonists, but still his theory will be found not to account for the interstratification, and passage into each other of fossiliferous limestones and dolomites. It supposes the reaction of river waters holding in solution carbonate of soda, with sea-water contained in shallow basins, and further decompositions of chloride of calcium and subsequently of sulphate of magnesium into bicarbonates of calcium and magnesium respectively; the former being precipitated first, but that, under certain conditions, a mixture of the two may be precipitated together. "The subsequent action of heat upon such magnesian sediments, either alone or mingled with carbonate of lime, has changed them into magnesite or dolomite."† I am at a loss to see why Dr. Hunt's own objection to Von Morlot's theory does not also apply to this. In both cases only a mixture of the two carbonates is obtained in the first instance, and the element of sufficient heat may be supposed as well in the one case as in the other. But besides this, the whole theory fails altogether to account for the carboniferous dolomites of Ireland: for the facts that it is possible to produce specimens from the same bed, of fossiliferous unaltered limestone, and of true dolomite, and that beds of dolomite lie above and below highly fossiliferous limestone, as I shall show hereafter. Moreover, the number and development of the fossils with which the limestones abound, as well as the general stratigraphical character of the deposits, and the extremely capricious manner in which the dolomites occur, show that they could not have been formed in a series of shallow seas, unless we admit an extraordinary series of changes of level, and of physical features, during the period of the formation of the carboniferous limestone—a position which is quite untenable.

I take the dolomites of the carboniferous limestone as a test of these theories, not only because I am best acquainted with them, but be-

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* Bischof, viii., p. 161.—Also, Ann. de Chem. and Phys., xxiii. Also, Report Brit. Assoc., 1849 (Birmingham), Transactions of Sections, p. 36, where an abstract of his views is given.

† Chem. and Geol. Essays, pp. 80–90. On the Chemistry of Dolomites and Gypsums, also pp. 91–92, 309, *et multis aliis*. I should not refer so particularly to this in the present instance, but that Dr. Hunt applies his theory to the formation of "all magnesian limestones."

cause while they are of extremely frequent and extensive occurrence in Ireland, they are also found under perhaps the most favourable conditions for the determining any points with regard to either Plutonism or physical phenomena.

On the subject of Irish dolomites, two valuable papers are extant. Many years ago Dr. Scouler communicated his views on that subject to the Geological Society of Dublin;* his opinion being that dolomite was produced by a metamorphism of the original limestone, and, following Virlet, he considered the change to be readily accounted for by the infiltration of water charged with carbonate of magnesia; which water would at the same time remove some of the carbonate of lime. But an important point in his paper is that he considers dolomite to occur usually near some source of magnesia—either near an igneous or ancient palæozoic rock, or close to a break in the strata, where a thermal spring might have existed. This is a point which I shall presently dwell upon, as many dolomites occur under circumstances which do not agree with any of these conditions, and where the supply of magnesia is far below that of lime.

The reading of the above paper led Dr. Apjohn to make several analyses of Irish dolomites, which he has published in the same journal.† The conclusions he came to as to the origin of dolomites appear to be that they are original formations; first, because they are often fossiliferous, and, secondly, because their composition is definite. At the same time he suggests that some dolomites may have been produced by the solvent action of carbonated water on limestones containing some magnesia, in removing carbonate of lime, until at last the rock would consist of the two carbonates in the correct proportion.‡

Probably the most comprehensive account yet published of the dolomite question is that given by Bischof, who, in his classical work on chemical geology, has discussed nearly all the foregoing views, together with many of those held by other writers. He dismisses as improbable all those which call in the aid of volcanic or Plutonic agencies, and shows that the action of water by infiltration through limestone can alone explain the processes of dolomitization; that is, either by

* Observations on Beds of Dolomite which occur in connexion with the Carboniferous Limestones in different parts of Ireland. By John Scouler, M.D., &c., Jour. Geol. Soc. Dub., vol. i., pp. 382–5.

† Analyses of some Irish Dolomites. By James Apjohn, M.D., &c. Jour. Geol. Soc. Dub., vol. i., pp. 369 *et seq.*

‡ I am inclined to adopt a modification of the above hypothesis, viz., that the greater part of the carbonate of magnesia was originally secreted along with the carbonate of lime, but that dolomite is a true metamorphic rock—the alterations being due to the extraction of the surplus of carbonate of lime. Some so-called dolomites having the crystalline structure and the obliteration of fossils *en regle*, are by no means of definite composition; they usually contain a considerable percentage of uncombined carbonate of lime, which dissolves out in weak acid.

the action of water holding carbonate of magnesia in solution, penetrating the rock, and depositing carbonate of magnesia, while at the same time removing a portion of the carbonate of lime; or, as he admits, it *may* occur in some cases by the simple removal of carbonate of lime from a magnesian limestone by water containing carbonic acid; the result being, of course, a gradual increase in the proportion of carbonate of magnesia. While admitting this process, which was first suggested by Grandjean, to be possible—as he shows by two experiments, which prove carbonate of lime to be actually more soluble than carbonate of magnesia in water containing a small percentage of carbonic acid—he, however, appears to give the preference to the first process, viz., the infiltration of carbonate of magnesia, and removal of lime.* But there appear to be one or two weak points about this. 1st. That with so little difference in solubility of the two salts, a substitution of one for the other would hardly take place to the extent required.† 2nd. That the lime removed must always be equal—proportionally to their respective atomic weights—to the magnesia deposited, or the rock would increase in bulk. 3rd. That the result would only be a carbonate of lime with carbonate of magnesia deposited in crevices or interspaces left by the removal of the excess of carbonate of lime; and 4th, that there is a difficulty sometimes in imagining a sufficient supply of magnesianized water in localities where, as in the central plain of Ireland, there are none but limestone rocks, the water from which, containing a much larger quantity of lime than magnesia, could hardly, therefore, produce the supposed effect; yet all these limestones are highly dolomitic.

Any alteration that has taken place in these must have been entirely produced by surface-water, or rain-water, which could contain little or no constituents capable of affecting the limestone rocks, except carbonic acid. To the action of this agent I attribute the alteration which most of the Irish limestones have undergone in their passage into dolomite. At the same time, I think it quite possible that water *highly charged with carbonate of magnesia*, which may be the case if it has percolated a *magnesian rock*, may deposit the magnesia while it removes the lime, and thus aid in the metamorphism; but, as I shall show hereafter, waters containing any appreciable amount of carbonate of magnesia are rare; and after all, as Bischof shows, in such a case the chief work is done by the action of the carbonic acid.‡

If we suppose a limestone rock, containing, as very many limestones do, carbonate of magnesia to the extent of 12 per cent., to

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* Chem. Geol., vol. iii., p. 164.

† Bischof failed, after "taking much pains," to effect the mutual decomposition of carbonate of lime and carbonate of magnesia. In one case he digested fragments of chalk with pure carbonate of magnesia, for several years, without any effect.—*Op. cit.*, vol. iii., 167.

‡ Chem. Geol., vol. iii., p. 174. (In effect, although not in these precise terms).

be subjected to the action of carbonated water, assuming this to be capable of removing a greater quantity of carbonate of lime than of carbonate of magnesia—*in proportion to that in the rock*—it is clear that in the process of time we should have the percentage of magnesia becoming greater and greater, until at last the rock approached in chemical composition to a true dolomite. Moreover, the removal of carbonate of lime would give rise to a cavernous or porous condition of the rock, and the calcareous water trickling over the sides or into these cavities would result in a deposit of crystals of more or less pure carbonate of lime therein. Every one who has paid any attention to this subject is, no doubt, aware that the above are characteristics of dolomite limestone.

Upon the above assumption, which I have now good reason to believe a certainty, I based a number of experiments with the view to ascertain whether, when placed under conditions as near as possible to those obtaining in nature, limestone does not yield more lime than magnesia, when submitted to the action of carbonic acid in water.

At the time I had not Bischof's book at hand, and all the statements I had seen gave just the opposite opinion. I was subsequently much pleased to find that Bischof's two experiments* are confirmatory of my results, and they being unknown to me then could have had no biasing effect.

It is without exception received, I believe, that carbonate of magnesia is much more soluble than carbonate of lime; but the few experiments I have made on this point do not appear to show any great difference; and I have been led to imagine, therefore, that its behaviour in the presence of ammonia salts may have been taken by some to represent its character under other circumstances. In the process of chemical analysis, when it is desired to separate magnesia from lime, a little chloride of ammonia is added to the solution, and an alkaline carbonate then precipitates the lime with just a trace of magnesia. If, however, ammonia is not previously added, both salts are almost instantly precipitated by carbonate of soda.

But, even admitting that carbonate of magnesia is *per se* a trifle more soluble than carbonate of lime, it is certain that, when both are mingled together in a limestone rock, just the reverse takes place when they are subjected to the action of carbonated water. My experiments will show this. Before proceeding to refer to them, however, I should like to mention the results obtained by previous experimenters.

Professors W. B. and R. E. Rogers, at the Meeting of the British Association at Birmingham, in the year 1849, read a paper on some experiments as to the solvent power of carbonated water on various minerals.† In the course of their experiments they were led to inves-

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* See *post*.

† "On the Decomposition and Partial Solution of Minerals, Rocks, &c., by pure water, and water charged with Carbonic Acid." By Prof. W. B. Rogers, and Prof. R. E. Rogers. Rep. Brit. Assoc. 1849; Trans. of Sections, p. 40.

tigate *the comparative solubility of carbonate of lime and carbonate of magnesia in carbonated water.*

The means which they employed were—1st, what they designate as the method with the *tache*, consisting in digesting for a few minutes a small quantity of the mineral, *finely powdered*, on a filter with carbonated water, and then collecting the filtrate and examining it for lime and magnesia. 2nd. By agitating briskly for some time, in a large glass bottle containing carbonated water, a quantity of the mineral, in this case also *finely powdered.* The water was then evaporated, and the residue examined. In both these cases, magnesian limestone so treated yielded a larger quantity of carbonate of magnesia than of carbonate of lime, proportional to their relative amounts in the rock; and the Professors Rogers infer that in nature this process would result in the limestone *becoming less magnesian, instead of approaching to a dolomite, as is generally maintained.*

Now I wish to point out that the process sketched above cannot by any means be held to represent that which takes place in nature. The very act of powdering the dolomitic limestone has destroyed any value the experiment might otherwise have had. We do not find rocks *in situ* thus prepared for the invading action of carbonic acid; and we know that dolomites entirely, and magnesian limestones to a great extent, resist the action of much stronger acids than a merely carbonated solution, so long as they remain solid; but once they are powdered up, they are readily dissolved with evolution of carbonic acid. In effect, this fact is made use of in testing rocks in the field; dolomitic limestone being scarcely affected at all by moderately dilute hydrochloric acid, and can therefore be readily distinguished from ordinary limestone.

I do not know if the amount of magnesium carbonate obtained by the above method was quantitatively determined by Professors Rogers, as I have not been able to consult their detailed paper in the American Journal of Science; but it is curious that Bischof obtained just the contrary result to theirs, in the two experiments I have already referred to, although his method of proceeding is essentially the same. His results agree very well with my own.

*Bischof's Experiments.* The composition of the limestone being ascertained, a portion was powdered finely, and placed in water for 24 hours. The water was then examined, and proved in the cases tried to contain either no trace, or a very small one, of magnesia. I shall copy one of these for example, as it will be useful to compare with my results.

*Black Magnesian Limestone.* From Stadtbergen.*

I. ANALYSIS.

| | |
|---|---|
| Carbonate of lime, . . . . . . . . | 84·57 |
| " magnesia, . . . . . . | 11·54 |
| " iron, . . . . . . . . | 1·15 |
| Silica and carbon, . . . . . . . . | 1·36 |
| | 98·62 |

II. AMOUNT OF CONSTITUENTS DISSOLVED *in* 24 *hours, from* 6660 *grains.*

| | Grains. |
|---|---|
| Carbonate of lime, . . . . . . . . | 4·29 |
| Carbonate of magnesia, . . . . . . | no trace. |

There appears to be, for the quantity taken, and the time occupied, more carbonate of lime dissolved than occurred in any of my experiments; however the powdering of the rock might give rise to this. But this important fact still remains, that, when treated with a weak solution of carbonic acid, limestone yields more carbonate of lime proportionally than carbonate of magnesia.

Perhaps it is well to notice here the curious difference that pressure makes, not only in the solvent power of carbonic acid, which is increased, but in its relative effects on the two carbonates. It appears certain that, under the ordinary atmospheric pressure, and in such proportions as it occurs in most surface or even underground waters, it will chiefly attack the lime, while under a high pressure, and in large quantity it seems to confine its attentions, I may say, strictly to the magnesia. Advantage has actually been taken of this property to procure salts of magnesia, such as the sulphate, from dolomite; the process consisting in submitting the rock, finely ground, with water, to the action of carbonic acid, under a pressure of about four atmospheres. It is then found that nearly all the carbonate of magnesia is removed, without admixture of carbonate of lime.†

This is worth noting, as it may serve to account for the large quantities of carbonate of magnesia which are occasionally, *but not often*, found in spring waters; and may also explain the production of deep-seated dolomites by infiltration of magnesian water.

As it is, however, with dolomites formed under circumstances not taking in the element of pressure we shall have to deal at present, I shall not enter more fully into the above matter just now; but proceed to describe the experiments I have referred to.

It appeared to me that if it could be proved by some process as

* Bischof, *op. cit.*, vol. iii., p. 195.
† Dingl. Polyt. J., ccix., 467.—*Abs.* Jour. Chem. Soc., vol. xii., p. 96.

nearly as possible akin to that which goes on in nature, that more carbonate of lime is dissolved than carbonate of magnesia by a weakly carbonated solution, it would go far towards solving the question, as to the formation of some dolomites.

The process I adopted was very simple. A limestone was selected which contained a fair percentage of magnesia, it was analysed, and the proportions noted. A portion of the rock was then broken up into small fragments, somewhat less than half-an-inch across. These were placed in a jar open to the atmosphere, with distilled water, and carbonic acid was passed in. A piece of litmus paper was placed in the jar, and the flow of gas was stopped as soon as this became reddened. Whenever the paper showed any indication of returning to its original tint, the solution was again saturated with the acid, and so on. In this way an over saturation with acid (which might have had too energetic an effect on the rock) was prevented, and the whole experiment brought as near to nature as is possible in a laboratory, in having a mildly carbonated solution acting on *surfaces* of the rock, and not on minute particles.

With the process carried on in this manner, I found the action of the carbonic acid to be extremely slow, compared with the results obtained from powdered rock by other experimenters, several days being required to dissolve sufficient of the carbonates for estimation; but in every case the carbonate of lime was much in excess. Some of my experiments were merely tentative, and are not worth recording; but I shall now mention the details of some of the more important ones.

No. I.—Limestone from the interior of the Cave of Dunmore, Co. Kilkenny. A light grey compact magnesian limestone.

ANALYSIS.

*Mean of two specimens.*

| | |
|---|---|
| Carbonate of lime, | 68·21 |
| Carbonate of magnesia, | 24·00 |
| Peroxide of iron, ,, alumina, | 4·32 |
| Silica, | 1·92 |
| Carbonate of iron, | 0·90 |
| | 99·35 |

It will be observed that this is a remarkably pure limestone, the amount of silicates, &c., being very small. The rock is evidently becoming dolomitic, for the limestone above and around the cave is not by any means highly magnesian.

*Exp.* 1.—A quantity of the limestone was broken up small. 110 grains were taken and placed in a jar with distilled water, and carbonic acid gas was passed in almost continuously for 72 hours. At the expiration of that time the solution was carefully filtered off and examined. It contained both carbonate of lime and of magnesia, but in extremely small quantity, viz.:—

| | |
|---|---|
| Carbonate of lime, . . . . | 0·05 grains. |
| Carbonate of magnesia, . . . | 0·007 ,, |

Calculated now according to the percentage of carbonate of lime in the rock, *i. e.*, 68·21, the above gives the respective proportions dissolved to be—

| | |
|---|---|
| Carbonate of lime, . . . . . | 68·21 |
| ,, magnesia, . . . | 9·32 only, |

or less than half the proportion of carbonate of magnesia actually in the rock. It is clear, therefore, that this operation, continued sufficiently long, must result in a dolomite.

*Exp.* 2.—About the same quantity of the Dunmore limestone was taken—110 grains, and placed in a jar with water as before. Carbonic acid gas was then passed in, nearly continuously for 44 days. For about a week or so of that time no gas was passed in, but for the most part of this experiment the water was supersaturated with the acid, the result of which will be presently seen.

The liquid, having been carefully filtered off, evaporated to dryness, and the residue examined yielded the following result:—

| | |
|---|---|
| Carbonate of lime, . . . . . | 1·04 grains. |
| ,, magnesia, . . . | 0·306 ,, |
| ,, iron, . . . . . | a trace. |
| Total dissolved, . . | 1·346 |

Calculating again according to the proportion of carbonate of lime in the rock, we have—

| | |
|---|---|
| Carbonate of lime, . . . . . . . | 68·21 |
| ,, magnesia, . . . . . | 20·06 |

I attribute the high percentage of magnesia carbonate dissolved in this instance to the supersaturated condition of the carbonic acid solution, which was allowed to become quite in excess of anything that could occur in nature. Nevertheless, it is evident that the carbonate of lime was the most rapidly dissolved in this case also.

It seems remarkable also that so small a portion of the limestone was dissolved after such long continued action. However, this was confirmed in other experiments, and I apprehend it is due to the magnesian character of this rock. It is certain that the action of small quantities of carbonic acid on limestones is in an inverse ratio to the amount of magnesia in them—dolomites being almost unassailable. Experiments 4 and 5 will show how well this is borne out.

*Exp.* 3.—As the limestone used in the last was hardly diminished at all, it was again covered with distilled water, and carbonic acid passed in. Care was taken to keep the solution just slightly acid, and to avoid the error of Experiment 2. The action was continued for 20 days. The solution was then filtered off, evaporated, and examined as before, with the following result:—

| | |
|---|---|
| Carbonate of lime, . . . . | 0·55 grains. |
| ,, magnesia, . . . | 0·07 ,, |
| ,, iron, . . . . . . | a trace. |
| Total dissolved, . . | 0·62 |

This experiment bears out the second very well, as to the total quantity of substance dissolved, the time occupied being half of that, and the total dissolved about half also. The proportion of magnesia is less, however, no doubt owing to the precaution of using a weak solution of acid. The proportion calculated as before would give—

| | |
|---|---|
| Carbonate of lime, . . . . . | 68·21 |
| ,, magnesia, . . . | 9·04 |

This agrees almost exactly with the proportions determined in Experiment 1.

No. II.—Limestone from the breccia of the roof of the Shandon Cave, Dungarvan, Co. Waterford. A bluish-grey fossiliferous limestone, apparently not very magnesian. It turns out, however, to contain a rather large proportion of carbonate of magnesia.

Analysis.

| | |
|---|---|
| Carbonate of lime, . . . . | 79·89 |
| ,, magnesia, . . . | 12·71 |
| ,, iron, . . . . . . | trace. |
| Peroxide of iron, . . . . . } Alumina, . . . . . . . . } | 4·08 |
| Silica and insoluble residue, . | 3·40 |
| | 100·00 |

*Exp.* 4.—187 grains of the limestone, broken in small pieces as before, were placed in a large jar with distilled water,* and carbonic

* It should be noted that in all the experiments except No. 1, the same quantity of water was used, viz., about 20 oz.; care being taken to supply loss by evaporation.

acid passed in: supersaturation with the acid was guarded against, and the limestone was allowed to remain in the water for 40 days. The liquid was then examined, and it yielded:—

| | | |
|---|---|---|
| Carbonate of lime, | . . . . . . . | 3·59 grains. |
| ,, magnesia, | . . . . . | 0·47 ,, |
| ,, iron, | . . . . . . . | trace. |
| | | 4·06 |

This, calculated according to the percentage of carbonate of lime in the rock, would give for the proportions dissolved:—

| | | |
|---|---|---|
| Carbonate of lime, | . . . . . . | 79·89 |
| ,, magnesia, | . . . . . | 9·34 |
| | | 89·23; |

there being in the rock as much as 12·71 of carbonate of magnesia: so that in this case also it will be seen that the result must be a gradual increase in the amount of that constituent.

It will be noticed also, that although the experiment was not continued for quite so long a period as No. 2, the total amount of carbonates dissolved is more than double.

*Exp.* 5.—The fragments of limestone from Shandon, used in the last experiment, were subjected to the further action of carbonic acid, in the same way, the action being allowed to go on for 20 days. The solution being then examined yielded the following:—

| | | |
|---|---|---|
| Carbonate of lime, | . . . . . . | 1·15 grains. |
| ,, magnesia, | . . . . . | 0·11 ,, |
| ,, iron, | . . . . . . . | a trace. |
| Total dissolved, | . . | 1·26 |

Calculated as before, the percentage dissolved will be in the proportion—

| | | |
|---|---|---|
| Carbonate of lime, | . . . . . . | 79·89 |
| ,, magnesia, | . . . . . | 7·64 |
| | | 87·53, |

a result sufficiently near that of the former experiment. The total amount dissolved in this case is not quite half that dissolved in double the time in the former experiment.

These investigations prove the following points:—

1°. That in a weak solution of carbonic acid, limestones in the mass, not powdered, yield more carbonate of lime than of magnesia.

2°. That in equal times the more magnesian limestones are least susceptible to the action of such a carbonic acid solution.

3°. That other things being equal, the relative proportion of the two bodies dissolved appears to remain fairly unaffected by the time occupied in the experiment.

I should mention that the experiments detailed above are not the only ones made which verified the above points: but it would be tedious and uninteresting, I conceive, to enter into particulars of all of them.

[*Note added in Press.*—In order to test the effect of more energetic acids, the following experiment was made since the foregoing was written.

A piece of dolomite from Ballyfoyle, near Kilkenny, having the following composition, was taken:—

ANALYSIS.

| | |
|---|---|
| Carbonate of lime, | 55·48 |
| ,, magnesia, | 43·52 |
| Ferric oxide and alumina, | 0·68 |
| Silica, &c., | 0·34 |
| | 100·02 |

SPECIFIC GRAVITY, 2·73.

Being broken up small, pieces were carefully selected, so as to be as free as possible from other minerals, such as carbonate of iron, calcite, &c. 141 grains were placed in a beaker with distilled water, to which a little hydrochloric acid was added. The solution, although weak, caused copious effervescence *from the interstices.* The experiment was continued for about a month—a few drops of acid being added, when test-paper denoted that the acid previously added had been neutralised. Having left home for a fortnight, I found on my return that a flocculent precipitate—probably carbonates of iron and lime—had been thrown down, no doubt induced by absorption of carbonic acid from the air. The addition of a few drops of acid dissolved this. The whole was then allowed to stand for more than another month; at the expiration of which time a little acid was added to dissolve the precipitate that had again formed—but not enough to affect the undissolved dolomite — and the solution was filtered off. Both solution and undissolved residue were then carefully analysed.

The following Table gives the result:—

| | I. In undissolved Residue. | II. In Solution. | III. Total. |
|---|---|---|---|
| | Grains. | Grains. | Grains. |
| Carbonate of lime, . . | 38·50 | 40·10 | 78·60 |
| ,, ,, magnesia, . | 31·25 | 29·65 | 60·90 |
| Ferric oxide and alumina, | 0·63 | 0·33 | 0·96 |
| Insoluble residue (silica, &c.), . . . . . . . | 0·48 | — | 0·48 |
| | 70·86 | 70·08 | 140·94 |
| *The above reduced to Percentage Composition.* | | | |
| Carbonate of lime, . . | 54·33 | 57·22 | 55·76 |
| ,, ,, magnesia, . | 44·10 | 42·31 | 43·20 |
| Ferric oxide and alumina, | 0·88 | 0·47 | 0·68 |
| Insoluble residue, . . . | 0·67 | — | 0·34 |
| | 99·98 | 100·00 | 99·98 |

So far from the carbonate of magnesia being the most soluble here, it will be seen that the result of the experiment has been actually to bring the composition of the magnesian limestone nearer to that of true dolomite than it was before. The proper proportions being about 52·08, Ca $CO_3$ to 46·50, Mg $CO_3$. It will also be observed from column II. that the carbonate of lime dissolved was much in excess of carbonate of magnesia.]

It had, some time before, struck me that if magnesian carbonate were really more soluble under the circumstances which occur in nature than carbonate of lime, we ought to find some account of it in the stalactites and stalagmites so invariably found where water has percolated through limestones. It has been long known that these accumulations are usually free from magnesia, and the Messrs. Rogers, in the paper already cited, refer to this as a proof of the greater solubility of the carbonate of magnesia, since they say the latter is carried off in solution, while the carbonate of lime is deposited.* Now it is difficult to imagine that all the carbonate of magnesia would so completely disappear, and one would rather suppose

* Bischof, in describing the mode of formation of the sprudelstone from the Carlsbad hot springs, appears to coincide with this opinion, since he considers the magnesia to be carried away wholly in solution. In this case, however, the water has a ready means of escape, and the deposition of carbonate of lime is due to loss of carbonic acid, and not to evaporation.

the possibility of a few layers of it in stalactites, had it ever been held largely in solution. At any rate, the drippings, which would under such a supposition be charged with carbonate of magnesia, falling on the floor, say of a cave, if they produced any stalagmite, should produce a magnesian one, or one containing a very considerable proportion of that body. It appears, however, that neither the one nor the other contains any appreciable amount of it at all, and even those from magnesian limestones follow the general rule. I can hardly think that, in the case of *stalagmites*, some of the magnesian carbonate, if it had been present in the solution which formed them, would not remain. It ought, certainly, to be found in the upper layers, as stalagmite is by no means porous, but this seems not to be so. I am speaking now of stalagmite formed in places where the water could have had no ready means of escape except evaporation.

On the other hand, the argument as to the most soluble being carried away entirely ought to hold good as respects the carbonates of lime and iron. As the latter is least soluble of all, whenever it occurs in stalactites they should consist nearly entirely of it, if the above idea were correct. A great amount of the more soluble lime-salt would be carried off while the carbonate of iron was crystallising, and we would have stalactites containing usually a very large percentage of iron; but this is rarely the case.

As analyses of stalactitic bodies are not numerous, I give those of two or three which I have examined.

No. I.—Stalagmite—from the floor of Dunmore Cave, Co. Kilkenny.

A part of the upper layers where the thickness was at least 6 inches.

ANALYSIS.

| | |
|---|---|
| Carbonate of lime, . . . . . . . | 97·12 |
| ,, magnesia, . . . . . | 0·79 |
| ,, iron, . . . . . . . | 1·86 |
| Peroxide of iron, alumina, . . . . | 0·23 |
| | 100·00 |

This stalagmite was of a dirty grey colour, and apparently full of impurities.

No. II.—Stalagmite from roof breccia of the Shandon Cave, Dungarvan :—

This stalagmite forms an extremely pretty mass, of a clear creamcolour, and is well crystallized. It occurs in large quantity, and often in considerable masses amongst and underneath the breccia. The specimens examined adhered to the under side of the limestone, a portion of which was analysed and experimented on. (See Experiments 4 and 5.) It is therefore reasonable to suppose that its materials were derived from that very magnesian rock.

ANALYSIS.

| | | |
|---|---|---|
| Carbonate of | lime, | 99·25 |
| ,, | magnesia, | 0·70 |
| ,, | iron, | trace |
| | | 99·95 |

The iron present was hardly sufficient to give the pale yellow colour to the mass. The parent rock of these stalagmites being so very magnesian, we should expect to find a very appreciable amount of magnesia in them if, as is thought by so many, the carbonate of magnesia in limestone rocks is so very soluble. But what can have become of it? for I shall show presently that the waters of limestone districts contain a very trifling amount of magnesia.

It is hardly conceivable that, were the carbonate of magnesia in such rocks the most soluble in weak carbonic acid, there should be barely traces of it in these deposits; and from this circumstance, as well as from its scarcity in spring waters, we should rather be led to infer its greater insolubility, even without the experiments I have brought forward.

No. III.—Stalactites from a highly magnesian limestone, Railway bridge, Thomastown, Co. Kilkenny.

ANALYSIS.

| | | |
|---|---|---|
| Carbonate of | lime, | 99·25 |
| ,, | magnesia, | 0·50 |
| | | 99.75 |

One link in the chain is still wanting, viz., the analysis of waters which have undoubtedly passed through such limestones as the above-mentioned, and which have deposited stalactitic matter. Some information on this point I hope to have a future opportunity of conveying to the Academy, as I have commenced some analyses of the waters which have dripped from the roof of the Cave of Dunmore. But I am compelled for the present to fall back on the accounts of various waters already published by different authors.

In Dr. Sterry Hunt's paper on the Chemistry of Natural Waters,* a series of nineteen analyses of various American waters is given, in five of which carbonate of lime is much in excess of carbonate of magnesia, and in some others chloride of calcium is in very large proportion to that of magnesia. In the remainder, however, the amount of carbon-

* *Op. cit.*, p. 92, *et seq.*

ate of lime and of carbonate of magnesia is about equal. These are the only analyses of water I have seen in which the amount of magnesian salts at all approaches that of the lime salts.

In the valuable abstracts of chemico-mineralogical papers published in the Journal of the Chemical Society, from vol. ix. to vol. xiv., inclusive, I find very many analyses of mineral waters, with one or two exceptions European, ordinary river water, chalybeate and thermal springs, &c. In all of these the carbonate of lime is in great excess of that of magnesia; the chlorides also occupy the same relative position. In all these analyses there is no instance to the contrary. The proportions are very variable of course, in some cases carbonate of magnesia being altogether absent. The lowest proportion in which it is stated in any of these is *

| | |
|---|---|
| Carbonate of lime, . . . . . . . . | 145 |
| ,, magnesia, . . . . . . . | 7 |

The highest is,† for total lime and magnesia salts: they are calculated only as oxides—

| | |
|---|---|
| Lime (Ca O.) . . . . . . . . . | 74·94 |
| Magnesia (Mg O.) . . . . . . . | 20·54 |

and the average proportion appears to be about 14 to 1.

About thirty or forty analyses are included in the above *resumé*. In no single instance was carbonate of magnesia in excess of carbonate of lime. All these scattered analyses are the more valuable in their agreement on the point I am urging, from their authors having, apparently, no particular theory to bring forward, and, though taken at random, the persistence in the larger amount of lime salts is very marked. I may now refer to the capital table of analyses of river waters given by Bischof,‡ which includes forty-eight examples, in every one of which carbonate of lime is very largely in excess of that of magnesia. These range as follows:—

| | | |
|---|---|---|
| Carbonate of lime, . . | 1·28 to 18·23 | In 100,000 parts. |
| ,, magnesia, . | 0·09 to 1·47 | |

In many cases no carbonate of magnesia is recorded at all, even where the corresponding lime salt is so high as 26·2, nor is there in any case a large proportion of the more soluble salts of magnesia, sulphate, or chloride. This shows, therefore, that carbonate of magnesia

* Chalybeate spring at Sellafield, near Whitehaven. W. H. Watson, Chem. News, xxxii., p. 11. *Abs.* Jour. Chem. Soc., vol. xiii., p. 1169.

† Rhine water, near Köln, Dr. Vohl. *Abs.* Jour. Chem. Soc., vol. ix., pp. 213–14.

‡ *Op. cit.* i., pp. 76, 77.

is nowhere so abundant in surface-waters as some writers on this subject apparently consider, and that we are justified in rejecting the statement that most dolomites are formed by infiltration of magnesian water, at least until more evidence on that head is produced.

It would appear, in fact, to be more reasonable to assume that the lime in limestone rocks was conveyed into them by percolation of mineral waters, than that the magnesia of dolomitic rocks so originated.

A very important paper bearing on this subject, and perhaps the only one in which it has yet been definitely treated, is that of E. V. Gorup-Besanez, on the Dolomite Springs of the Jura.* The author gives a series of analyses of waters of springs rising in the Jura, many of them in the neighbourhood of, or as it would appear, actually rising from, dolomitic limestones; and he finds that in some cases the carbonate of lime, and of magnesia, are actually present in dolomitic proportions. For instance, two springs give the following—

| | I. | II. |
|---|---|---|
| $Ca\ CO_3$, . . . | 57·32 | 57·21 † |
| $Mg\ CO_3$, . . . | 42·68 | 42·79 |

This is very remarkable indeed.

Some of the analyses gave, however, the following :—

| | | | | |
|---|---|---|---|---|
| $Ca\ CO_3$, . . . . | 88 | 89 | 70 | 68 |
| $Mg\ CO_3$, . . . . | 12 | 11 | 30 | 32 |

and the mean of the analyses was—

| | |
|---|---|
| $Ca\ CO_3$, . . . . . . | 53·71 |
| $Mg\ CO_3$, . . . . . . | 14·29 |

The author is led to agree, therefore, with Bischof in the opinion that, from *perfectly formed dolomites*, water containing carbonic acid dissolves out $Ca\ Co_3$ and $Mg\ Co_3$ together in fixed proportions,‡ but does not coincide with him in the idea that the presence of magnesite in cavities of the magnesian limestone prove the dolomite to be a perfectly formed one,§ since crystalline magnesite would not be deposited from such solutions. He considers the geological formation of dolomite a subject yet quite unsettled, and is opposed to Bischof's admission

* Ann. Chem. Pharm. Suppl. Band. viii., 230–242. *Abs.* Jour. Chem. Soc., vol. x., p. 59.

† In all the analyses, other constituents proved too trifling for notice.

‡ See Bischof, Chem. Geol. iii., p. 196.

§ See Bischof, *op. cit.*, iii., p. 196.

that carbonated water may dissolve out only carbonate of lime until, at last, the proper dolomitic proportions are reached.*

It will be noticed, however, that in the analyses given in the paper just referred to, there is after all, in most of them, a considerable range of proportion outside the dolomitic limit, and the mean given of all the analyses shows that, in most cases, the magnesian carbonate cannot have been present to an extent of more than 14 or 15 per cent., and that in all, it is much less than the lime carbonate—thus completely verifying my experiments, and showing that those of Professor Rogers are not based on natural processes.†

I think, on the whole, it might be safely asserted that in every case where atmospheric water acts on a limestone rock, it will remove proportionately more carbonate of lime than carbonate of magnesia. The reason for this it would be difficult to give, seeing that there can be no doubt as to the somewhat greater solubility of magnesian salts under *laboratory* conditions.

If we suppose, however, that the carbonate of magnesia, in whatever proportion it is present in the rock, is originally combined *as dolomite*, it might account for what otherwise appears to be an anomaly. Is there any difficulty in supposing that the small amount of magnesian carbonate which it is known many corals and molluscan shells contain, sometimes reaching as much as 7·6 per cent., may have been secreted as dolomite?

Forchammer has shown that some corals, annelids, and molluscan shells, contain an appreciable quantity of carbonate of magnesia; in the annelidæ especially it being very high (7·6 per cent.) Bischof, commenting on this fact, remarks, the limestones formed by *serpulæ, corallium, isis*, and probably other genera, ought to be termed dolomitic limestone.‡

It is possible that many other organisms, such as build up rocks, secrete carbonate of magnesia to a perceptible amount. Many plants also secrete carbonate of magnesia, and it is just possible that in such cases the carbonate of lime and of magnesia may be combined as dolomite. In such an event the removal of the excess of carbonate of lime, which might in these instances be regarded as a matrix, would soon result in a dolomite.

It cannot be said that the foregoing analyses of waters prove much with regard to the relative solubility of the carbonates, since we have

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* See Bischof, *op. cit.* iii., pp. 162, 196, 200, 203, &c. Bischof does not, however, entirely favour this theory, which is Grandjean's, not his own, but allows merely that such a process is possible in some cases.

† Bischof asserts that even springs rising in dolomite must always contain more carbonate of lime than of magnesia, as, from his experiments, carbonated water extracts little or no carbonate of magnesia from dolomitic rocks—*op. cit.*, vol. i., p. 81.

‡ Bischof, *op. cit.*, vol. i., p. 183; vol. ii., pp. 48, 49.

in few instances any information as to the composition of the rocks over or through which they passed; and these rocks may have contained but a trace of magnesia. But we can assert this much; that on the generally received notion as to the relative solvency of those bodies, and with which, save in the event of their being combined in rocks—when it certainly seems to reverse its behaviour—I must coincide, the result of such waters percolating through rocks would be, if anything, to form limestone, and not dolomite, since the carbonate of lime being more abundant, as well as less soluble than the carbonate of magnesia, would be more likely to be deposited. In all these supposed infiltration theories too, the bulk of the rock would necessarily be increased, unless it is taken for granted that some of the carbonate of lime is removed in the process, and replaced by carbonate of magnesia.

The only way in which the production of at least the Irish dolomites can be accounted for is, by the gradual removal of the excess of carbonate of lime. It is quite possible, and indeed likely, that in such a process, as the solution contains some carbonate of magnesia, a part of it in the form of dolomite may be deposited in a different part of the rock from which it was derived; the waste of one portion going to help to build up another.*

One point in favour of the abstraction theory is, that the Irish dolomites are exceedingly porous, cellular, or cavernous. Another curious point is that the cavities are almost invariably filled with calcspar; and not bitter spar or dolomite, as is generally stated. I have carefully examined the dolomitic limestones which occur so plentifully in the Counties Carlow and Kilkenny, and are spread over a large area, as well as some in the Counties Waterford, and Tyrone; and I can safely say that in no case have I found specimens of dolomite or magnesite in the cavities, but, on the contrary, calcspar most abundantly.

At Drumreagh, near Coal Island, Co. Tyrone, several beds of dolomite are interbedded with the ordinary blue fossiliferous limestone, and one of the beds merges gradually into the limestone, showing conclusively that it is metamorphosed limestone, and not the result of original chemical deposition on the sea bottom, according to Dr. Sterry Hunt's theory of such rocks. It is a light brown, extremely hard, crystalline, but compact dolomite; but so very cavernous that it is most difficult to obtain a fracture of it showing the true structure. The cavities are often large, as much as a foot in diameter, and coated, or often entirely filled, with nearly pure calcite, which may be obtained in large, nearly transparent rhombohedrons. The dolomite is perfectly unaffected by acid, in the cold. I should say that fully half the original rock is wanting, being now only represented by the spar-coated cavities.

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* I think Bischof makes a similar suggestion.

It is perfectly clear that these cavities were produced by the action of water, no doubt acting on the more calcareous parts of the rock, which of course would not be homogeneous in composition. Such a removal of the lime in one part might be accompanied nearly simultaneously by the deposition in a previously formed cavity of some of the material brought away. The calcareous water trickling down the sides of such a vacancy would have a good opportunity of evaporating, and depositing its freight. It is possible in such cases both the percolation and the evaporation of the water would be slower, and more uniform than in large caverns; and thus largely crystalline masses of calcite would result, instead of finely crystalline stalactites.

This cellular character of dolomitic limestone is exceedingly well shown in a quarry at Loughry, near Cookstown, County Tyrone, in which is the following section:—

*Section at Rockhead, near Loughry.*

| | Feet. | Inches. |
|---|---|---|
| 3. Boulder clay, . . . . . . . . . | 5 | 0 |
| 2. Purplish crystalline encrinital limestone passing downwards into purple dolomitic limestone, with large cavities, | 3 | 10 |
| 1. Sandstones and grits, . . . . . . | 7 | 1 |
| | 15 | 11 |

The upper beds, which are dolomitic, are eaten away in curious cavities, as shown in the sketch (fig. 1, Plate 41). These were possibly formed during the alteration of the limestone. They could hardly have occurred since, because dolomite once formed is so insoluble. The cavities also are coated with calcspar.

In the south-east of Ireland the carboniferous limestone is much dolomitised, and affords good opportunities for the study of that mineral. In some places, as in the county Carlow, a persistent band of black dolomite extends for miles, as may be seen on glancing at the Carlow Sheet of the Geological Survey Map.* Here it occupies such a definite position in the carboniferous series, that it might be taken to be an important division of it. The rock, where perfect, is hard, compact, and sub-crystalline, but it is wonderfully cellular, fully a third of it being wanting. The cavities are, so far as I can judge, coated only with calcspar. After many searches I was unable to find a single specimen of bitter spar, or dolomite, which can only occur here in a very few isolated localities, if at all.

Professor Jukes made a certain distinction between varieties of the

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* Sheet 137.

dolomites of the south of Ireland, *i. e.*, dolomites of original deposition, and dolomites produced by alteration of the original rock, with the former of which the Carlow rock appears to have been classed, while that of Kilkenny is supposed to be metamorphic. I rather think, however, that they both are metamorphic, only in different degrees.

The Kilkenny magnesian limestones are true dolomites both in appearance and composition. They contain from 30 to 44 per cent. of carbonate of magnesia; they are usually very crystalline, of a light yellow to a pearly grey colour, and do not effervesce when treated with acid, except occasionally in the interstices between the crystals, owing to infiltrated carbonate of lime. They are remarkable for the same cellular or cavernous structure which I have noticed in all the other dolomites of Ireland; the vacancies being coated, or filled entirely with calcspar. In some places the material has been removed in an exceedingly curious manner, the vacant spaces running parallel to each other, and forming apparently lines of bedding, which, however, they are not, as the true bedding is often also visible in such instances. Sometimes they give the similitude of false or current bedding, as is shown in the sketch (fig. 3, Plate 41).

As a rule, the bedding *is* obliterated, and in weathering the rock assumes at the surface of the ground, or wheresoever else exposed, a ruggedly pointed aspect, as if dipping vertically, along the lines of joints; and this often gives rise to picturesque hillocks or escarpments; the dolomite remaining, while the more easily dissolved limestone is eaten away to a lower and more uniform level, contrary to the general idea which assumes that dolomite is more soluble than limestone, because under certain influences it disintegrates more rapidly.*

Near the city of Kilkenny very extensive masses of dolomite occur, which could only have been formed by the metamorphism of the original limestone; and in one locality—Riverview, 1½ miles west of the town—there is a very fair opportunity of studying the mode of its production. And it will be seen that this can be reasonably explained

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* A well-known instance of this is shown by the decay of the stones used in the present Houses of Parliament, being magnesian limestones from the Mansfield Woodhouse quarries, and from Anston, Yorkshire. (See Building and Ornamental Stones, Prof. Hull, p. 200.) Under the influence of the vitiated atmosphere of London, some of this stone soon commenced to crumble away. It must be remembered that the disintegration of dolomite is not due always to the dissolution of the whole rock, but is most often merely the result of the solution of the carbonate of lime, which cements the crystals of true dolomite together. Any one who has observed the process of weathering of dolomites will remember that the minute crystals of which the rock is composed merely fall away from each other, resulting in a loose sand-like mass, but they do not readily decompose.

According to Ansted, the most durable magnesian limestones, for building purposes, are those containing nearly equal parts of carbonate of lime and of magnesia *in a state of perfect combination*—that is, true dolomite.—See Ansted's Geological Science (Orr's Circle of the Sciences), p. 208.

on the theory put forward already, that is, the extraction of carbonate of lime from the limestone rock.

A small stream runs from the railway down to the Nore at this place. On one side of it, to the south, dolomite crops out, with its usual rugged aspect. On the other side, blue fossiliferous limestone. At first sight it would seem that the limestone ended abruptly against the dolomite, but in reality it dips underneath it. The dolomite presents the usual characteristics, being highly crystalline, and full of drusy cavities, with calcite. The limestone is a compact bluish rock, in thick beds; the upper beds are magnesian, although not yet dolomitic, but they are beginning to show the drusy cavities, and are undoubtedly some distance on their way in the direction of dolomite. The most interesting fact, however, is, that between every individual bed of the limestone is a thick layer, or rather bed of calcite, from three to nine inches thick; and this is even visible on the top of the uppermost bed, which there is overlaid by a thin coating of drift clay or soil; but eventually disappears under the dolomite. (See fig. 2, Plate 41.)

Now it is perfectly evident that the calcite layers are derived from the limestone beds above them. It would be difficult to prove that each layer was derived solely from the immediate bed above it, but this is not impossible. The calcites are of a fairly uniform thickness, and the quantity abstracted from the overlying beds would be quite sufficient to alter very materially the composition of the limestone. These beds are about eighteen inches thick, and the corresponding calcites three to nine inches. Taking the latter, and assuming, for argument sake, that the limestone originally contained about 12 per cent. of carbonate of magnesia, the removal of sufficient calcite to form a layer nine inches thick would increase the percentage of magnesia carbonate in the limestone to over 20 per cent., which would nearly correspond to the composition of some dolomites.

One other point with regard to the Irish dolomites I have already partly referred to—viz., that they help to supply further evidence in refutation of Dr. Hunt's theory as to the origin of dolomitic rocks, that is, their original deposition as sediments from an evaporating sea basin, and subsequent modification by heat. I cannot do better than here quote more fully Dr. Hunt's words. (See "Conclusions" of his paper on the Chemistry of Dolomites and Gypsums.*) "Dolomites, magnesites, and magnesian marls, have had their origin in sediments of magnesian carbonate, formed by the evaporation of solutions of bicarbonate of magnesia. These solutions have been produced either by the action of bicarbonate of lime upon solutions of sulphate of magnesia, in which case gypsum is a subsidiary product, or by the decomposition of solutions of sulphate or chloride of magnesium by the waters of rivers or springs containing bicarbonate of soda. *The subsequent action of heat upon such magnesian sediments, either alone or*

* Chem. & Geol. Essays, p. 90.

*mingled with carbonate of lime, has changed them into magnesite or dolomite.*" I cannot see that this theory differs in any essential respect from that of Von Morlot (see *ante*, p. 705), which Hunt himself condemns; but it altogether fails to account for what frequently occurs near Kilkenny.

(1). The dolomites are often interstratified with ordinary blue limestone highly fossiliferous. The section at Riverview is one out of many that shows this. On the evaporation theory we should suppose a most extraordinary series of oscillatory movements, alternating between a deep and clear sea, fitted to sustain the life of corals and such organisms, and again a land-locked lagoon merging into a salt lake: all this repeated many times, in the process of producing a few hundred feet of the interstratified rocks. This is, I venture to say, inconceivable. In order to get a deposit of carbonate of lime alone, at least three-fourths of the sea water must be evaporated, as Bischof has shown;* but even then the carbonate of magnesia will remain in solution a considerable time longer. By the time the water became sufficiently dissipated for the latter to subside, the sea would have become a veritable pickle in which few organic forms could live.† Yet we have highly fossiliferous dolomites, which would prove that the animals lived in the sea water during the time of the deposition of those rocks, and that, during a very considerable time besides. In fact, on the evaporation theory we should have only the following distinct groups:—(1), carbonate of lime; (2), magnesite; (3), gypsum; (4), common salt; but no dolomite. It is quite possible, however, that some dolomites, such as those of the Permian formation, may have been indirectly the result of evaporation; thus, that during the process of concentration a greater amount of carbonate of magnesia might be assimilated by the animals then living in the lagoon; and thus that the alteration to dolomite might be sooner effected afterwards. It seems to me that it is only by this assimilation, and the subsequent removal of the excess of carbonate of lime, that large masses of dolomite could be formed; for if we consider the very small percentage of carbonate of magnesia or lime present in sea water, and suppose even a portion of it enclosed in a position favourable to evaporation, it is clear that the beds of sulphate of lime, and of the chlorides, would bear an enormous proportion to those of carbonate of magnesia or lime, or to dolomites.

(2). Again; were the dolomites originally deposited chemically, they should form perfectly definite beds—dolomite, and nothing else. It would be perfectly impossible, under any circumstances of evaporation, to have the same bed at one place limestone highly fossiliferous, and at another (a few yards off) truly dolomitic, the fossils

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* Chem. Geol., i., p. 177.

† Except perhaps those remarkable salmon which, as related by Smollett, in "Humphrey Clinker," the Scottish laird kept in a tank, to which he gradually added more and more salt, &c.; so that at last they could be taken alive ready pickled!

altogether obliterated. But this is a constant occurrence among Irish dolomites.* I have already referred to one instance of it in the Co. Tyrone; it is also frequent in the County Kilkenny, in many places within a circle extending from Gowran to near Ballyragget; and I have hand specimens showing the gradual alteration, the fossils being completely obliterated, and the blue limestone at one side becoming perfect crystalline dolomite at the other. Large masses of dolomite are seen, which, when traced out, are found to abut against and merge into limestone, and in some places, as at Ballyfoyle, there will be as many as twenty or more alternations of limestone and dolomite in a distance of less than half a mile; the limestone always full of marine fossils, by no means dwarfed in appearance. (See figs. 4, 5, 6, Plate 42).

[*Note added in Press.*—I have mentioned that limestones are by no means homogeneous in composition, and that the cellular structure would be capriciously determined by the most calcareous, and therefore most soluble parts. I have lately analysed some limestones from Ballyfoyle, which are interlarded with and pass into dolomite. The following were made from specimens of the same bed, taken a few yards apart:—

ANALYSIS OF LIMESTONE FROM BALLYFOYLE.

| | I. | II. |
|---|---|---|
| Carbonate of lime, . . | 87·72 | 91·06 |
| ,, ,, magnesia, . | 3·80 | 1·00 |
| Ferric oxide and alumina, | 2·52 | 2·05 |
| Insoluble residue, . . . | 5·80 | 5·70 |
| | 99·84 | 99·81 |

SPECIFIC GRAVITY, 2·89.

*Specific Gravity of Dolomite.*—On the principle I have advocated, viz., the removal of carbonate of lime from limestones, and the consequent porosity of the resulting dolomite, the specific gravity ought to be less than that of limestones. I am aware that Dr. Apjohn has, in the paper already cited, stated the contrary; but it must be remembered that the determination is rendered very difficult in the case of dolomite by the circumstance that, while in the mass, it is porous and cellular, and *must* be of less specific gravity than limestones, which are compact—the small pieces, which could only be weighed on our balances, are usually compact. However, those I have tried certainly possess a lower specific gravity than limestone. This is shown in the examples given above of the Ballyfoyle dolomite and limestone.]

* Bischof refers also to this fact as common to dolomitic formations.

*Crystallization.*—The very distinct crystalline appearance of dolomite is a matter requiring important consideration, but it is in truth one of the chief difficulties of the whole question. From whatever stand-point we approach the subject, and whatever the theory which we adopt may be, this is not very easy to account for. The infiltration of carbonate of magnesia could hardly of itself afford this peculiar structure, for it would only give a perimorph, or at least a pseudomorph, of magnesite, by replacing part of the carbonate of lime in the calcite. But even magnesite after calcite is not frequent. Blum and others refer to it as occasionally occurring in lodes, and in geodic cavities; but it is not likely often to be discovered, for Bischof found it impossible to effect any decomposition between carbonate of lime, and a solution of bicarbonate of magnesia.*

On the other hand, all limestones, with the exception of the earthy varieties, are more or less crystalline, and the crystals of calcite differ only to a very slight amount from those of dolomite—so little that the principal angle of the rhombohedron of calcite being 105°5′, that of dolomite is 106°15′, a difference quite inappreciable, without the aid of delicate instruments. This being so, if a quantity of superabundant carbonate of lime be removed from a highly magnesian limestone, such as would, according to Bischof, be formed by the agency of certain organisms, the crystalline structure would appear very distinctly, even in magnesian limestones that were still far removed from dolomites. In fact in few dolomites are the crystals really distinct until the rock has begun to decompose, and I could point out many localities near Kilkenny where true dolomites are perfectly compact, to all appearance, where unweathered, but once attacked by the atmosphere show themselves to be highly crystalline; the process being just what I have suggested above, viz., the removal of the superfluous carbonate of lime. This is, however, an extremely difficult province of the question to enter upon, and an opinion on it is not to be advanced without great diffidence, during the existing state of our information about it.

*Conclusions.*—(1). It appears, therefore, that the Irish carboniferous dolomites could not have been completely originated by organic agency, nor could they have been formed by chemical deposition due to evaporation of sea water; and there seems to be evidence of few other dolomites being formed in the latter way.

(2). The experiments recorded in the preceding paper, showing the much greater solubility of carbonate of lime than of carbonate of magnesia, from rocks treated with a carbonic acid solution, appear to bear out the theory that dolomite may be formed by the extraction—by water holding in solution small quantities of carbonic acid—of the excess of carbonate of lime from magnesian limestone rocks.

In this way, also, it is easy to account for the fissures and cavities

* See Note to p. 708.

so common to dolomites, and the filling up or coating of these cavities with carbonate of lime.

The frequent occurrence of quantities of carbonate of zinc in dolomites may also be explained thus : the concentration, simultaneously, of the carbonates of zinc and of magnesia being accomplished by the removal of the carbonate of lime.* The resulting dolomite being then less soluble that the carbonate of zinc, the latter would be dissolved out and again deposited alone in the lower cavities of the rock.

On the other hand, the percolation of water containing carbonate of magnesia would add to the bulk of the mass, unless something was abstracted in place of the carbonate of magnesia deposited. This could only be carbonate of lime, but Bischof's experiment is against that. Besides, as water usually contains about ten times as much carbonate of lime as of magnesia, were any deposition to take place, the lime would certainly be deposited before the magnesia, and would not only increase the bulk, but neutralise the dolomitization.

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* I have already pointed out that zinc is nearly always associated with, or an accessory of, magnesian minerals. *Vide* On the supposed Substitution of Zinc for Magnesium in Minerals, Proc. Roy. Ir. Acad., 1874.

# PLATE 40.

ILLUSTRATIVE OF DR. PERCEVAL WRIGHT'S PAPER "ON A NEW GENUS AND SPECIES OF SPONGE."

*Vide* Proceedings R. I. Acad., Vol. 2, Ser. 2, p. 754.

Fig. 1. Kalispongia Archeri, gen. et spec. nov., × 50 (side view).
2. ,, ,, front view of head portion, × 50, of another specimen.
3. ,, ,, stem portion of an apparent variety, × 50.
4. ,, ,, portion of tissue of stem, × 250.
5. ,, ,, ,, ,, of head, × 250.

## PLATE 41.

ILLUSTRATIVE OF MR. HARDMAN'S PAPER "ON THE IRISH CARBONIFEROUS DOLOMITES."

*Vide* Proceedings of R. I. Acad., Vol. 2, Ser. 2, p. 705.

Fig. 1. Rockhead Quarry, Loughry, Co. Tyrone.

2. Section at Riverview, Co. Kilkenny.
   *a, a, a.* Dark grey limestone.
   *b, b, b.* Intervening layers of calcite.

3. Dolomite, near Jenkinstown, Co. Kilkenny, showing cellular structure simulating "current bedding," the cavities filled with calc-spar.

# PLATE 42.

ILLUSTRATIVE OF MR. HARDMAN'S PAPER "ON THE IRISH CARBONIFEROUS DOLOMITES."

Fig. 4. Plan of limestones and dolomites, Ballyfoyle, Kilkenny.
5. Section at Ballyfoyle, showing limestone passing into dolomite.
6. Enlarged section at (*a*), fig. 6, showing passage of limestone into dolomite.

## PLATE 43.

ILLUSTRATIVE OF DR. MOORE'S PAPER "ON IRISH HEPATICÆ."

*Vide* Proceedings R. I. Acad., Vol. 2, Ser. 2, p. 591.

Fig. 1. Lejeunea patens, Lindberg; natural size.
2. ,, ,, × 15.
3. ,, ,, × 30.
7. ,, leaf and portion of stem, × 100.
8. ,, amphigastrium, × 100.
9. ,, portion of leaf, mag. × 400.

Drawn from specimen supplied by Dr. Lindberg.

4. ,, dorsal aspect of plant, with colesule and male amentulæ, × 25.
5. ,, branch, with colesule, × 50.
6. ,, ventral aspect of plant, with male amentulæ.

Drawn from plant collected at Glenad, Co. Leitrim, 1875.

# PLATE 44.

ILLUSTRATIVE OF DR. MOORE'S PAPER "ON IRISH HEPATICÆ."

*Vide* Proceedings R. I. Acad., Vol. 2, Ser. 2, p. 591.

Fig. 1. Lejeunea Moorei, Lindberg; natural size.
2. ,, ,, × 10.
3. ,, ventral aspect of plant, showing colesules and male amentulæ, × 25.
4. ,, leaf and portion of stem, × 50.
5. ,, amphigastrium, × 100.
6. ,, portion of leaf, × 400.

## PLATE 45.

ILLUSTRATIVE OF DR. MOORE'S PAPER "ON IRISH HEPATICÆ."

*Vide* Proceedings R. I. Acad., Vol. 2, Ser. 2, p. 591.

Fig. 1. **Frullania Hutchinsiæ, β integrifolia, Nees; natural size.**
2. ,, ,, × 10, with male amentulæ and colesules.
3. ,, leaves and portion of stem, × 25.
4. ,, amphigastrium, × 75.
5. ,, portion of leaf, × 400.
6 & 7. ,, portion of stem, leaves and amphigastrium of typical form of *a*. after Hooker.

# PLATE 46.

ILLUSTRATIVE OF DR. M'NAB'S PAPER "ON A REVISION OF THE SPECIES OF ABIES."

*Vide* Proceedings R. I. Acad., Vol. 2, Ser. 2, p. 673.

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In the Description of Plates 46, 47, 48, and 49, all the figures are magnified 20 diameters. The letters refer to all the figures—e. Epidermis. h. Hypoderma. c. Resin-canals. s. Sheath of the fibro-vascular bundles.

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Fig. 1. Abies bracteata. From specimen cultivated at Elvaston Nurseries, Borrowash, Derby.

2. ,, religiosa. From specimen cultivated at Castle Kennedy, N. B.

3. ,, amabilis. From a graft, from Douglass's plant, cultivated in the Royal Botanic Garden, Edinburgh.

3*a*. ,, amabilis. Near Lake Chilukweyak B. C.; Cascade Mountains, 49° N. lat., Dr. Lyall, 1859: Kew Herbarium.

4. ,, grandis. From a layer, from Douglass's plant, cultivated in the Royal Botanic Garden, Edinburgh.

4*a*. ,, grandis. From a specimen raised from Jeffrey's seeds, and cultivated in the Royal Botanic Garden, Edinburgh, as A. lasiocarpa.

5. ,, Lowiana. From a specimen raised from Jeffrey's seeds, and cultivated in the Royal Botanic Garden, Edinburgh.

6. ,, concolor. From Kew Herbarium: Fendler, "Pl. Novo-Mexicano," No. 828, 1847.

7. ,, lasiocarpa. From Kew Herbarium, "sp. typica," coll. Douglas.

7*a*. ,, lasiocarpa. From Kew Herbarium, unnamed specimen, marked "America Boreali-occidentalis," D. Douglas.

# PLATE 49.

ILLUSTRATIVE OF DR. M'NAB'S PAPER "ON A REVISION OF THE SPECIES OF ABIES."

*Vide* Proceedings R. I. Acad., Vol. 2, Ser. 2, p. 673.

Fig. 28. Abies sp. Drummond. From a specimen cultivated in the Royal Botanic Garden, Edinburgh.

29. Pseudotsuga nobilis. From a plant cultivated in the Royal Botanic Garden, Edinburgh.

29*a*. ,, nobilis. From a plant cultivated in the Royal Botanic Garden, Edinburgh, and sent under the erroneous name of A. amabilis of Douglas.

29*b*. ,, nobilis. Leaves from Kew Herbarium of the type specimen of P. amabilis, Sabine, Douglas, sent by Professor Oliver, F. R. S.

30. ,, magnifica. From a plant cultivated by Mr. Anthony Waterer, Knap Hill Nursery, near Woking, Surrey.

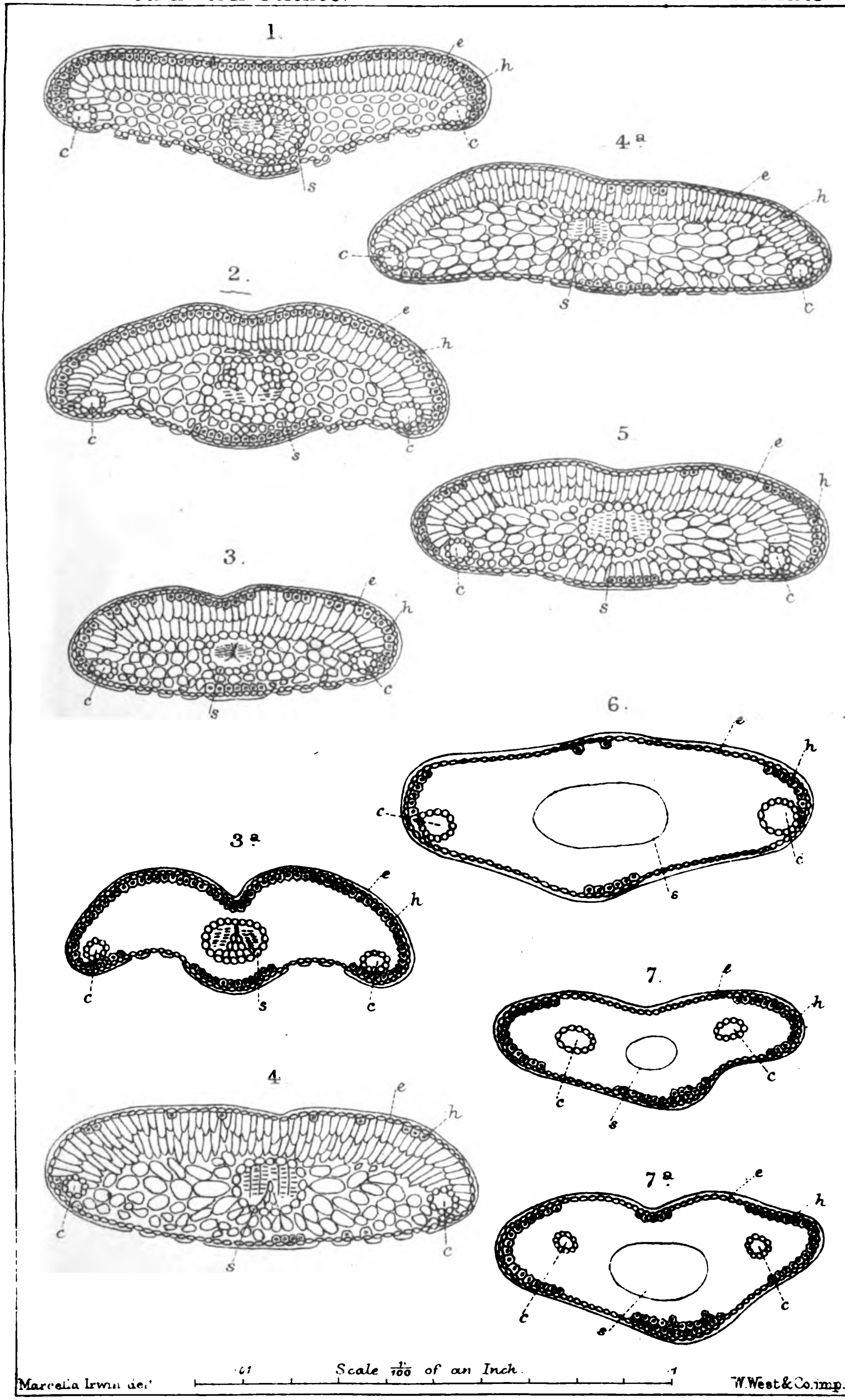
30*a*. ,, magnifica. Kew Herbarium: "441. 150–200 ft. Sierra Nevada, L. California. W. Lobb."

31. ,, Fortunei. From a plant cultivated by Messrs. Veitch and Son, Chelsea, and forwarded under the name of Abies Jezoensis.

32. ,, Douglasii. From a plant cultivated in Elvaston Nurseries, Borrowash, Derby.

32*a*. ,, Douglasii. Kew Herbarium : "Rocky Mountain, Independence Bluff. Nuttall."

32*b*. ,, Douglasii. Herbarium, Trinity College, Dublin : New Mexico, Fendler, No. 829.

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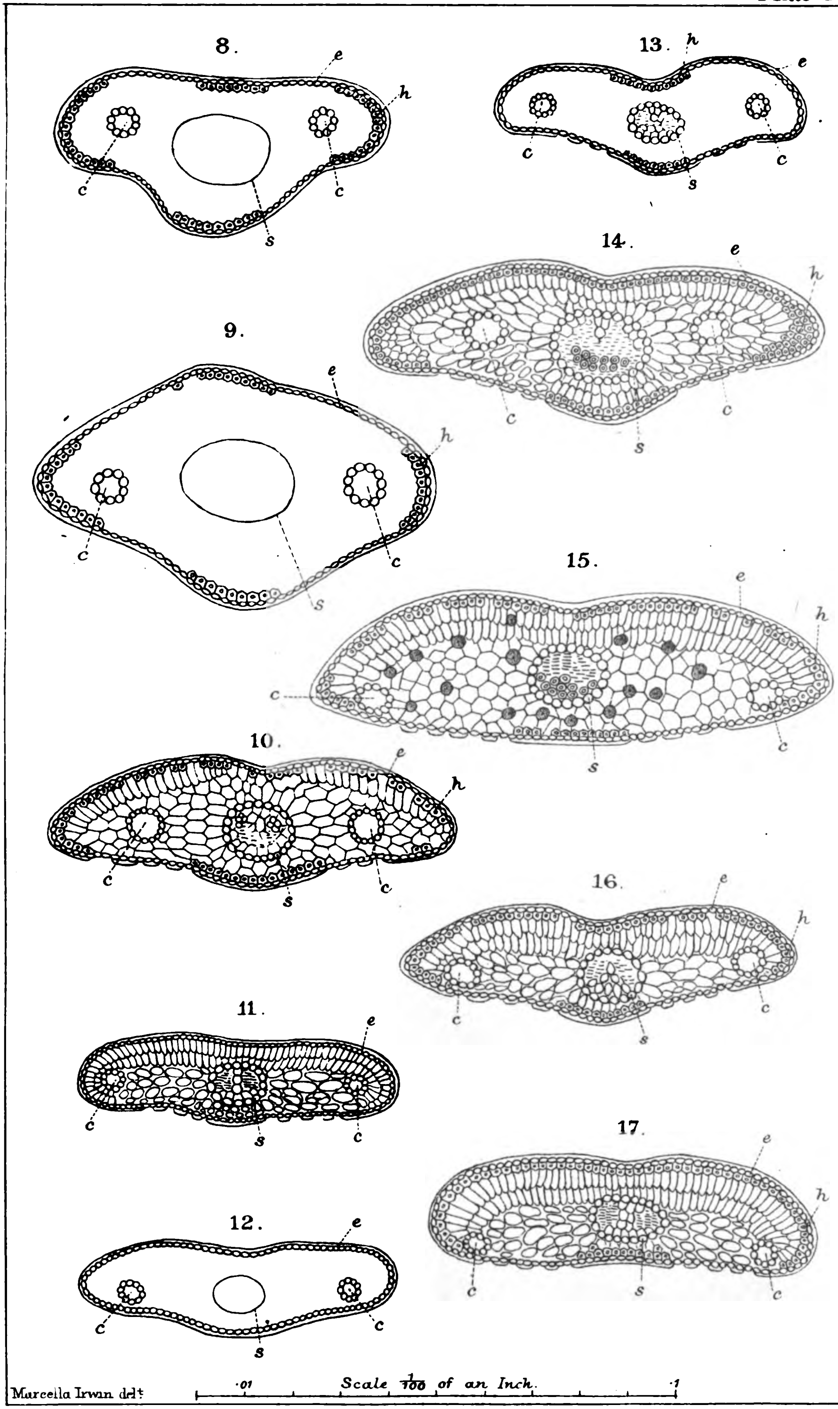


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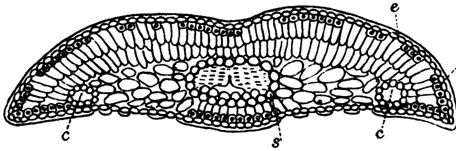


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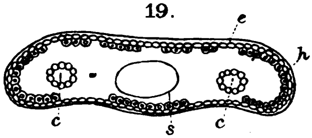


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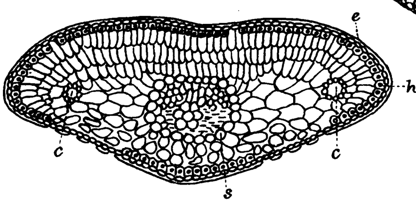


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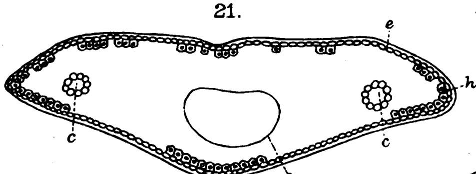


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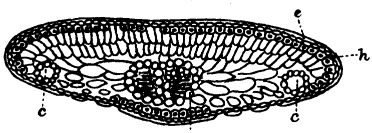


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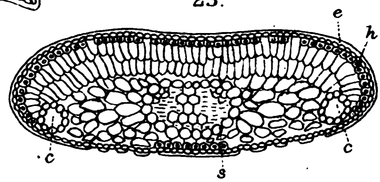


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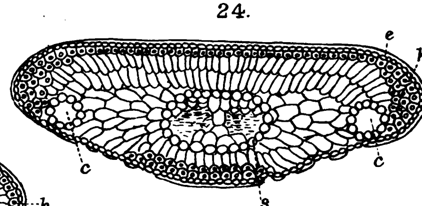


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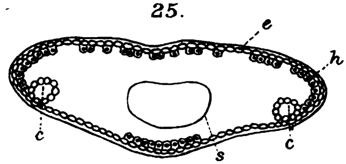


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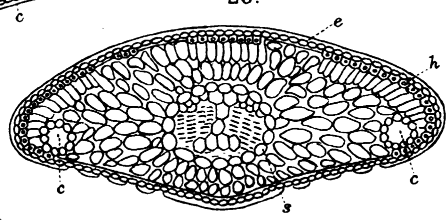


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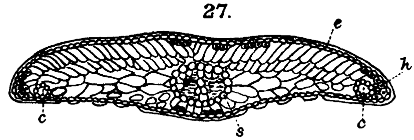
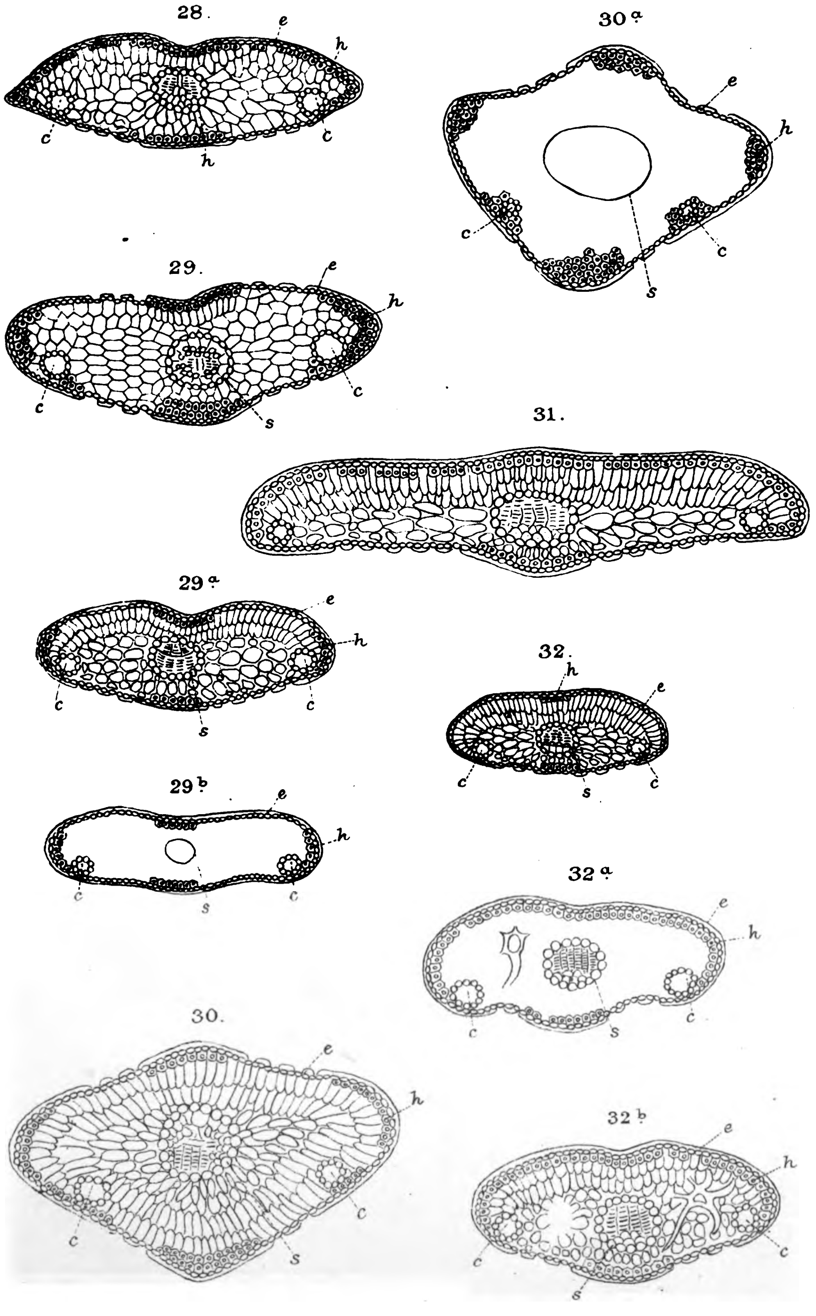



Marcella Irwin. del.^t ·01 Scale: 1/100 of an Inch ·1 W. West & Co. imp.

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