P. GREGUSS

IDENTIFICATION OF LIVING GYMNOSPERMS ON THE BASIS OF XYLOTOMY

AKADÉMIAI KIADÓ
BUDAPEST

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PREFACE

Great is the number of works published on the xylotomy of gymnosperms. They survey the earlier and the latest results, and treat of them in detail. Despite their great value and scientific significance, these books and papers are deficient in one respect: either they only deal with wood and its applicability as a commercially important raw material, or they are devoted to some single problem of detail, to some of the more important families or genera, and thus do not even attempt to provide a comprehensive guide to the identification of all living gymnosperms on the basis of xylotomy. Mostly they are without any good illustrations of the individual species, or if they do bring detailed photomicrographs and drawings, then the xylotomic descriptions in them are imperfect and incomplete. Yet, obviously, there is nothing that would more warrant success in the xylotomic identification of the genus or species of, say, a critical conifer than good photomicrographs and accurate drawings accompanied by detailed and exact diagnostical descriptions. Ready and reliable identification is undoubtedly of great practical importance, particularly at a time when archeology and palaeontology can no longer do without the latest results of the art of xylotomy, and when they are indispensable to a number of large industries such as the building, furniture, paper, cellulose and artificial silk industries, even the machine tool industry depending on them. With timber one of the most essential raw materials of the age, scientific research work on wood has become of paramount interest to national economy.

The writer's earlier work, entitled "*Identification of Central European Trees and Shrubs on the Basis of Xylotomy*", has received recognition in our branch of science. The present book is its continuation to embody the description of the xylotomic characteristics of the genera, and as far as possible of the species, of all the living gymnosperms and, in an appendix to the volume, of all the chlamydosperms. There is not one family or genus, respectively, among those of the known living coniferous plants of which at least one species would not be worked up in this book. Of some others, a quite considerable number of species is elaborated, e.g., 70 *Pinus* species, or about 80 per cent of all known to be living. (An independent work of the present author on the xylotomy of the *Pinus* was published in 1950).

In compiling this large-scale comprehensive work the first step was to obtain adequate material of a specification carefully determined in advance. Laborious efforts having secured it, the next task was to prepare microscopic sections, photographs, accurate drawings, detailed descriptions and to develop synoptic keys easy to handle and readily affording quick identifications of reasonable reliability.

The specimens were collected from the most different parts of the world. Requests for them met with ready compliance in all quarters. The writer wishes to record his thanks to all who most kindly facilitated his bringing together a collection rich enough for the purposes of the present work. For specimens furnished he is under particular obligation to Mr. J. W. ADAMS, Curator of the Morris Herbarium, University of Pennsylvania, Philadelphia, Pennsylvania; Mr. I. BÁNÓ, Scientific worker of the Forest Research Institute in Kámon, Szombathely, Hungary; Professor P. A. BARANOV, Assistant Director of the Chief Botanical Garden of the Academy of Sciences, Moscow, U.S.S.R.; Dr. Jutta BERGEMANN, Bundesanstalt für Forst- und Holzwirtschaft, Reinbeck, Bez. Hamburg, Western Germany; Mr. John T. BLACK, Cultural Officer of the Foreign Service of the U.S.A., American Legation, Budapest, Hungary; BOTANICAL GARDENS, KAUNAS, U.S.S.R.; BOTANICAL GARDENS, NEW YORK, U.S.A.; BOTANY SCHOOL, CAMBRIDGE, England; BOYCE THOMPSON ARBORETUM, Yonkers, New York, U.S.A.; Mr. H. CALLENS, Director of the Jardin "Gillet", Kisantu, Belg. Congo; Professor C. L. CHANG, Forest Chemistry Laboratory, Nanking, China; CHIEF FOREST PRODUCTS OFFICER, Forest Products Institute, Pretoria-

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partment of Agriculture and Natural Resources, Manila, Republic of the Philippines ; Mr. M. de VILMORIN, Director of the Arboretum des Barres, Nogent sur Vernisson, France ; Messrs. WEBNER (PTY.) LTD., Cape Town, South Africa, Mr. Alexander WOLSKY, Delhi, India. B. CHOLNOKY, Pretoria Universiteit, E. T. H. Laboratorium f. Holzforschung, Zürich, (H. H. BOSSHARD) Editor of Tropical Woods, New-Haven (W. STERN; Academica Sinica, Peking (DR. YU)

Wherever possible, use has been made of the results reported in the literature. Particular benefit has been derived from the following works : W. Gothan: Zur Anatomie lebender und fossiler Gymnospermenhölzer (1905) ; R. Kräusel: Die fossilen Gymnospermenhölzer (1949) ; I. Phillips: Identification of Softwoods (1948) ; E. C. Jeffrey : The Anatomy of Woody Plants (1917) ; K. Mägdefrau: Paläobiologie der Pflanzen (1953) ; W. Zimmermann: Phylogenie der Pflanzen (1949) ; Br. Huber: Mikroskopische Untersuchung von Hölzern (1952) ; W. Müller-Stoll: Mikroskopie des zersetzten und fossilisierten Holzes (1951) ; F. Hollendonner: Vergleichende Anatomie der Nadelhölzer (1913).

Not infrequently it was found difficult to decide on the use of botanical names. With a view to achieving uniformity in nomenclature, the names accepted are with a very few exceptions those adopted in A. Rehder's Bibliography of Cultivated Trees and Shrubs (1949) and Dalimore-Jackson's A Handbook of Coniferae (1948.)

All the drawings and photographs have been made and the descriptions drawn up, directly from the material itself.* To a certain extent, this independent originality was felt to be a drawback, for in a degree it precluded consideration of and comparison with the findings of other research workers. This is a deficiency of the present work, but one for which, in part at leart, des fart is respomible has the writer was unable to secure material for comparative purpotes from the same habitat and, what is more important, of the same age. Thus it was not always possible to decide, for instance, whether a certain histological feature, in most cases some peculiar arrangement of wood elements, to be found in a particular specimen, a piece of branch or stem, was a specific constant, or whether it was due in part to the modifying action of external conditions. (The capital letters *Y* and *M*, respectively, set at the end of each item in the keys, and at the termination of the preliminary remarks to the detailed description of the individual species, indicate whether samples of *young* or *mature* wood have been examined by the writer). In spite of these deficiencies, it is hoped that on the whole this book will help readers to find their way in the xylotomy of the extinct and living *Gymnospermae* and *Chlamydospermae*, and to identify critical woods on the basis of xylotomy.

*The Numbers in brackets at the end of each item in the keys, and at the termination of the preliminary remarks to the detailed description of the individual sqecies, refer to those works of earlier authors, enumerated in the bibliography, in which that particular wood has already been described from a xylotomical point of view.

On the completion of this work, the writer deems it his pleasant duty to offer thanks to Mr. Imre Horváth, a former student of his and university demonstrator, for having prepared a part of the sections and elaborated the genus *Picea ;* to Mr. István Varga, another of his students, now secondary-school teacher, for having assisted in working up the genus *Pinus ;* to Mr. Pál Simoncsics, the writer's assistant at the university, and to Mr. Béla Nemessányi, for their valuable help in preparing sections and copies of photomicrographs ; to Messrs. György Bodrogközy, József Matuszka and János Maácz, assistant professors of the university, for help given in the technical completion of the manuscript, in the making of some drawings and in the compilation of tables. Thanks are due to Dr. Margit Szabados, assistant professor of the university, and to Miss Lenke Gosztonyi, who under the guidance of the writer prepared the drawings of the individual species and helped to compile some of the tables ; to Mrs. Alajos Kalmár, administrative worker of the institute, who undertook the typing of the text and assisted in the execution of minor technical details.

The author it greatly indebted to his friends, Prof. Gábor Andreánszky and Prof. Árpád Haraszty, who have read the original manuscript and offered constructive suggestions; to Mrs. L. Jócsik, for having made the translation from the Hungarian, and once again to Prof. Gábor Andreánszky for the supervision of the English text. Las but not least the author wishes to record his heartfelt thanks to his wife, Dr. Therese Forray, who gave him invaluable help and the benefit of constant encouragement as the compilation of

the subject matter for this work progressed for ten years.

The writer is fully aware that this work, whatever its merits may or may not be, owes its perhaps not untimely completion to the collective efforts of these collaborators as well as to assistance by word and deed from other friends and acquaintances, to whom he likewise acknowledges his indebtedness.

In conclusion, the author expresses his sincere gratitude to the *Hungarian Academy of Sciences* for the financial support, which enabled him to compile and write this comprehensive and expensive work, and has made its publication possible. This book has been prepared in the Botanical Institute of the University of Szeged in the years of 1946—1954.

Szeged, December 31., 1954.

P. Greguss

CONTENTS

CIRCUMSTANTIAL PART

INTRODUCTION

Modern taxonomy divides the gymnosperms *(Gymnospermae)* into six classes (orders), namely :

I. *Pteridospermae* (Cycadofilices)
II. *Cycadinae* (Cycadales)
III. *Bennettitinae* (Bennettitales)
IV. *Cordaitinae* (Cordaitales)
V. *Ginkgoinae* (Ginkgoales)
VI. *Coniferae*

Of these, *Pteridospermae*, *Bennettitinae* and *Cordaitinae* are extinct, *Cycadinae* and *Ginkgoinae* have a few living species, while not fewer than about 550 living members are known of *Coniferae*. Phylogenetically intermediate between the gymnosperms and the angiosperms are the *Chlamydospermae* or *Gnetales* with three families : *Ephedraceae* including about 40, *Gnetaceae* about 35, and *Welwitschiaceae* a single living species. Wood anatomy furnishing manifold evidence of phylogenetic relationship existing between the *Gymnospermae* and the *Chlamydospermae*, these, too, require to be included into this work on comparative xylotomy, however briefly and if only for the sake of completeness.

Many relationships particularly interesting from the point of view of phylogeny have already been detected with the aid of comparative xylotomy. For this reason, although the primary aim of the present work is the anatomical identification of the *Coniferae*, it is not intended to neglect those histological characteristics of the other extinct and living gymnospermous and still existing chlamydospermous plants that will enable us to identify on a xylotomic basis not only recent but also fossil representatives of these phylogenetically extremely interesting types. Accordingly, over and above containing the xylotomic identifications of the living species of the *Gymnospermae* and *Chlamydospermae*, this work intends to show how the results flowing from them should be built into the framework of phylogenesis. The overwhelming majority of the studies undertaken refers of course to the living *Coniferae*, of which about 350 species are worked up in this book.

As to methodology, by way of introduction this book briefly acquaints the reader with the rudiments of a working knowledge of xylotomic identification, and of the indispensable technical procedures. Photomicrography, maceration, drawing, etc. are mentioned but fleetingly in view of the many valuable and very useful reference works and papers on these subjects. This is followed by a brief glossary of the technical terms used in the identification of woods. The book then proceeds to describe the manner in which by virtue of their anatomical characteristics wood sections and cuttings are classed into families as a preliminary to their final identification on the authority of generic and specific characters.

With a view to ensuring a higher rate of reliability in the identifications to be undertaken with the aid of this work, there are four different microphotographs and a plate of drawings submitted for each individual species. Identification work is believed to be further facilitated by a number of annexed tables permitting an easy survey of the xylotomical features of the individual species within the families.

GENERAL PART

PRELIMINARIES TO THE XYLOTOMIC EXAMINATION OF THE LIVING GYMNOSPERMS (ANATOMICAL TECHNIQUE)

a. SECTIONING OF MATERIAL

In identifications of gymnospermous woods on the basis of their xylotomy it is well to take account of a number of other than histological features. Generic or specific differences frequently manifest themselves on macroscopic inspection, e.g., in *specific gravity*, *colour*, *odour*, *taste*, *touch*, etc. However, the final exact identification of a critical piece of wood will always depend on microscopic examination. For this the sample to be identified has to be adequately prepared. The simplest procedure of course is to prepare appropriate *cross*, *tangential* and *radial* sections from freshly cut stems or branches. But seldom is such material received. Samples submitted for identification are usually in a dry condition, in which they are not suitable for being studied. For cutting sections they must first be softened by means of an adequate procedure. The direct way of softening a sample is to boil it for from one or two hours to two or three days, or to let it soak in water for two or three weeks. KISSER's boiler greatly facilitates the process. It makes it possible to reduce the dry material with a guided hot steam jet to the required grade of softness. In the absence of such an apparatus it is advisable to do the boiling or soaking in a 2 to 4% solution of caustic potash. Useful information on this point is contained in HUBER's Mikroskpoische Untersuchung von Hölzern (Mikrosk. i. d. Techn. V/1.) and KISSER's Die botanisch-mikrotechnischen Schneidemethoden (Abderhaldens Handbuch d. biol. Arbeitsmethoden. XI/4. 1939. 391—738).

Reichert sliding microtome and the *Sartorius* microtome, respectively, was used by the writer in cutting sections in the three main planes, i. e., in preparing cross, tangential, and radial sections from the properly pretreated material. In thickness they varied between 10 and 20 μ. The selected ones were immediately put in 3 to 4 cu. cm. of "Eau de Javelle" and heated to boiling over a small flame. They were then allowed to stand in the solution for an additional 8 to 10 minutes to ensure a degree of bleaching as high, and an extraction of the cellular contents as complete as possible. Occasionally, their contents make possibly occurring longitudinal parenchyma cells more readily observable in untreated sections. Excessive Javelle-treatment is not adviseble, because it makes the sections too soft. The next step was to transfer the sections from the alkaline solution into an acid medium (1—2% acetic acid) for neutralisation. From the acid bath they were removed into distilled water to be thoroughly washed in case they were to be stained. It is advisable to do the removal with the help of a brush because owing to the boiling and soaking the cuttings are liable to become weak in structure. Thereafter a part of the sections was stained either with malachite green or with fuchsin and picric acid. When applying basic fuchsin and picric-acid staining the sections were first thoroughly soaked in water, then put into a 2% aqueous solution of fuchsin for 20 minutes, thereafter washed, allowed to stand for 5 minutes in concentrated alcoholic picric acid (the solution having previously been diluted to the half), and finally washed in alcohol until they no longer released any dye. The reason for this procedure was that picric acid is known to blotch the staining of the sections. In the majority of the cases, the sections were subjected to carbonization instead of staining.

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b. CARBONIZATION PROCESS

From the writer's experience it would appear that carbonized sections are superior to stained ones for they are not only quick and easy to prepare but bring out contrasts in structure to better advantage.

Carbonization is carried out as follows: the same as in preparing for staining, the thin sections are first freed of their protoplasmic contents, in the manner described above, in order to prevent the latter from getting burnt into the cell walls impairing thereby microscopic examination and photographic reproduction. Thereafter the sections are subjected to dehydration by being immersed first into a 50%, then a 75% solution of alcohol and, finally, run up into absolute alcohol. Complete dehydration is indispensable because sections containing the least amount of water will crack and burn on the slides during the carbonization prrocess.

Dehydration effected, the sections are placed by means of a fine brush or a spatula between two carefully cleaned microscopic slides or glass (photographic) plates held together at both ends by film clips. Thin slides or glass plates should be used because thick ones are apt to crack when heated or cooled suddenly. The sections are then carbonized, under constant agitation, over a feeble Bunsen flame until they turn sandy-coloured, but in this the subsequent browning effect of the hot slides must duly be taken into account. Provided they have been properly cleaned and dehydrated, their own weight will cause the sections to slip readily from the clean slides free of fat. Should they fail to come off by themselves, a very thin razor blade will suffice to remove them from the slides.

Following carbonization, the sections are immediately immersed in xylol, allowed to stand for from 5 to 10 minutes, and then mounted in Canada balsam. Thin tangential and radial section require to be carbonized to a slightly darker colour than cross sections to contrast all the details of structure.

c. PHOTOMICROGRAPHIC REPRODUCTION

Employing the above-described procedure, sections were cut in three planes (cross, tangential, and radial) of each and every species dealt with in this work, and four photomicrographs were made of each of these sets containing three sections. The simplest picture of the inner structure of a wood is most conveniently observed in the cross section. This is the section that affords a good view of the width and delimitation of growth rings, of the pattern and arrangement of tracheids and parenchyma cells, of ray structures, a. s. o. These structural features are brought out to best advantage under moderate magnification. Accordingly, of the cross sections photographs were taken at very moderate (30 ×) magnification, and for the study of the finer structure, at moderate (100 ×) magnification. The tangential sections of a part of the material were also megnified 100 ×, but the rest of them and all the radial sections were enlarged 300 ×. By enlargement to this extent the finer details are made apparent and structural differences are more readily discernible. Uniformly, these three magnifications were used throughout the material so as to allow conclusions to be drawn from the comparative study of the individual species. Most of the pictures were taken with a "*Promar*" photographic apparatus of the system *Leitz*. In a very few instances, perhaps 10 to 15 in all, when photographing tangential and radial sections, it was not possible to get hold in a single picture of all the anatomical details characteristic of the particular wood; in these cases two parts of the identical section were photographed separately and their pictures fitted together subsequently. The very few pictures adapted in this manner are marked with an asterisk.

d. MACERATION

Histological examination of the individual species was not confined to the spatial arrangement of the tissue elements; in some cases it was extended to the finer structure of the elements building up the wood. For this purpose, the wood was reduced to its components, following *Schulze*'s procedure. (For a detailed description of it cf. Vol. I. of that author's work.)

e. REPRESENTATION BY DRAWINGS

Photomicrographic reproductions do not always reveal the finer morphological features of the various tissue elements. To make up for this deficiency, representation by drawings has been resorted to. Drawings were prepared at a scale of 1 : 300, exceptionally at 1 : 400, in the first place of the radial structure of rays, the structure of rays and tracheids, their pitting, and of the radial structure of tracheids in every type of wood dealt with in the present work. Their approximately identical scale facilitates comparing them. The actual scale applied is marked on each plate, and is easy to control. Photomicrographs and drawings are supplementary one to the other, and are explained in detail in the descriptions of the woods by species. The four photomicrographs, the drawings, and the detailed descriptions of the individual species together afford a reliable basis for, and greatly facilitate, the identification of the sample.

FUNDAMENTALS FOR IDENTIFYING WOODS ON THE BASIS OF THEIR XYLOTOMY

Successful identification of a coniferous wood on the basis of its xylotomy requires knowledge of its structural features, its elements, their spatial arrangement, a number of fundamental conceptions, etc. In addition, it must be kept in mind that each species is best characterized by the spatial arrangement of its elements. This invariably results in a peculiar pattern, visible to some extent to the unaided eye and repeating itself identically in the wood of practically all the species of the *Coniferae*. However, subjected to microscopic inspection, the inner structure, i. e. the shape and arrangement of the elements, reveal in the majority of the cases quite peculiar finer patterns characterizing the species.

Reference is made to Plate 1. This is a schematic drawing intended to assist the reader in understanding the technical terms used in this book, and to help visualizing the spatial arrangement of the individual wood elements. It has been designed by the writer, basing himself on the microscopic features of *Picea excelsa*, and was drawn, under his guidance, by MISS LENKE GOSZTONYI. It clearly shows the three main planes, in which wood is customarily examined. The section cut in the longitudinal plane dividing the cylinder is called the *radial section ;* in the text this is always denoted with the letter *R*. The section cut in the plane parallel with the long axis, and which is a chord of the curved surface of the tree, is the *tangential section*, and is referred to by the letter *T* in the descriptions of woods by species. Finally, the section cut in the plane transverse to the long axis, is the *cross* or *transverse section*. In the text and on the photographs this section is always denoted with the letter *C*. The numerals 1 to 4 in the text and on the photographs refer to the following : 1 denotes cross sections enlarged 30 × or 100 × ; 2 always denotes tangential sections enlarged 100 × ; 3 invariably indicates radial sections magnified 300 × ; and 4 tangential sections magnified 100 × or 300 ×. In the drawings, the various letters serve to obtain a clear conception of the positions of the tissue elements to be found commonly in the wood.

In the drawing on Plate 1, the thin-walled tissue elements in the axis of the young tree constitute the *pith* (No. 9). Sporadically, this is interrupted by transversely aligned thick-walled *sclerenchyma cells* (No. 10). The annular layer bounded by concentric cylinder jackets in the wood is called *growth ring* or *annual ring*, within which we distinguish *spring-* or *earlywood* (No. 7) and *summer-* or *latewood* (No. 8). Between two growth rings lies the *growth ring boundary*. The rows of cells passing radially across the growth rings are known as *xylary rays*, or *wood rays*, or simply *rays* (No. 12). The cells on the upper or the lower margins of a ray, differing from those in the body, are called *marginal cells* (or in *Picea* they are designated as *marginal tracheids)* (No. 14). Likewise in the rays there are the *horizontal resin ducts* (No. 6), while the *vertical resin ducts* (No. 5) extend parallel with the axis. The so-called *epithelial cells* (No. 15), which line the resin ducts, are thick-walled in *Picea*. The layer which covers the outer surface of the wood like a cylinder jacket is the *cambium* (No. 4). This underlies the *phloem* or *bast* (No. 3), which is bounded on the outside by the *periderm* (No. 2). The outermost continuous layer taking the place of the *epidermis* is the *paracortex* (No. 1). The portions inside the *phloem* and *cortex*, respectively, constitute what in the narrower sense of the word is called the *wood* or *xylem*. *It should be noted from the outset that the present work is solely concerned with these portions of gymnospermous woods, i. e., with the histological structure of wood or xylem*, leaving the phloem entirely out of consideration. Regarding the latter, the reader is referred to *Hohlheide*'s excellent book entitled "Anatomie mitteleuropäischer Gehölzrinden".

In *cross sections*, the more or less tiny pores visible sometimes to the unaided eye or through the lens are really the transverse sections of the longitudinal *tracheids* or other elements in the xylem.

In *radial sections*, the cellular bands of varying width, at right angles to the axis and visible sometimes to the unaided eye, are but the lateral surfaces of the *rays*.

In the *tangential sections*, the longitudinal cells

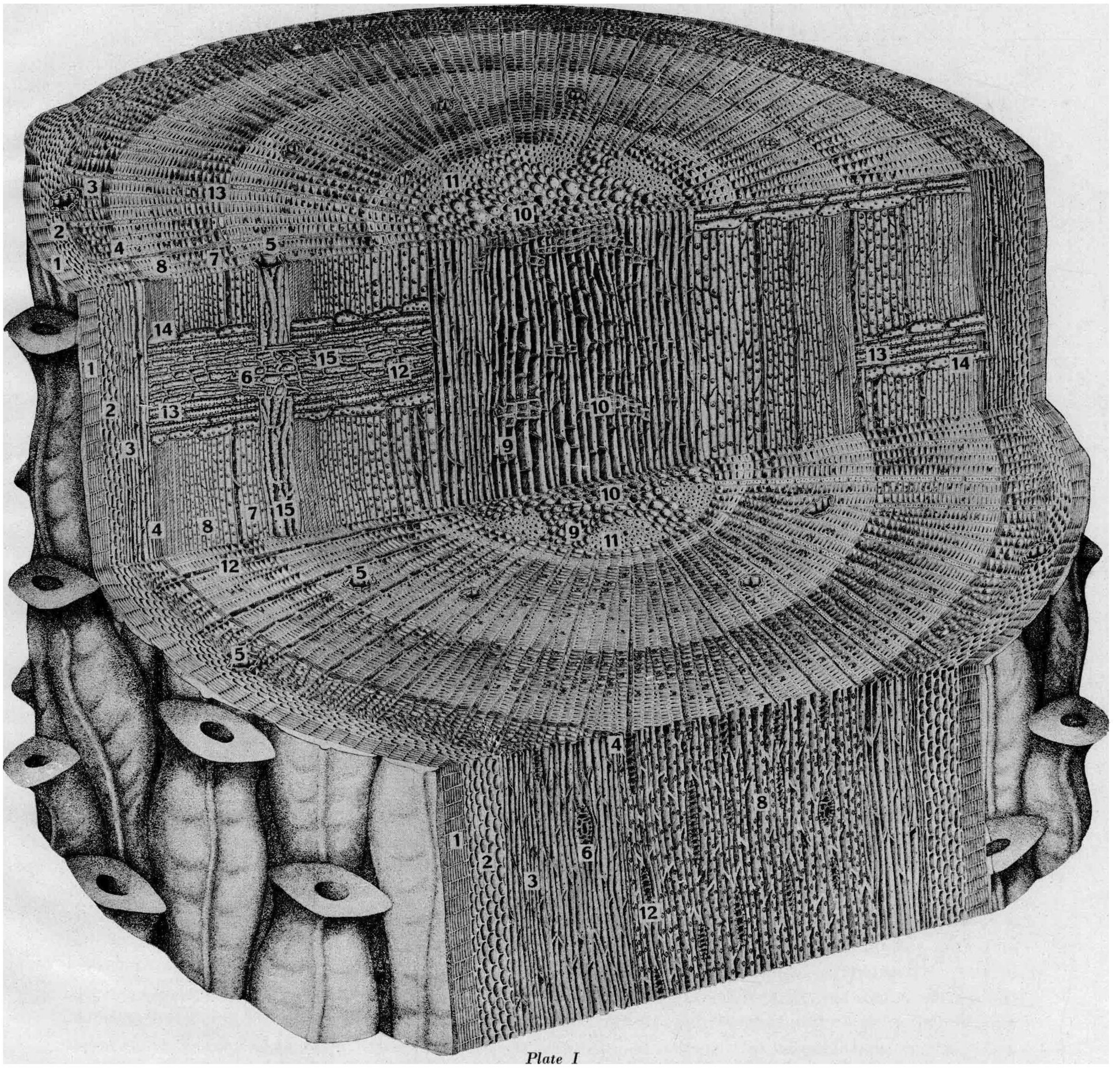


Plate I

Schematic drawing showing the wood of a 3-year old spruce twig in three planes of section. 1. Epidermis. 2. Periderm. 3. Phloem. 4. Cambium. 5. Vertical resin duct. 6. Horizontal resin duct. 7. Earlywood. 8. Latewood. 9. Pith. 10. Pith sclerenchyma. 11. Primary wood. 12. Medullary ray (seen in tangential view). 13. Thick-walled ray cells. 14 Marginal cells, transverse tracheids. 15. Thick-walled epithelial cells.

are really the tracheids in the wood, while the shorter but as a rule much sturdier cell rows represent the cross sections of *rays* (No. 12) and *resin ducts*, respectively.

But in addition to finding one's bearings by gross inspection microscopic examination of the wood is invariably required, and also a good knowledge of the essential fundamental concepts derived from the latter. The most important technical terms employed in descriptive softwood anatomy are given under the next caption, arranged alphabetically.

GLOSSARY OF TERMS USED IN IDENTIFYING WOODS

Alternate *(araucaroid)* pitting: bordered pits extending in oblique rows across the cell wall and polygonal due to crowding *(Araucaria, Agathis.* Plate IV, Figs. 32—34).

Annual ring: see growth ring.

Araucaroid pitting: see alternate pitting.

Autumn wood: see latewood.

Bark: the tissues of the stem and root outside of the cambium and consisting of *inner* living and *outer* dead bark (Plate I, Fig. 3).

Blind pit: a pit with its aperture leading into an intercellular space between two cells.

Bordered pit: a pit in which at certain points thickening of the secondary wall gives rise to semi-lentiform recesses with circular, rod-shaped, elliptic, or slitlike *apertures* in the middle. In surface view, bordered pits are round, ovoid, or angular (Plate IV, Figs. 32—33) (Text Fig. 2).

Bordered pit pair: two complementary bordered pits directly opposite each other on the walls of contiguous cells. In shape, the pair is suggestive of a biconvex lense. The equal-sized spaces in the two pits are separated by the pit membrane and the torus, respectively (Text. Fig. 2).

Callitroid thickening: the well-developed thickening bands surrounding the bordered pits of the tracheids in some *Callitris* species *(Callitris glauca.* Plate IV, Fig. 35).

Cambium: layer of meristematic tissue between the xylem and phloem (Plate I, No. 4).

Circoporoid pit: see dacrydioid pit.

Coefficient of rays: the ratio in the rays of rows of parenchyma cells to rows of horizontal tracheids. It is obtained by the formula

$$\text{coefficient of rays} = \frac{\text{number of rows of parenchyma cell}}{\text{number of rows of horizontal tracheid}}$$

Compound resin duct: see resin duct.

Compression wood: see redwood.

Crassulae: thicker portion of the intercellular layer above and below primary pit fields; formerly called *Bars of Sanio* or *Rims of Sanio* (Plate VII, Fig. 80).

Cross field *(also known as ray crossing)*: the area bordered by the horizontal walls of a ray cell and the vertical walls of a tracheid or wood parenchyma cell in back of it. Cross-field structure is very frequently of diagnostic significance (Plate VI, Figs. 60—74).

Crytals: occasional inclusions of calcium oxalate in the parenchymatous elements or tracheids (ray tracheids) of the wood. Their presence is sometimes of diagnostic value (Plate VII, Figs. 75, 76 and 77).

Cupressoid pits: pits in the cross field with their apertures invariably oblique or vertical in position; they themselves are oblique ellipses and the apertures lie in the direction of the latter's conjugate axis (Plate VI, Figs. 65—70).

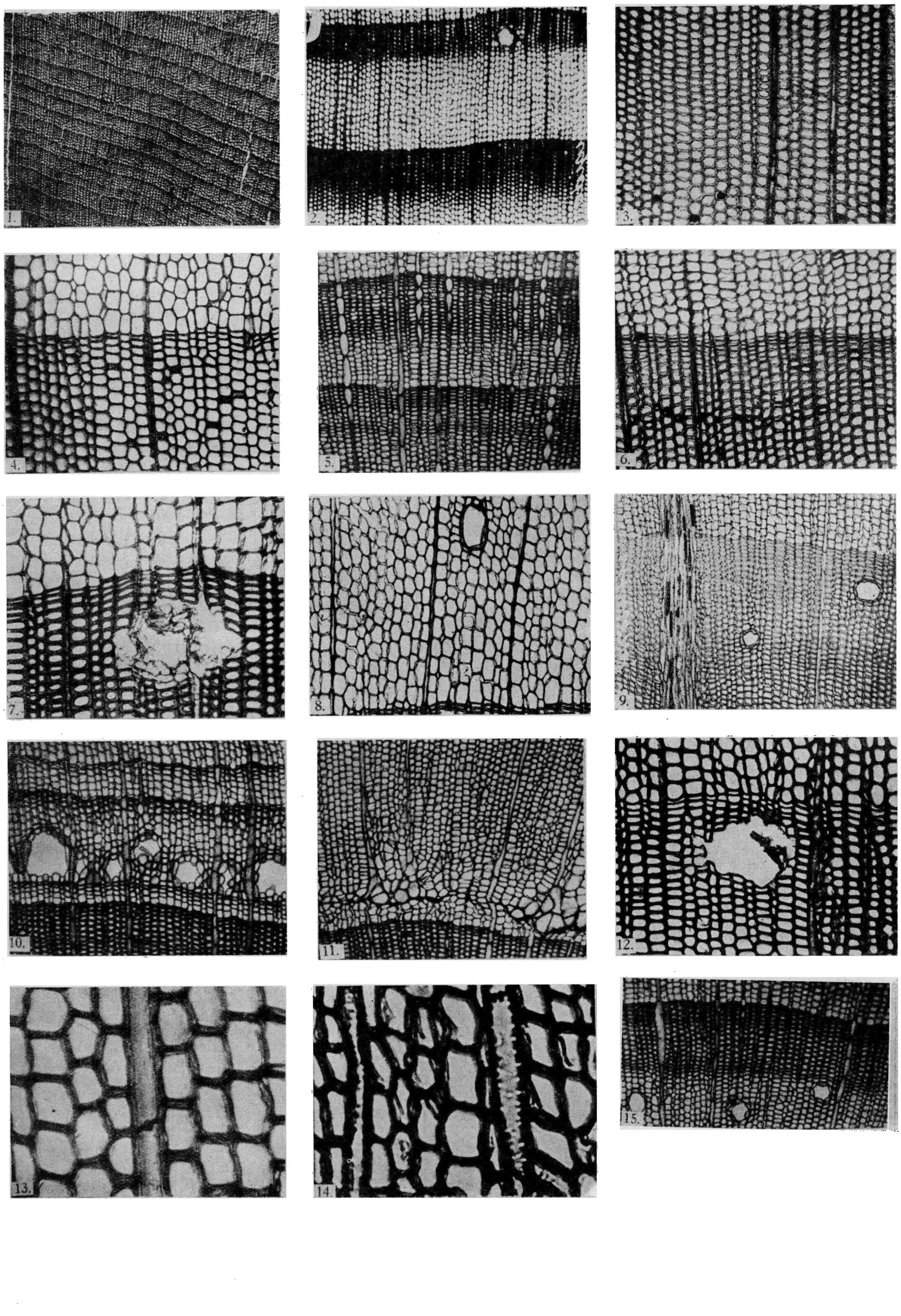
Dacrydioid pit *(also called circoporoid pit)*: a circular pit partly or entirely filling a cross field. Occasionally there are two in one cross field.

Diffuse parenchyma: parenchyma cells scattered among the fibrous elements, as seen in cross section (Plate II, Fig. 4).

Earlywood or springwood: the differently wide inner portions of growth rings

Plate II

Coniferous woods in cross section. 1. Extremely narrow growth rings *(Microcachrys tetragona* 30×). 2. Wide growth rings with latewood conspicuous *(Pinus rigida* 30×). 3. Indistinct growth rings *(Callitris glauca* 100×) 4. Wood parenchyma scattered in latewood *(Taxodium mucronatum* 100×). 5. Barrel-shaped ray cells *(Abies veitchii* 100×). 6. Terminal wood parenchyma *(Widdringtonia dracomontana* 100×). 7. *Pinus*-type resin duct *(Pinus ponderosa var. Jeffreyi* 100×). 8. *Larix*-type resin duct *(Larix europaea* 100×). 9. *Picea*-type resin duct *(Picea jezoensis* 100×) 10. Resin cyst *(Abies arizonica* 100×). 11. Cell proliferation on outer edge of growth ring *(Picea koreana* 100×). 12. Uniformly thick cell walls in both late- and earlywood *(Pinus montezumae* 100×). 13. Smooth horizontal and nodular tangential walls in ray cells *(Sequoia sempervirens* 300×). 14. Horizontal and tangential ray-cell walls pitted (Cedrus atlantica 300×). 15. False growth rings and resin cyst *(Abies veitchii* 100×).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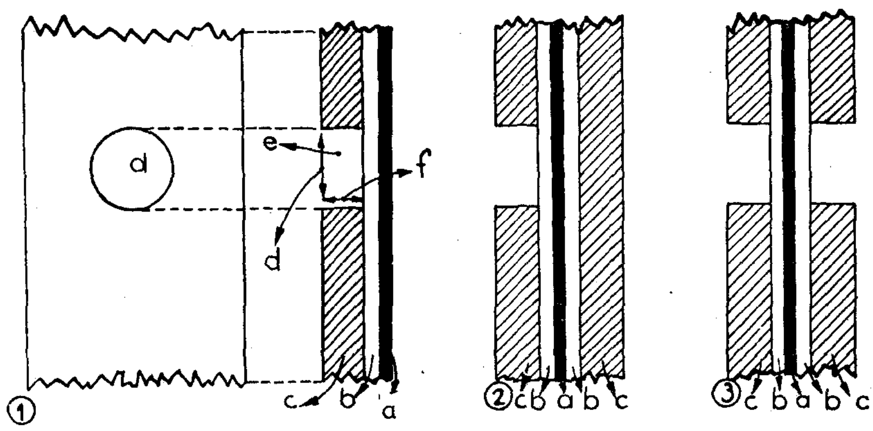
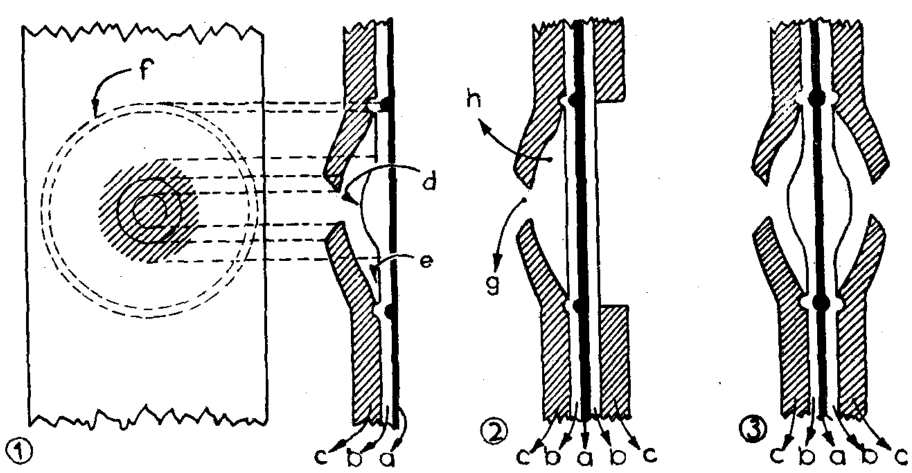
containing the elements formed at the beginning of the growing season. Radially, in some *Conifers* the earlywood tracheids measure 5 to 6 times as much as the outermost latewood tracheids; the growth ring delimitations are then always distinct (Plate II, Figs. 2 and 7).



Text fig. 1. Diagrams showing the origin and structure of a simple pit. In 1: a = middle lamella (fat line); b = primary wall; c = secondary wall; d = simple pit in surface view and aperture in lateral view, respectively; e = pit canal; f = depth of pit. 2: Unilateral simple pits are structural features of the secondary wall alone, the primary wall is not involved. 3: Simple pit pair with the primary wall and the middle lamella in between. (After *Boureau)*



Text fig. 2. 1: Structure of a bordered pit. 2: Compound pit pair. 3: Bordered pit pair. Bordered-pit structure in surface view: f = pit annulus; e = closing membrane; d = torus; g = bordered-pit aperture; the inner aperture opens into the cell lumen, the outer aperture into the chamber; h = pit chamber. In all three diagrams: a = middle lamella; b = primary wall; c = secondary wall. (After *Boureau)*

E p h e d r o i d   p e r f o r a t i o n: a perforation plate between two vessel segments with small groups of bordered pit like hexagonal or circular openings in it (Plate VII, Fig. 83).

E p i t h e l i a l   c e l l s: the thick- or thin-walled, apparently unlignified, parenchymatous cells mostly devoid of pits, which line the resin ducts (Plate I, Figs. 5—6, and Plate III, Figs. 16—19).

F a l l   w o o d: same as l a t e w o o d.

F a l s e   g r o w t h   r i n g s: they arise in consequence of disturbances during the growing season, e. g. insect infestation. Whenever they appear, these false rings, always narrower than the true ones, are wholly included within the normal ones (Plate II, Fig. 10).

G r o w t h   r i n g s: concentric layers representing seasonal increment. They vary in width depending upon external factors and the age of the tree. For identification purposes width is not an absolutely reliable property (Plate II, Figs. 1, 2, 5).

G r o w t h   r i n g   d e l i m i t a t i o n is made up of the contrast between the final rows of latewood cells and the succeeding rows of earlywood cells in transverse section. When the narrow-lumened and thick-walled elements in the latewood are followed by wide-lumened and thin-walled earlywood elements the delimitation is called distinct (Plate II, Figs. 2, 5).

G r o w t h - r i n g   f i e l d: the portion of a single growth ring bounded by two adjacent rays; its width varies with the closeness of the spacing between them and is sometimes a useable diagnostic feature.

H a l f - b o r d e r e d   p i t: a bordered and a simple pit communicating with each other in the walls of two adjoining cells. In surface view they generally appear as two concentric circles within the pit border (Text Fig. 2).

H e a r t w o o d: the inner core of the woody stem differing from the outer sapwood by its darker colour and its density. In conifers, this difference is rarely to be seen, yet in some species it is marked *(Larix, Metasequoia)*.

H e i g h t   o f   r a y s: a term of convenience used in expressing the number of superposed cell rows in a ray. It greatly varies, as a rule, within the same specimen, yet in some instances it may be a feature of importance in identification. As regards *ray cells*, their height and width and the

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