CLASSIFICATION OF THE STRUCTURAL ELEMENTS OF THE SECONDARY WOOD OF DICOTYLEDONS, USING DECIMAL INDICES FOR CLASSIFICATION AND IDENTIFICATION OF WOOD SPECIES

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I. INTRODUCTION.

An outline of the development of wood anatomy in the last few years will reveal a general need of a system in which all species of wood

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can be arranged according to their mutual relationship (Record 1931, 1934 b, 1936 a; Chalk 1937), while this classification is to form the basis for the identification.

The desirability of arriving at an internationally standardized method of classification and identification was brought to the fore by Pfeiffer (1932) at the Zurich congress of the International Association of Testing Materials, where he gave an outline of the work done in this field in Holland. The International Association of Wood Anatomists started the investigation of this problem, and a number of preparatory publications — dealing with the terminology of wood description (1933) and the dimensions of a few wood elements (1937 and 1939) — have since been issued. Further, monographs have appeared about the wood structure of numerous plant families, as well as publications concerning the variability of certain anatomical characteristics and their destribution over different systematic botanical units (for an outline, see Record 1936 b). Many of them are from the pen of I. A. W. A. members. At present a number of classification and identification schemes may be found in the literature based on widely divergent principles. A universal system of classification and identification is still lacking, and it is the object of the present paper to suggest a new procedure for such work. Its advantages and disadvantages are compared with those of other authors' methods.

Some investigators have asked themselves whether it would be possible and desirable to set up a general identification table for woods according to families, or whether it would be preferable to make a direct identification of genera and species omitting an arrangement by families. They defend this latter method (among others, Beversluis 1925) on the strength of the fact that each characteristic is found throughout the botanical system and is not confined to only one family. Further, more or less typical group features may vary considerably within the smaller units of that group.

Pfeiffer (1926 b), in his discussion of Beversluis' work, pointed out already that such drawbacks are also met with in morphological systematics, but that combinations of very definite frequently varying features may be characteristic of families. In this connection Thonner's little book (1917) is mentioned, which shows that, in spite of the above difficulties, it is quite possible, to set up a general table of families. Nevertheless, various main sections of his system contain representatives of different families recognized as a botanical unity. It seems therefore quite feasible to compile a corresponding table based on the anatomy of secondary wood.

In connection with the above-mentioned problems Pfeiffer, as early as 1921 worked out a scheme as described under III (see Tectona 16, 1923, 1095 and the Yearbook of the Netherlands East Indies Department of Agriculture, Industry and Commerce, 1922, 154—166) for a general classification of dicotyledonous woods using decimal indices, while he also made an identification table for a large number of families.

The hand lens method used here has been fully adapted to the possibility of identification in practice, in the same way as shown in the works of Beekman (1920), Den Berger and Beekman (1922), and

Bienfait and Pfeiffer (1924). As regards reliability this method is hardly inferior to that requiring the use of a microscope and it has, moreover, the advantage that it can be used everywhere, both at laboratory and emporium, in factory, saw-mill or in the forest. It has further been found that field men lacking a preliminary botanical training are capable of mastering this procedure in little time. The system of classification and identification therefore rests exclusively on characteristics which can be observed by means of a hand lens and a hand lens micrometer (Pfeiffer 1926a). Apart from structural features it includes specific gravity, hardness, colour, gloss and smell.

The data were not published because they only formed part of a working programme for a preliminary investigation. The object of this investigation was to find out whether it would prove possible to use such a decimal system in actual practice. This method of classification has since been applied by its author to more than a thousand different species of wood with satisfactory results.

It has meanwhile become evident that the quick — and for practical work important — hand lens identification method has fully succeeded in holding its own beside the microscopic method. For this reason the original working programme as designed by Pfeiffer in 1921* has been mainly left unchanged, and microscopic characteristics have not been added.

The second author has brought the scheme into line with the literature and compared the two. He has further suggested the possibility of applying the microscopic investigations to the decimal classification and identification method as well (see under V.). If a decimal scheme is worked out for microscopical characteristics, the two methods might be used side by side and supplement each other. In this way a classification system might be built up by which all species of wood are arranged in accordance with uniform rules, and which makes it possible to identify these woods both with hand lens and microscope.

The well-known advantages of a decimal system are a quick and mathematically certain classification and identification. A further advantage is the fact that the number of woods included can be continually added to, while the filing of cards in a card-index system in accordance with numerical series (see IV C) makes it very easy to find the data required for identification.

The last advantage is the possibility of collecting the classification numbers for certain botanical genera, generic groups, families or family groups, and ascertaining which sub-group indices they have in common or which are closely related. In this way it is very easy to find the indices of the botanical groups and from them infer the systematical value of the various characteristics, so that the most condensed key can be prepared. It will then be found that the distinctions used in morphology are by no means always the most suitable for systematic purposes.

A drawback of the system suggested is a certain inflexibility, which is not in agreement with the peculiarities of living nature; it is a

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drawback, however, which attends every classification of such matter. Moreover a great difficulty is the correct selection of the group divisions and their subdivisions. It is only by rigorous application of the system by routine and by the critisism of others that the most effective classification will be realized.

II. OUTLINE OF SOME CLASSIFICATION AND IDENTIFICATION SCHEMES TAKEN FROM THE LITERATURE.

In the present discussion we have not aimed at giving a complete outline of all the classification and identification systems, mentioned in the literature.

First of all these schemes are dealt with that are intended to allow of a non integrant classification in which the number of woods can be added to arbitrarily (Pfeiffer 1921, Beversluis 1925, Swain 1927, Bianchi 1931, Clarke 1938).

Second come the schemes that are based on the above elaborated hand lens method (Beekman 1920, Den Berger and Beekman 1922, Pfeiffer 1926 a, Record 1934 a). The descriptions of woods occurring in these publications may be used as the starting point for the practical application of the decimal method.

In the third place such authors are mentioned as have given a more or less complete picture of the microscopic structure of wood. (Moll and Janssonius 1906—1936, Pfeiffer 1917, Perrot 1922, Lecomte 1923, Normand 1934, Record 1934 a, Record and Chattaway 1939). The features described by these authors may form the basis for a decimal arrangement of microscopic characteristics.

A. Dutch schemes of description.

THE SCHEME OF MOLL AND JANSSONIUS (1906).

In the general part of the "Micrographie des Holzes der auf Java vorkommenden Baumarten" Moll gives a scheme for the description of secondary wood. This scheme is based on the work of Sanio (1863), and for the first time describes the structure of wood in accordance with the Linnean method. This makes it necessary to treat of the woods in a fixed order. The various elements are described spatially. The scheme relates to the microscopic structure of wood.

Constituants which do not form part of the secondary xylem as such (e.g. included phloem, and latex elements) are not mentioned in it, although use has been made of these features in the identification tables of vol. VII, while they are also included in the descriptions of woods.

The subject of micrography is divided into cytology, histology and microscopic anatomy.

The chemical composition of wood is discussed so far as the microchemical reactions on cell wall material are concerned. The scheme does not include physical features such as specific gravity, gloss, hardness and smell.

We would finally add a few remarks on the way in which the features are arranged in the system. In the description of a certain structure various characteristics of it may be subordinate to each other, which is expressed in their numbering and lettering (see e.g., p. 46, No. 22: parts of a bordered pit). In other cases, however, features of unequal value are arranged together (see e.g., p. 40, Nos. 1—5 incl.). The method of classification used, which is no doubt of great importance to arrive at a fixed order of description, does not seem very much suited to the purpose in view, i.e. to obtain an outline of the distribution and variability of features. To make it possible to set up such a "phylogeny of features" it is not only necessary that the various feature groups should be quickly visualized, but it is also desirable for them to have indices in common. This point is of paramount importance in compiling a general identification table. It is not impossible that if the decimal classification of microscopic features is applied to the work of Moll and Janssonius, a wealth of additional data may appear.

PFEIFFER'S SCHEMES (1917 AND 1926).

Unlike Moll and Janssonius, Pfeiffer used a method of description enabling quick identifications to be made in actual practice. The simple instruments required are a hand lens, a pocket knife and a hand lens micrometer in which the surface area of two or three square centimeters is subdivided in different ways. The use of a compound microscope has been avoided. In principle Moll's method of perspective description has been followed. Further, the topography and the description of elements have been kept separate.

The numerical data about the dimensions of the elements are tabulated; the text of the description only includes the relative dimensions.

This method, which was only briefly indicated in 1917, was greatly extended and improved in "The woods of Surinam" (Pfeiffer 1926a). In connection with the foregoing it is clear that cytological features, such as the pitting of elements, have in most cases not been mentioned, since these are mostly visible only through a compound microscope. (Very important exeptions are the vessel perforations and the structure of the ray cells, which may be described with the aid of a hand lens). As against this, the method includes important features visible to the naked eye, which are not mentioned in Moll's scheme, e.g. specific gravity, gloss, hardness and combustibility. The descriptions moreover include a large number of characteristic chemical reactions.

THE SCHEMES OF BEEKMAN (1920), AND DEN BERGER AND BEEKMAN (1922).

Just like Pfeiffer's schemes of description, those of Beekman and Den Berger and Beekman are directed to quick identification in actual practice. Features that can be observed only through a compound microscope have therefore been omitted. However, a number of physical characteristics have been included (such as specific gravity, hardness, grain, colour, gloss and smell). A few chemical reactions with aqueous

and alcoholic extracts are discussed. Beekman introduced the cutting of radial surfaces as an aid to identification. It has the great advantage that the vessels can be perceived over a large distance. In Beekman's work 78 Preanger woods are described, an identification table being added as well. Den Berger and Beekman give a description of twelve wood samples of which the different structural features can be demonstrated in the smallest possible number of species. Although this work was published at a later date, it may be regarded as an introduction to the former.

THE SCHEME OF BEVERSLUIS (1925).

Beversluis based his method of identification on a number of structural features (altogether 66). About the classification of these features he says on page 44 of his work:

> "I did not need to take much trouble in deciding on the order and "significance which would have to be assigned to the features from "a systematic point of view"

and on page 64:

> "the degree of constancy and sharpness, and their probable presence "decided the priority".

In ascertaining the order which has been chosen it strikes one that features relating to vessels, rays, parenchyma and libriform fibres are described in different places in the system. This will cause no end of trouble when afterwards conclusions of the various features about the distribution and variability must be drawn from the descriptions. Unlike this method, the decimal classification followed by us has the great advantage that if certain features have a factor in common, e.g. that all of them are related to the vessels, this fact is also shown in the arrangement.

For a detailed discussion of this work we refer to the criticism by Pfeiffer (1926 b) and Den Berger (1926), from which it is sufficiently clear that Beversluis' scheme must be considered unsuitable to serve as a basis for a general system of classification.

THE SCHEME OF BIANCHI (1931).

In this identification method use is made of a card divided into squares and bearing the names of the woods to be examined. The card is manifolded (e.g. printed). A small number of cards is printed on red paper, the rest on white. For each feature of identification a white card is reserved. This feature is written on top of the card; the squares of all species showing this feature are marked and carefully cut out.

In this system a red card is used as a basis. If a white card is placed on top of it, the names of the species presenting the feature in question remain visible. If a second white card is placed on the preceding one, the names of the species showing both the features remain visible.

If more cards are added, the number of red squares decreases continually, until finally one remains bearing the name of the species desired.

The advantages of the method are:

1) No use need be made of features which cannot be determined with certainty.
2) Particular features may be employed which quickly lead to identification, but which are preferably not included in an ordinary table in the beginning so as to prevent mistakes.
3) It offers the possibility of combining groups of features, e.g. anatomical characteristics with morphological and chemical features or with data about the geographical distribution.

Some disadvantages of the system are:

1) The way to be followed is shown in a table, while it will sometimes be difficult to see from the card-index system which feature is to be used first.
   In order to meet this drawback Bianchi suggests the preparation of a supplementary card-index system in which each species has a separate card with squares relating to definite features. If, in course of the identification, one wants to know which feature is to be used, the cards of all the species which still enter into consideration are placed on one another, whereupon it is at once clear which features may be left out.
2) The cost of manifolding is high.
3) A drawback not mentioned by Bianchi and which may render his system somewhat unsuitable for the preparation of a universal identification table, is the fact that the number of species that can be included is determined by the dimensions of the cards. Bianchi had 720 squares available, 522 of which were used. The size of the cards was 28 by 42 cm. (11 by 16.5 in.)

An outline of the features used in the identification is not given.

B. Anglosaxon schemes of description.

THE SCHEME OF SWAIN (1927)

An identification system in which 200.000 species of wood can be classed has been described by Swain. It chiefly includes hardwoods because the identification of coniferous woods requires the observation of microscopic features, which have been omitted in the scheme. In this case also identification takes place by means of a hand lens. It has not been attempted to link up the system with the "present pseudo-natural botanical system". Some twenty primary groups have been compiled, including species with vessels, without vessels and without rays (?). These groups are subdivided into sections according to weight and porosity, where the following woods are distinguished (p. 736).

coarsely porous woods		very light woods
finely porous woods	combined with	medium weight woods
minutely porous woods		heavy woods
non-porous woods		very heavy woods

The twenty primary groups are further classified according to features arranged in five decimal schemes. A striking fact is that the physical features bulk large in the classifications; thus specific gravity, colour, smell, taste ash and cleavability are often mentioned before important structural features are given.

THE SCHEME OF RECORD (1934).

In the introduction attention was already called to the "Glossary of terms used in describing woods", prepared under the auspices of the I. A. W. A. As this glossary was concise and not illustrated, Record (1934 a), in his work "Identification of the timbers of temperate North America", worked out the definitions and showed their practical application. The identification table includes both a number of economically important coniferous and hardwood species. Like the decimal classification used by us, the main division is based on features which may be observed without the aid of — or with simple — specially adopted means (hand lens method). Features that are only visible under a compound microscope come second, and are indicated with small letters. The classification is artificial as compared with the natural relationship between the species described. The arrangement is such, however, that species greatly resembling each other in appearance, properties and use, are united.

Not only structural features, but also physical characteristics are made use of. The features described in the general part have not been correlated with each other by means of letters or figures, such as would be desirable for the purpose we have in view. Record's scheme may, however, be important as an aid in drawing up a decimal classification of microscopic features.

THE SCHEME OF CLARKE (1938).

The non-integrant identification system of Clarke is based on Bianchi's (loc. cit.) and is worked out in the way suggested by Record (1932). Each species of wood contained in the system has its own card: along its margin there are a series of perforation each of which corresponds to an identification feature. If a wood presents a certain feature, the appurtenant hole is made to run on as far as the margin. In the case of missing features the holes do not run on. If a bar is stuck through a hole in the complete set of cards corresponding to a particular feature, the cards showing this feature drop down on shiffling. This operation is repeated until one card is left bearing the name of the species required. The features included in the accompanying scheme relate both to the structure as it can be observed by hand lens and microscope, and to physical characteristics. The geographical distribution is also mentioned as a feature. The total number of features that can be used (88) is limited, however, by the dimensions of the cards.

It may be a drawback in this system that the holes which do not run on are subject to wear, as a result of which all the cards tend to drop down in the long run if they are shuffled. This drawback appeared

when a similar system was used for a different purpose, viz. the classification of literature data.

THE SCHEME OF RECORD AND CHATTAWAY (1939).

A list of 115 anatomical features has been drawn up by Record and Chattaway. This list is more extensive than Clarke's and is intended to be employed with a perforated card index system. Physical and geographical features are not included. The authors have numbered the features consecutively, which is the only possible method to be followed in their identification card system. Yet they apparenly felt the need of bringing to expression in the list whether features are subordinate to each other. This purpose has been fulfilled only by means of a particular arrangement (identation) relative to the marginal line, not by numbering. As a result, common indices of features are lacking, just as in all the other schemes mentioned above.

C. French schemes of description.

THE SCHEME OF PERROT (1921—1922).

In the description of woods Perrot makes use of loose cards on which microscopical features are noted. In order to facilitate the application of this method in actual practice, the number of features is kept small. Not only the structure, but also physical properties are described, while in each case semi-schematical drawings of the transverse and tangential surfaces, magnified 50 diameters, are added. This scheme must be considered unsuccessful because the wood elements are not described three-dimensionally, but are separately noted on the transverse and tangential surfaces. The cards that are used refer to woods of Madagascar. The Ivory Coast and Gabun. An identification system is entirely lacking; the cards each of which represents one species are numbered consecutively.

THE SCHEME OF LECOMTE (1923).

In his little book "Les bois coloniaux" Lecomte gives a brief outline of the structure of wood. The various features are arranged in groups, but are hardly provided with numbers or letters. They are elucidated by means of fine pictures, and each feature is illustrated by reference to a number of woods. This general part is followed by a survey of the principal colonial species in which a numerical classification is suggested for the benefit of the trade.

> "Si les exploitants, les commerçants et les praticiens se refusent "absolument à adopter les noms appartenant à la nomenclature "botanique, du moins pourrait-on à la rigueur en s'inspirant des "principes de la classification décimale — préconisée par quelques-"uns, en bibliographie par exemple — adopter une numérotation qui "se substituerait avec avantage à une série de noms dépourvus de "toute signification" (page 86).
>
> "Dans la réalité, elle ne serait qu'une forme nouvelle donnée à la "classification botanique. Et si elle était adoptée par les pays

"étrangers, elle permettrait à l'acheteur de bois de toute provenance "de connaître sans difficulté la nature de ceux qui lui sont oferts" (page 87).

The method of numbering is indicated, but has not been worked out. This idea has meanwhile been realized. Van Heurn (1944), in agreement with the divisions of the "International Committee for Universal Classification" has drawn up a list in which a few thousand numbered woods are classified according to family. (The range 674.03 of the U. D. C.).

THE SCHEME OF NORMAND (1934).

Normand gives a scheme of description based on data taken from French, Dutch, English and American publications. Nevertheless, this scheme, which contains many interesting particulars, has remained very concise. The author himself says: "il permet la rédaction de descriptions d'importance moyenne". Considering the practical applicability of the scheme, microscopic features have been made use of as little as possible. The terminology is in agreement with that of the I. A. W. A. The feature groups are numered, but not their subdivisions. A bibliography is added dealing with the examination of wood in general.

III. THE CLASSIFICATION OF STRUCTURAL ELEMENTS USING DECIMAL INDICES.

This chapter contains 20 tables in which a more detailed description is given of the various subdivisions of the groups indicated by letters and figures.

In delimiting the various groups of dimensions the standard terms of the I. A. W. A. are used. Likewise, the definitions and descriptions given by the I. A. W. A. are mostly employed unchanged in our classification. As to the divisions that are not internationally normalized we have followed the detailed descriptions of Den Berger and Beekman (1922) given in Communication VII of the Experiment station for Forestry at Buitenzorg (Java). As far as possible the features have been arranged according to systematic and genetic principles.

Altogether 20 groups are used, each of which is provided with 10 different indices (1—10). Thus 100 trillion (Amer. 100 quintillion) indications are available.

Depending on the formations to which they relate, the 20 groups are combined into 5 sections, and further subdivided into 2 to 5 subgroups, which latter indicate differences between features that are more important in identification and classification than the differences indicated by the various indices in one and the same group.

The main utility of these subgroups is that they render the whole system more flexible, thereby allowing of a better agreement with the classification by the botanical system.

The classes and groups are arranged as follows:

Section I. Vessels.

Section I. Vessels. Group A. Perforation plate.

Sub-groups	Index	Description
a	1	**vessels are lacking**
b		**all or most perforation plates are cribriform**
	2	all perforation plates cribriform
	3	most perforation plates cribriform, the others scalariform
	4	most perforation plates cribriform, the others simple
c		**all or most perforation plates scalariform**
	5	most perforation plates scalariform, the others cribriform

Section I. Vessels. Group A. Perforation plate (continued).

Sub-groups	Index	Description
	6	all perforation plates scalariform
	7	most perforation plates scalariform, the others simple
d		**all or most perforations simple**
	8	most perforations simple, the others perforation plates cribriform
	9	most perforations simple, the other perforation plates scalariform
	0	all perforations simple

This classification according to type of perforation plate, which must be regarded as one of the principle features from a systematic point of view, does not by any means satisfy all the requirements.

The delimitation of the four subgroups according to the three typical means of perforations is not sharp, except, of course, in subgroup a.

It will sometimes be difficult to find out whether a particular wood belongs to c 7 or to group d 9, and there are many genera (*Vaccinium spp.* and *Glochidion spp.*) representatives of which belong to both subgroups and exhibit all transitional forms.

Another subgrouping, e.g. b all perforation plates cribriform, c all perforation plates scalariform, d all or most perforations simple, might have been sharper, but, as far as can be judged at present, it is less correct from a systematic point of view.

It is often very difficult to determine whether one or another type of perforation predominates, because the various kinds of perforation strike the eye very unequally. In the case of doubt, or if there is a great chance of mistakes being made, both subgroups or indices are used.

Perforation plate the middle part of which is scalariform and where the bottom and top ends of the oblique plate are cribriform, are all regarded as cribriform (*Platea* fam. *Icacinaceae*).

Plates the perforations of which are arranged in a circle are considered scalariform if the bars of the wheel-like plate can be distinctly and sharply perceived as slender rods. If, however, the perforations consist of round openings and this typical radial structure is absent, the plates are looked upon as cribriform.

Often the perforation plates are so fine that they are invisible under a lens with a magnifying power of 10 diameters. If the radial surface receives incident light, the scalariform perforation plates with many bars show a peculiar grey coloration, which changes if the object is moved in a certain direction. Moreover, these plates are mostly very much inclined, the more horizontal ones usually having few and clearly perceivable bars. This latter observation has already been made, among others, by Frost

(1930 and 1931). The factors determining the axial height of the plates have been analysed by Chalk and Chattaway (1935).

The cribriform perforation plates are usually almost perpendicular to the axial direction or make only an obtuse angle with it; they are generally plainly visible therefore on the cross-section.

If the perforations are so fine that they are invisible under a hand lens, they show a grey discoloration similar to that of the scalariform perforation plates, but in this case without any effect of a particular angle of incidence of the light.

As the fully closed perforation plates (i.e. those only provided with pits or bordered pits) are very rare in secondary wood, they may in most cases be taken to be cribriform if various almost horizontally placed seemingly imperforate plates are observed.

An outline of the different types of perforation plates and a comprehensive bibliography on this subject has been given by Chalk (1933 and 1937). Record (1936 b) has drawn up lists of families characterized by a special type of perforation plates.

Section I. Vessels. Group B. Grouping of the vessels.

Sub-groups	Index	Description
a	1	**vessels are lacking**
b		**most or nearly all vessels solitary**
	2	nearly all vessels solitary
	3	most vessels solitary, the others in groups of 2—4
	4	most vessels solitary, the others in groups of 2-many
c		**most or nearly all vessels in groups**
	5	most vessels in groups of 2—4, without distinct radial arrangement
	6	most vessels in groups of 2-many, without distinct radial arrangement
	7	nearly all vessels in groups, but without distinct radial arrangement
	8	most vessels in groups of 2—4, with pronounced radial arrangement
	9	most vessels in groups of 2-many, with pronounced radial arrangement
	0	nearly all vessels in groups with pronounced radial arrangement

In cases that the vessels are not absent, the subgroups are delimited on the one hand by b "most or nearly all vessels solitary", and on the other hand by c "most or nearly all vessels in groups".

This subdivision was chosen because the distinction "most vessels solitary", as against "most vessels in groups" is of relatively great systematic value, while the distinction "nearly all or most vessels with pronounced radial arrangement" as against the groups of 2—4 or 2—10, however important from a systematic point of view, may yet be observed in comparatively closely related species.

The distinction between the vessel groups that are and those that are not in clearly radial arrangement was originally included as a subdivision, but afterwards only expressed in the indices, because, however important this separation may be systematically, the demarcation of the two groups is very indefinite and it would therefore be required to include both groups so often that the classification in the card-index system would be unnecessarily complicated.

Typically radial groups may be observed, among others, in the *Ebenaceae* and the *Sapotaceae*; groups in which the typically radial arrangement is absent are formed in *Erethia longiflora* (fam. *Borraginaceae*) and *Aralia spinosa* (fam. *Araliaceae*). These latter groups are more frequent in woods from temperate zones.

The drawing of the border lines, just as the determination whether the groups are in the majority or not, must take place arbitrarily. In cases of doubt, or when both formations are observed locally over a fairly large surface area of the transverse section (a few sq.cm), two cards are made.

It must likewise be arbitrarily decided whether the wood vessels are arranged in groups of 2—4 or 2-many. This should not be determined according to whether a group of more than 4 vessels is somewhere to be found, but whether such groups occur regularly, be it scarcely. To give an idea, we would suggest that each two sq.cm. should contain one such group. For the purpose of this classification, only the groups of normal vessels are to be taken into consideration, and not the radial groups or clusters of vessels or vascular tracheids, which are much smaller than the ordinary vessels and mostly of somewhat different shape.

Section I. Vessels. Group C. Arrangement of vessels or vessel groups.

Sub-groups	Index	Description
a	1	**vessels are lacking**
b		**vessels or vessel groups are scattered**
	2	scattered, without any distinct arrangement
	3	scattered, but zones with clearly different numbers of vessels are present
	4	scattered, as 2 or 3, but moreover in almost continuous, sometimes slightly interrupted, tangential series on borders of growth ring
c		**vessels or vessel groups arranged in short radial rows either or not combined with oblique rows**

Section I. Vessels. Group C. Arrangement of vessels or vessel groups (continued).

Subgroups	Index	Description
	5	arranged in short or broken rows, most of them having a distinctly radial direction
	6	arranged as number 5, but moreover in fairly continuous, sometimes interrupted, tangential series on borders of growth ring
	7	arranged in short, mostly obliquely or only more or less radially directed, waving, sometimes also branching rows
	8	arranged as under 7, but moreover in almost continuous, sometimes more or less interrupted, tangential series on borders of growth ring
d		**vessels or vessel groups in short tangential rows**
	9	arranged in many short or broken sometimes waving, chiefly tangentially directed rows
	0	arranged as under 9, but moreover in almost continuous, sometimes more or less interrupted, tangential series on borders or growth ring

So far as vessels are present, the subgroups are formed by the distinctions whether the vessels or vessel groups are scattered, or occur in short radial or oblique rows (or both), or in short tangential rows.

The distinction whether continuous tangential series are present or absent, is regarded as a secondary feature, for the reason that, although it is often of great systematic value, it forms a distinction between two species that are sometimes rather closely allied. Such rows may even occur together in one and the same species. In the case of these distinctions also it will often be necessary to make arbitrary decisions.

For there are two kinds of arrangement: one where the series are visible both with a hand lens and the unaided eye (e.g. *Quercus* and *Calophyllum spp.*), and others where this arrangement is clearly visible to the unaided eye only on the planed transverse surface (various *Lauraceae* and *Myrtaceae*). Both kinds are, however, treated of in this table as equally valuable; in reality they are not: the former is more important systematically than the latter.

In classifying woods it should not be asked whether such series occur occasionally, but whether the majority of the vessels are arranged as discussed above, or whether this arrangement is distinctly visible locally over fairly large surface areas.

Almost continuous tangential series occuring beside other groupings — mostly on zone borders — are mentioned in this connection only, if the

vessels are more numerous there, or if they are conspicuous by their large size or particular irregularity. (*Tectona grandis* and *Cedrela spp.*).

These series may also occupy several wood vessels (fam. *Verbenaceae*); this is specially the case with woods from temperate zones.

Section I. Vessels. Group D. Size and number.

Sub-groups	Index	Description
a	1	**vessels lacking**
b		**without pronounced regularity in size difference**
	2	vessels extremely small to medium sized; very few to moderately few
	3	vessels extremely small to medium sized; moderately numerous to very numerous
	4	vessels moderately large to extremely large; very few to moderately few
c		**size in growth ring varying systematically**
	5	vessels extremely small to medium sized; very few to moderately few
	6	vessels extremely small to medium sized; moderately numerous to very numerous
	7	vessels moderately large to extremely large; very few to moderately few
d		**clearly occur in two different sizes, the most numerous kind**
	8	extremely small to medium sized; total number very few to moderately few
	9	extremely small to medium sized; total number moderately numerous to very numerous
	0	moderately large to extremely large; total number very few to moderately few

The subgrouping, in this case, is formed by the way in which the difference in size of the wood vessels comes out, i.e. without any pronounced regularity, systematic variation in the growth ring or the presence of two clearly different types.

The systematic size variation of the vessels in the growth ring is a feature of frequent occurrence in tropical woods (e.g. *Tectona grandis*; various *Euphorbiaceae*); the periodicity must, however at once be clearly visible with a hand lens and must be capable of being ascertained with sufficient certainty without carrying out measurements, otherwise the species is to be grouped under; without any pronounced regularity in size difference.

It is only seldom that two clearly different sizes of vessels occur in tropical woods, but it is more frequent in woods from the temperate zone. The introduction of this fact in subgroups will in various cases lead to an undesirable division of closely allied species, but nevertheless we hold that the advantages will offset the drawbacks. The very small vessels or vascular tracheids which often occur as groups in the neighboorhood of larger vessels are left out of consideration here.

The size and numerousness, which are often of systematic importance in distinguishing between different species, but which may be highly divergent in the closely allied woods, form the subdivision of the subgroups.

The combination "moderately large to extremely large" with "moderately numerous to very numerous" was not included, because this combination will not occur except in very rare cases. It is possible, however, that the combination "moderately large to extremely large, very few to moderately few" must be extended to include also "very few to moderately numerous". In the case that the combination "moderately large" with "moderately numerous" occurs, it is advisable to use the same index as that for "moderately large and moderately few", as the vessel size is of more importance, in our opinion, than the number.

In ascertaining both number and size, the above-mentioned groups of much smaller vessels or vascular tracheids are left out of consideration.

The average number of wood vessels that is taken to occupy a few mm is determined by the number present in the normal wood elements; the bands with a larger or smaller number of vessels are ignored in counting. As regards the division of subgroup d it is from the most numerous vessels that the size is ascertained, and it is also they which form the basis for counting the numbers.

The size of the vessels has been normalized by the I. A. W. A. (1939) after Chalk (1938) had carried out the necessary measurements.

Both the classes and the terms used by this association in their agreement have been adopted by us. This classification differs but little (5 μ on the demarcation between the first two classes) from that of Den Berger and Beekman (loc. cit.).

As regards the division of the number of vessels we have followed the latter investigators. Miss Chattaway (1932) has recommended this classification for unchanged international normalization both as to the terminology and the numbers mentioned.

These examples should once more show the great utility of the hand lens method.

Section II. Rays.

Section II. Rays. Group A. Types and structure.

Subgroups	Index	Description
a		**all rays of one type**
	1	built up completely of procumbent cells

Section II. Rays. Group A. Types and structure (continued).

Sub-groups	Index	Description
	2	consisting of procumbent cells with 1—3 rows upright
	3	consisting of procumbent cells with 1-many rows upright
	4	built up completely of upright cells
b		**two types of rays, depending on dimensions**
	5	both types consisting completely of procumbent cells
	6	the narrow type with 1—3 rows upright, the wider type consisting entirely of procumbent cells
	7	both the narrow and wide types consisting of procumbent cells with 1—3 rows upright
c		**two types of rays, depending on cell structure**
	8	the narrow type consisting entirely or almost entirely of upright cells; the simple wider type entirely of procumbent cells
	9	the narrow type consisting entirely or almost entirely of upright cells; the simple wider type with 1—3 rows upright
	0	the narrow type consisting entirely or almost entirely of upright cells; the simple wider type with many rows upright cells or completely built up of them

In this group 3 subgroups are distinguished: a. "all rays of one type", b. "two types of rays, chiefly depending on dimensions", c. "two types of rays, chiefly depending on the essentially different structure of the rays consisting of different kinds of cells".

The above definition of rays in one and two types differs from that given by Den Berger and Beekman (l. c.).

In the further division of the subgroups according to structure we would in the first place point out that by the expressions "1—3 (or 1-many) rows of upright cells" is meant: along the upper or lower border of the rays, or along each of the two borders of simple, not vertically fused rays (sensu Den Berger, 1926, p. 420). Vertically fused rays often contain some rows of upright cells in the middle being twice or almost twice as numerous as those at the borders, so that, when the simple rays have at most 3 rows of upright cells, 4 or 5 rows of upright cells may occur in the middle of a vertically fused ray. These rows are left out of consideration.

This situation is complicated still more if two types of essentially different structure are present. Then not only the broader types and occasionally the narrower types may occur combined, but also combinations of a narrower with a broader type are possible, forming heterogeneous

vertically fused rays with many rows of upright cells, which for the rest, closely resemble simple rays, while the genuine simple broader rays are either without or with 1—3 rows of upright cells.

In finding such rays it is advisable to ascertain whether the number of rays with many rows upright cells corresponds to the number of heterogeneous vertically fused rays which in all probability may be expected. This latter fact can to some extent be inferred from the number of combinations of two broad rays. The separation of the two broad parts of many of this type of vertically fused rays by many rows of upright cells will further indicate the presence of simple rays with many rows of upright cells.

In cases of doubt, both features are considered; sometimes (for example in some genera of the family *Euphorbiaceae*) the number of vertically fused rays is so large that neither the subgroup nor the index can be ascertained with any degree of certainty, and the real type can only be deduced on the analogy of allied species. The number of vertically fused rays may be so great that prolonged searches are necessary to find a simple broad ray, while sometimes also the number of narrow or broad rays may be so small that a close investigation is required to decide whether there are two types. In such cases a card with subgroup a is also made.

If the narrower rays consist of chiefly upright cells with a few rows of radially shortened and axially elongated cells (so-called short high cells), they are regarded as being entirely composed of upright cells and essentially different from the broader rays with procumbent cells.

In the *Malvales* tile cells generally occur. These have been described by Miss Chattaway (1933 a).

Chalk and Chattaway (1933) found perforated ray cells in 74 species of 17 families; first in *Lacistema aggregatum*. These cells connect the elements of vessels running on both sides of a ray. As neither the tile cells nor the above-mentioned perforations are visible under a hand lens, they have not been included in our scheme of classification.

Section II. Rays. Group B. Number and ratio between the numbers of both types.

Sub-groups	Index	Description
a	1	**total number of rays very few rather numerous (1—10 per running mm)**, if two kinds are present: the narrowest greatly in the minority — in the minority (< 2/5 of total number)
	2	ditto; the narrowest kind equally numerous (2/5—3/5 of total number)
	3	ditto; the narrowest kind predominating (3/5—4/5 of total number)
	4	ditto; the narrowest kind strongly predominating (> 4/5 of total number)

Section II. Rays. Group B. Number and ratio between the numbers of both types (continued).

Sub-groups	Index	Description
	5	particular formations, e.g. disjunctive rays, present
b	6	**total number of rays numerous — very numerous (11 or more per running mm)**; if two kinds occur: the narrowest kind greatly in the minority — in the minority (< 2/5 of total number)
	7	ditto; the narrowest kind equally numerous (2/5—3/5 of total number)
	8	ditto; the narrowest kind predominating (3/5—4/5 of total number)
	9	ditto; the narrowest kind strongly predominating (> 4/5 of total number)
	0	particular formations, e.g. disjunctive rays, present

The classification of the number of rays per running mm is that also used by Den Berger and Beekman (loc. cit.).

The subgrouping and subdivision of this group do not require further discussion. An arrangement into three subgroups, namely "number of rays very few to few, moderately few to rather numerous, numerous to very numerous", which might render good service in many cases, was omitted here, because then it would in a great many species be impossible to make a choice between the first and the second subgroup.

The same or closely allied species often show 4—8 rays. The number of rays is usually counted on the transverse surface, so that in reality the surface area which they occupy in tangential direction is determined rather than the actual number. An advantage of this method is that the elements of heterogeneous vertically fused rays also come out in the right way (see also Pfeiffer 1917, p. 234).

The relation between the number of broad and narrow rays — for the broader rays may yield narrower ones by division — has been examined by Zijlstra (1909) and Chattaway (1933 b). These investigators made their measurements on tangential surfaces.

Section II. Rays. Group C. Width and ratio between the widths of the two kinds.

Sub-groups	Index	Description
a	1	**all rays extremely fine or very fine (< 25 μ)**; if two kinds are present: the narrowest kind extremely fine or very fine (< 25 μ)

Section II. Rays. Group C. Width and ratio between the widths of the two kinds (continued).

Sub-groups	Index	Description
b	2	**all rays moderately fine or medium sized (25—100 μ)** if two kinds are present: the broadest and the narrower ones very fine to moderately fine (15—50 μ)
	3	ditto, but the narrower rays extremely fine (< 15 μ)
c	4	**all rays moderately broad to very broad (100—400 μ);** if two kinds are present: the broadest and the narrower ones medium sized to moderately broad (50—200 μ)
	5	ditto, but the narrower rays very fine to moderately fine (15—50 μ)
	6	ditto, but the narrower rays extremely fine (< 15 μ)
d	7	**all rays extremely broad (> 400 μ);** if two kinds are present: the broadest and the narrower ones medium sized to moderately broad (50—200 μ)
	8	ditto, but the narrower rays very fine to moderately fine (15—50 μ)
	9	ditto, but the narrower rays extremely fine (< 15 μ)

The division of the rays by widths has been normalized by the I. A. W. A. (1939). This division has been adopted in the present system. The subdivision is such that the first three groups invariably include two classes of ray widths. This has been done to make it not too difficult to determine the subgroup with the available aids and appliances.

Section II. Rays. Group D. Height.

Sub-groups	Index	Description	
a	1	extremely low	(0.5 mm)
b	2	very low	(0.5—1 mm)
	3	low	(1—2 mm)
c	4	rather low	(2—5 mm)
d	5	moderately high	(5—10 mm)
e	6	high	(1—2 cm)
f	7	very high	(2—5 cm)
	8	extremely high	(5 cm)

For the indices the normal division has been followed, while it has been attempted to adapt the subgrouping to a division which is of the most systematic importance.

The division relates particularly to the broader rays if two kinds of rays are present; the narrower ones are almost without exception extremely low or very low.

If the rays (here the broadest) differ very much in height, that index is used which corresponds to the height of the highest rays occurring regularly. Zijlstra (loc. cit.) has biven an outline of the various heights of the rays in the secondary wood of *Fagus* and *Quercus*.

Section III. Parenchyma.

Literature review.

In this third part the selection of the features that are of the greatest importance systematically presents considerably more difficulties than in the previous sections.

For the description of parenchyma a great many schemes are known which are hardly comparable among themselves. In the accompanying scheme, however, an effort is made.

The methods of describing parenchyma fall into three groups:

The first group comprises the descriptions that follow Sanio's (1863) hardly modified or not at all. It is the classification into paratracheal, metatracheal, diffuse and terminal parenchyma. The term "terminal" is used neither by Sanio, nor by Moll and Janssonius (1906). The latter authors, however, in the general part of their work, mention as the last possibility of arranging the parenchyma: "Häufiger im spätholz der Zuwachszonen oder darauf beschränkt."

Den Berger and Beekman (1922) have used the above classification. They regard the four types of parenchyma as of equal value.

The I. A. W. A. (1933) holds the same view, except that it subdivides the paratracheal parenchyma. In addition the I. A. W. A. (loc. cit.) has adopted a special term for the parenchyma occurring in association with included phloem: "conjunctive tissue".

Two groups of authors — Pfeiffer (1921 and 1926 a) on the one hand, and Chalk (1937) and Record & Chattaway (1939) on the other, have noticed that the above classification of parenchyma does not suffice for the description of the greatly different groups possible. For this reason each of them made a new classification in which Sanio's types play a minor part. The two new classifications resemble each other in that they distinguish two instead of four main groups, i.e. paratracheal as against scattered (Pfeiffer) and paratracheal as against apotracheal (Chalk). In both systems terminal parenchyma takes a more or less separate place. Record and Chattaway (loc. cit.), who have adopted and extended Chalk's terminology, count this parenchyma as apotracheal. The terms "scattered" and "apotracheal" then include the diffuse, metatracheal and terminal parenchyma.

The classifications of Sanio, Pfeiffer, and Record and Chattaway are

TABLE I. Arrangement of the parenchyma according to several authors.

Sanio (1863) Moll and Janssonius (1906) Den Berger and Beekman (1922) I. A. W. A. (1933)	Pfeiffer (1921, 1926)	Chalk (1937) Clarke (1938) Record and Chattaway (1939)
1. Paratracheal	1. Paratracheal (Group A) Narrow rings or parts of rings or irregular flecks Very distinct complete, not aliform rings, which may be occasionally confluent Distinct aliform rings, which sometimes are confluent here and there Large irregular flecks, which completely enclose the vessels and are confluent here and there	1. Paratracheal Sparingly paratracheal (cells few, not forming complete sheath) Unilaterally paratracheal (caps or hoods, typically on outer side of pore) Winged (with lateral extensions or caps) Vasicentric (with circular or oval outlines) Vasicentric-confluent (joining without wings, often diagonally) Vasicentric-conglomerate (associated with pores in clusters and bands) Aliform (tangential wing-like extensions (note if short or long) Aliform-confluent (wing-like extensions joining laterally) Broken and irregular (tangential rather than concentric bands) Continuous and abundant (tending to form concentric bands including pores)
2. Diffuse 3. Metatracheal 4. Terminal	2. Scattered indefinitely arranged (not repeated periodically) (Group C) Diffuse Metatracheal definitely arranged (repeated periodically) (Group B) Diffuse Metatracheal Terminal	2. Apotracheal Diffuse (single cells only or very short rows or both) Reticulate (diffuse and short irregular rows, more or less anastomosing) Concentric uniseriate lines or narrow bands (typically less than 3 cells wide) Coarse bands (4 or more cells wide) Terminal or initial

tabulated side by side. The order of the arrangement of paratracheal parenchyma used by the latter investigators has been altered with a view to better bringing out points of resemblance with Pfeiffer's arrangement. For this reason the groups B and C "definitely arranged" and "indefinitely arranged" in Pfeiffer's terminology have been interchanged in the table.

The definitions and descriptions occurring in the second column will be fully discussed below. The term "concentric" used by Record and Chattaway comprises the metatracheal and terminal parenchyma. The systematic significance of the width of the concentric parenchyma band has been demonstrated by Miss Chattaway (1932 b).

The origin of wood parenchym is discussed by Torrey (1921). He argues that the parenchyma of *Telephragmoxylon* (*Pinaceae*) originates through the formation of partitions in long tracheids. The relationship between the various forms in which the wood parenchyma may occur has been explained by Pfeiffer (1926 a, p. 103) and Kribs (1937).

Definitions and descriptions.

The classification used here is still far from perfect, especially in regard to the **paratracheal parenchyma.**

In various genera, for instance, the paratracheal parenchyma is in fact only a part of the definitely arranged metatracheal or of the indefinitely arranged parenchyma, and it would therefore be necessary to classify the wood according to the first subgroup. As it would in a great many cases be exceedingly difficult to decide on this point, the above method has not been used.

Parenchyma bordering on the wood vessels is only considered to be metatracheal if belonging to long or short fairly continuous layers which run on unchanged where they touch the vessels, or at most partially surround one of the sides of the vessels without widening. If a band divides to enclose a vessel and immediately unites again, or if particular thickenings or spots occur, whether in direct association with the parenchyma band or not, it is considered that paratracheal parenchyma is present.

A similar distinction applies between the paratracheal parenchyma on the one hand, and the indefinitely arranged metatracheal and the diffuse parenchyma on the other hand, but in this case it is even more difficult to define. Only when these kinds of parenchyma, where they border on the wood vessels, are more abundant than in their immediate vicinity do we speak of paratracheal parenchyma.

By the term **definitely arranged parenchyma** we understand all parenchyma either arranged in long, mostly continuous although possibly irregularly divided bands, or in longer or shorter waving interrupted, broken or coalesced small bands, which themselves are periodically arranged in a regular manner. These bands mostly consist of purely metatracheal parenchyma, but may also be built up, wholly or partially, from similarly arranged diffuse parenchyma.

That these two formations are closely allied systematically is shown by the fact that they occur in all transitional forms in species of one and

the same genus (e.g. in *Xanthophyllum spp.* fam. *Polygalaceae* and *Quercus spp.* fam. *Fagaceae*).

By the term **indefinitely arranged parenchyma** we understand all metatracheal and diffuse parenchyma that is not periodically arranged in the above described way, so in the first place the typically diffuse parenchyma, short, moderately short or very short small bands and spots of different shape, so far as they occur throughout the wood or irregularly scattered in particular parts of the growth ring.

It is evident from the above that a more accurate definition of the terms **metatracheal** and **diffuse** must necessarily be introduced than was the case formerly and elsewhere (see Moll and Janssonius 1906, p. 58 and Pfeiffer 1917, p. 44).

In agreement with Den Berger and Beekman's definition (1922) we understand by purely diffuse parenchyma: individual cells, scattered between the libriform fibres, which may at most be grouped into very small flecks or short bands. As soon as a clearly tangential trend is noticeable, or when the flecks, in a tangential direction, at least reach from ray to ray, the parenchyma is called metatracheal.

Section III. Parenchyma. Group A. Paratracheal.

Sub-groups	Index	Description
a	1	**altogether absent or at least imperceptible**
b		**as narrow rings or parts of rings or irregular flecks**
	2	perceptible with difficulty or only occasionally
	3	more or less clearly visible around the majority of vessels
	4	more or less clearly visible in part of the growth ring
		visible as very distinctly complete not aliform rings which may be occasionally confluent
	5	visible around the majority of the vessels
	6	only in part of the growth ring
c		**visible as distinctly aliform rings, which sometimes are confluent here and there**
	7	visible around the majority of the vessels
	8	visible only in part of the growth ring
		as large irregular flecks visible, which completely enclose the vessels and are confluent here and there
	9	visible around the majority of the vessels
	0	visible only in part of the growth ring

So the typical paratracheal parenchyma is often seen only in combination with metatracheal or diffuse parenchyma; the complete picture is therefore not obtained until this group is combined with the groups B and C of the same section.

The subdivisions are: a. the absence of paratracheal parenchyma, b. the presence of flecks, parts of rings or simple rings, c. the occurrence of peculiarly shaped rings.

The distinction between the last two subgroups is to a certain extent parallel with the combination paratracheal and indefinitely arranged parenchyma.

In general, this distinction is of great systematic importance, but in some cases, such as with the family of the *Leguminosae* (*Acacia spp.*), both formations occur in different parts of the growth ring of one single species of wood; then the indices 8 and 0 of subgroup c are used together with one of the indices of subgroup b.

The parenchyma bands which are often found on one or both sides of the wing-like flecks are regarded as belonging to the definitely arranged parenchyma, as are also the broader very short bands or flecks that sometimes link the paratracheal parenchyma of some vessels together if this parenchyma makes the tangential wing like fleck three times as large as the radial one.

This also applies to the large irregular flecks of paratracheal parenchyma, which often coalesce, then form broad tangential parenchyma bands, which are in most cases short and irregularly divided (*Artocarpus integrifolia* L.f.), but which may occasionally become long and continuous (*Erythrina spp.* and *Pongamia spp.* fam. *Leguminosae*).

In the former case the occurrence of scattered metatracheal parenchyma is assumed if the distance between the wood vessels, in tangential direction, is more than three times greater than the tangential diameter of the vessels. In the latter case the occurrence of paratracheal parenchyma beside broad bands of definitely arranged parenchyma is assumed if the majority of the vessels in the border of the bands is completely enclosed by parenchyma, while practically all the vessels lying outside these bands are surrounded by distinctly visible parenchyma rings.

In all other cases these bands are exclusively regarded as definitely arranged metatracheal parenchyma (*Ficus spp.* fam. *Moraceae* and *Kakaona spp.* fam. *Celastraceae*).

Section III. Parenchyma. Group B. Definitely arranged (regularly arranged bands combined with continuous bands of metatracheal and diffuse parenchyma or otherwise).

Subgroups	Index	Description
a	1	**altogether absent**
b		**independent of the vessels or the paratracheal parenchyma or at least not clearly associated with it**

Section III. Parenchyma. Group B. Definitely arranged. (regularly arranged bands combined with continuous bands of metatracheal and diffuse parenchyma or otherwise) (continued).

Sub-groups	Index	Description
	2	in very few to few, mostly continuous, sometimes broken or/and waving, sometimes irregularly divided bands, consisting of metatracheal parenchyma or partly or wholly of diffuse parenchyma
	3	in rather few to very numerous, mostly continuous bands, sometimes interrupted or broken or coalesced
	4	in very few to very numerous bands, sometimes fairly continuous, mostly short or very short and frequently intermittent, broken or coalesced or blending into typically diffuse parenchyma.
	5	in few to very numerous, very short, regularly arranged bands, running from ray to ray, sometimes broken or coalesced, sometimes partly or wholly composed of diffuse parenchyma
c		**clearly associated with the wood vessels or with the paratracheal parenchyma**
	6	moreover formed as described under 2
	7	moreover formed as described under 3
	8	moreover formed as described under 4
	9	moreover formed as described under 5

As different types of definitely arranged parenchyma may occur in closely allied genera and in a few cases in one and the same genus, it was, for the purpose of subdividing the subgroups, observed whether, apart from the absence of definitely arranged parenchyma, the parenchyma is clearly associated with the wood vessels.

Something was said already on this association in the treatment of the paratracheal parenchyma. As a criterion for subgroup c it is ascertained whether by far the majority of vessels or the appurtenant paratracheal parenchyma (say, those present in that part of the growth ring in which the parenchyma occurs) is in contact with the bands and whether these bands, either by certain changes in direction or whether the vessels, by a particular arrangement, indicate that the frequent occurrence of contact is not merely accidental. As examples of the four indices of subgroup c we mention: *Tectona grandis* L; *Erythrina spp.*; *Dysoxylum spp.*; *Helicia serrata* Bl.

The four types of definitely arranged parenchyma comprise nearly all

cases. The type itself must sometimes be ascertained arbitrarily, especially the selection of indices 3 and 4 (7 and 8 resp.). Typical examples for b. 2 are: *Magnolia javanica K et V*; b 3: *Calophyllum inophyllum* L; b. 4: *Engelhardtia serrata* Bl.; b. 5: *Anonaceae.*

Section III. Parenchyma. Group C. Indefinitely arranged parenchyma (scattered at random, diffuse and metatracheal).

Subgroups	Index	Description
a	1	**both kinds are lacking**
b		**independent of the paratracheal parenchyma or of the vessels, preferably neither in their neighbourhood**
	2	purely diffuse parenchyma
	3	ditto, at the same time forming transitions to extremely short, fine, metatracheal bands
	4	parenchyma as described under 2 or 3; besides: short, irregularly distributed, sometimes waving or branching, more or less tangentially running bands and/or flecks of metatracheal parenchyma
	5	as under 3, but without the diffuse parenchyma
c		**for the greater part clearly associated with the paratracheal parenchyma or with the vessels, or at least mainly occuring in their immediate vicinity**
	6	moreover formed as described under 2
	7	moreover formed as described under 3
	8	moreover formed as described under 4
	9	moreover formed as described under 5

This group is subdivided like the previous one; a further division according to the occurrence of periodic differences in the growth rings was regarded as being of less great systematic importance than in the case of the paratracheal parenchyma. At any rate this comes out also in Section IV, Group D.

In the light of the above considerations the subdivisions of the subgroups will be sufficiently clear. We add the following examples in explanation:

b. 2:	*Vatica spp.*	fam. Dipterocarpaceae
b. 3:	*Alstonia villosa* Bl.	„ Apocynaceae
b. 4:	*Hopea spp.* and *Shorea spp.*	„ Dipterocarpaceae
b. 5:	*Vaccinium varingiaefolium* Miq.	„ Ericaceae
c. 6:	*Trigoniastrum spp.*	„ Polygalaceae
c. 7:	*Platea corniculata* Becc.	„ Icacinaceae
c. 8:	*Rhodamnia trinerva* Bl.	„ Myrtaceae
c. 9:	*Pithecolobium umbellatum* Benth.	„ Leguminosae

Section III. Parenchyma. Group D. Quantity
(paratracheal and indefinitely arranged parenchyma).

Sub-groups	Index	Description
a	1	**parenchyma of both types is lacking or, if present, is extremely scarce and practically imperceptible**
b		**if perceptible, paratracheal parenchyma occurs only locally**
	2	if present, indefinitely arranged parenchyma occurs only locally
	3	indefinitely arranged parenchyma scarce
	4	indefinitely arranged parenchyma superfluous
c		**paratracheal parenchyma scarce**
	5	if present, indefinitely arranged parenchyma occurs locally
	6	indefinitely arranged parenchyma scarce
	7	indefinitely arranged parenchyma superfluous
d		**paratracheal parenchyma superfluous**
	8	if present, indefinitely arranged parenchyma occurs locally
	9	indefinitely arranged parenchyma scarce
	0	indefinitely arranged parenchyma superfluous

In subdividing this group, the quantity and the local occurrence or otherwise of the paratracheal parenchyma was considered of greater systematic importance, than the same features of the diffuse metatracheal parenchyma of group C. We may add that "local" does not mean here a regular occurrence in special parts of the growth rings, but a quite irregular local occurrence.

The distinction between scarce and superfluous relates to the total quantity of parenchyma and geruires arbitrary decisions.

Section IV. Particular growths.

In general there is little to be said about particular growths. Except in the case of group D, the growth rings, we have exclusively to do with qualitative features, so that it is sufficient to refer here to what has been said on this point under "selection of subgroups and indices" (page 474).

Section IV. Particular growths. Group A. Included phloem, and oil cells.

Sub-groups	Index	Description
a	1	**both formations are lacking**
b		**included phloem absent**
	2	oil cells do occur, but exclusively in the rays
	3	oil cells occur in parenchyma and rays
	4	oil cells do occur, but exclusively in the parenchyma
c		**included phloem present, chiefly in groups or series**
	5	oil cells lacking
	6	oil cells present, exclusively in the rays
	7	oil cells present in parenchyma and also in rays or otherwise
d		**included phloem present, chiefly in rather long, distinct tangential series**
	8	oil cells lacking
	9	oil cells present, exclusively in rays
	0	oil cells present in parenchyma, and also in rays or otherwise

The included phloem is a very permanent and typical feature, but occurs in only a few genera and in small number of families; for this reason it has been included in the first group of the section for purposes of subdivision. The occurrence of oil cells and the tissue in which they occur, are also of great systematic importance, but sometimes these growths are difficult to perceive, which lessens the value of this feature.

Section IV. Particular growths. Group B. Resin canals, gum ducts and latex elements.

Sub-groups	Index	Description
a	1	**all of the above formations are lacking**
b		**only radial canals in the rays**
	2	occurring generally scattered
	3	occurring only locally
c		**axial canals, largely in long or shorter rows**
	4	occurring generally scattered, no radial canals

Section IV. Particular growths. Group B. Resin canals, gum ducts and latex elements (continued).

Sub-groups	Index	Description
	5	occurring only locally; no radial canals
	6	occurring generally; moreover, radial canals in rays
	7	occurring only locally; radial canals in rays
d		**axial canals, more or less independent, or scattered in small groups**
	8	radial canals are lacking
	9	radial canals occur as well
e	0	**there occur other canals, not to be included in the above descriptions**

This group is somewhat difficult to subdivide, because the available means do not allow of resin canals, gum ducts and latex elements to be distinguished from each other with certainty. It is possible, therefore, that various samples of one species, even of one and the same tree (with gum ducts) may occur both under a 1 and c 5, which might be a reason for altering the arrangement and let these groups follow each other, if not the same were possible with a 1 and b 3.

This might further induce us to give this group a still more unimportant place, if not the occurrence of resin canals in the rays and also axial resin canals was very characteristic of many genera from different families.

It is quite possible that a totally different subdivision of this group may afterwards prove desirable.

Section IV. Particular growths. Group C. Storied structure, radial intercellular canals, pith flecks and bast fibre formations.

Sub-groups	Index	Description
a		**storied structure absent**
	1	all of the above formations absent
	2	storied structure absent; radial intercellular canals absent **pith flecks present**; bast fibre formations absent
	3	storied structure absent; **radial intercellular canals present**, pith flecks absent; bast fibre formations absent
	4	storied structure absent; **radial intercellular canals present, pith flecks present**; bast fibre formations absent

Section IV. Particular growths. Group C. Storied structure, radial intercellular canals, pith flecks, bast fibre formations (continued).

Sub-groups	Index	Description
	5	storied structure absent; **bast fibre formations present**; radial intercellular canals and pitch flecks present or absent
b		**storied structure present**
	6	**storied structure present**; radial intercellular canals absent; pith flecks absent; bast fibre formations absent
c	7	**storied structure present**; radial intercellular canals absent; **pith flecks present**; bast fibre formations absent
	8	**storied structure present**; **radial intercellular canals present**; pith flecks absent; bast fibre formations absent
	9	**storied structure present**; **radial intercellular canals present**; **pith flecks present**; bast fibre formations absent
	0	**storied structure present**; **bast fibre formations present**; radial intercellular canals and pitch flecks present or absent

The subdivision of this group depends on the absence or presence of storied structure. This distinction is not of inconsiderable systematic importance in that the occurrence of storied structure is limited to only a few families.

As against this there is the fact, however, that although storied structure is a constant feature of some species, it is quite occasional in others, and is further useful as a general and specific characteristic in only very few genera.

Record (1927) has given a detailed outline with a biblography on orders, families and genera showing storied structure.

The systematic significance of the occurrence of storied structure has been explained by Janssonius (1931). He demonstrated that storied structure does not occur when the ground tissue consists of fibre tracheids. A similar negative correlation was noticed by Chalk (1937), which he extended to scalariform perforation plates and storied structure. As fibre tracheids and scalariform perforation plates are regarded as primitive features, storied structure must count as a highly specialized characteristic. Chalk calculated that of the 1272 Dicotyledonous genera examined by him only 18 per cent exhibited storied structure.

Intercellular canals, possessed by only very few genera, are often of limited local occurrence, so that only their presence is of importance systematically.

Pith flecks may be found in numerous species and can hardly be considered indications; it is only in a few species that they occur regularly; they are never a quite general, nor a specific feature.

The bast fibre formations of some wood species (*Eugenia spp.* fam. *Myrtaceae* and *Koompassia sp.* fam. *Leguminosae*), which, although not general, are peculiar to these species, are of a very special structure. They are tangential layers of a bark-like tissue of one to several mm thick, which, in axial and radial direction, mostly do not extend any farther than a few cm to at most 1 dm and which, in certain cases, are invariably intermittent, the various layers being connected by radial bands of a particular tissue resembling intercellular canals (especially in *Eugenia spp.* Kolat lapis).

A study about the identification of wood with included phloem, which does not enclose the above examples, has been published by Chalk and Chattaway (1937).

As these formations, if small, sometimes resemble pith flecks and intercellular canals and do occur in a few species only, to which they are then peculiar, the simultaneous occurrence or absence of both last-named features may be considered of so secondary an importance that no further subdivision has been based on it.

Section IV. Particular growths. Group D. Growth rings.

Sub-groups	Index	Description
a	1	growth rings lacking or vague
b	2	growth rings moderate to very conspicuous owing to pronounced periodicity in the **number or in the arrangement of the vessels** and **not** in the parenchyma
	3	growth rings moderate to very conspicuous owing to pronounced periodicity in the **size of the vessels** and **not** in the parenchyma
c	4	growth rings moderate to very conspicuous owing to pronounced periodicity in the **definitely arranged parenchyma** and **not** in the vessels
	5	growth rings moderate to very conspicuous owing to pronounced periodicity in the **definitely arranged parenchyma** and in the vessels **as well**
d	6	growth rings moderate to very conspicuous owing to pronounced periodicity in the **indefinitely arranged parenchyma** and **not** in the vessels
	7	growth rings moderate to very conspicuous owing to pronounced periodicity in the **indefinitely arranged parenchyma** and in the vessels **as well**
e	8	growth rings moderate to very conspicuous owing to pronounced periodicity in the **paratracheal parenchyma** and **not** in the vessels

Section IV. Particular growths. Group D. Growth rings (continued).

Sub-groups	Index	Description
	9	growth rings moderate to very conspicuous ownig to pronounced periodicity in the **paratracheal parenchyma** and in the vessels **as well**
f	0	growth rings moderate to very conspicuous, but characterized in different ways from those mentioned above

The above subgrouping is based on the occurrence or absence of periodicity in the various types of parenchyma. The periodicity in the vessels, both in size and number, is regarded as of secondary systematic importance, although this feature may be especially significant in distinguishing nearly allied species.

In this group the typical indices should be selected very arbitrarily and the principal ones chosen if a number of elements and tissues participate in the formation of growth rings. It is possible, for instance, that the wood vessels (in size and number) and the paratracheal, as well as the definitely arranged and indefinitely arranged parenchyma show a certain periodicity bringing out the growth rings (e.g. fam. *Leguminosae*). This case is then indicated as c/d 5/7; the formation b. 2 and b. 3 is included in c. 5, d. 7 and e. 9, while subgroup e, as being of secondary importance, is ignored.

Subgroup f is chiefly used to indicate a distinct periodicity in the tissue density; it is exclusively employed if this last-named formation is the only one in which the growth rings find expression, or if, beside others, it is very conspicuous.

Section V. Other characteristics.

The following characteristics are practically valueless in making primary and secondary distinctions in systematics, but very often yield useful, sometimes even the only features for telling apart allied species, and as such they are indispensable.

Section V. Other characteristics. Group A. Specific gravity.

Sub-groups	Index	Description	
a	1	extremely light	< 0.3
	2	very light	0.3 — 0.4
b	3	light	0.4 — 0.5
	4	moderately light	0.5 — 0.6
c	5	moderately heavy	0.6 — 0.75
d	6	heavy	0.75 — 0.9
e	7	very heavy	0.9 — 1.05
	8	extremely heavy	> 1.05

This subdivision, which is also given by Den Berger and Beekman (1922), is self-explanatory. The not elaborate division of the subgroups is more suited to the wood species that often differ rather considerably in specific gravity, although there will also be borderline cases here, where the letters of two subgroups have to be used.

Section V. Other characteristics. Group B. Cutting hardness and grain.

Sub-groups	Index	Description
a	1	**soft,** cuts easily, straight-grained without cross-fibres
	2	soft, cuts easily, straight-grained with cross-fibres
	3	soft, cuts easily, grain wavy or twisted
b	4	**moderately hard,** cuts with moderate difficulty, straight-grained without cross-fibres
	5	moderately hard, cuts with moderate difficulty, straight-grained, with cross-fibres
	6	moderately hard, cuts with moderate difficulty, grain wavy or twisted
c	7	**hard,** difficult to cut, straight-grained without cross-fibres
	8	hard, difficult to cut, straight-grained with cross-fibres
	9	hard, difficult to cut, grain wavy or twisted

As the hardness of a wood is, generally, a more constant type of feature than the trend of the grain, the former characteristic was used as a basis for the subdivision. It is evaluated according to the relative ease with which the end surface can be cut.

Section V. Other characteristics. Group C. Colour.

Sub-groups	Index	Description
a	1	dark brown, very dark yellowish brown to black
b	2	yellowish brown, deep brownish yellow or dark greenish yellow
	3	bright yellow, deep yellow, straw-yellow, etc.
c	4	light brownish yellow, light greyish yellow, light greyish brown, yellowish grey, brownish grey, greenish grey
	5	yellowish white, dingy white, greyish white, purplish white

Section V. Other characteristics. Group C. Colour (continued).

Sub-groups	Index	Description
	6	light grey, pinkish grey, light purplish grey, orange grey, light pink
d	7	dark pink, greyish red, grey reddish brown, greyish purple or dark grey
	8	bright reddish brown or brownish red, orange brown, greyish orange
e	9	bright orange, vivid red, brick red
	0	dark red, dark-reddish brown to almost black

The succession of colours chosen is such that the modifications occurring in various wood species or in one hand the same genus usually are in this order, so that, if two non-consecutive indices are stated, it may be assumed that colours belonging to intermediate indices occur as well. Only in a few cases (e.g. in the genus *Dialium* fam. *Leguminosae*) both extremes are found, the colours varying from red to dark red, to dark brown and yellowish brown. In such a case this is expressed by placing the highest indices in front and filling in the card as follows: e/b 9/2, which shows that also a. 1 is included.

If a genus, generic group or subgenus exhibits two quite different colours, transition colours being absent, this is indicated by means of a hyphen (e.g. b—d, 3—8, or a—c, 1—5).

Section V. Other characteristics. Group D. Gloss and smell.

Sub-groups	Index	Description
a	1	**smell not characteristic,** gloss slight
	2	smell not characteristic, gloss moderate
	3	smell not characteristic, gloss distinct
	4	smell not characteristic, gloss fine
	5	smell not characteristic, gloss very fine
b	6	**smell characteristic,** gloss slight
	7	smell characteristic, gloss moderate
	8	smell characteristic, gloss distinct
	9	smell characteristic, gloss fine
	0	smell characteristic, gloss very fine

This last group does not call for much comment, if characteristic, the odour is often a specific, but seldom a general feature, because it is sometimes lacking or disappears.

The gloss is often a general feature; it seldom occurs alone, but sometimes associated with some other characteristics. From these considerations we chose the presence or absence of a characteristic odour as a basis for the above subdivision. Odour, however, can hardly be considered as of more or less systematic importance.

IV. THE APPLICATION OF THE SCHEME IN PRACTICE.

A. Order and priority of the features.

As far as can be judged at present, the priority of the features, from a systematic point of view comes out most in the following order: I A, II A, III A—I B, II B, III B—I C, II C, III C—next IV A, IV B, IV C and IV D; then I D, II D, III D and finally V A, V B, V C and V D. The classification will anyway have to be started in this way.

Although, for purposes of classification alone, the simplest plan is to adopt exclusively the decimal system, it will be desirable considering the relationship between this scheme of classification and the botanical natural system, first to make a classification according to the subgroups (either wholy or partially) and then to resubdivide the resulting subgroups according to the indices, again going through the entire part of the classification system already used.

Provisionally a division by means of index cards alone is made according to the first series of group I A, II A, III A, I B, II B, III B, I C, II C, III C and based on the subgroups. In those cases where cards of different genera or even families coincide, a subdivision can be made in the manner best suited to that set of cards, although, as far as possible, one or more definite systems of further subdivision must nevertheless be used. Not until all families have been classed can any additional decisions on this point be made.

As stated above, it was at first attempted to group features in the order of their probable systematic importance. One should, however, not put one's expectations too high; as even the so called natural system on which the classification of plants in groups, families and genera is based has many exceptions and closely allied plants obviously exhibit fundamental differences, it goes without saying that such exceptions are much more frequent here. In the case of the perforation plate, for instance, i.e. the feature that we have provisionally adopted as the principal one, in the systematics of wood anatomy, different families show different types. Here are even different genera some species of whose secondary wood have exclusively simple perforations, others both simple and scalariform perforation plates, and still others exclusively scalariform perforation plates. The features of the different families sometimes overlap, so that one family whose perforation plates are constantly similar may suddenly be found to include a genus possessing another type of perforation. *Theaceae*, e.g. which,

according to Den Berger (1920) only have scalariform perforation plates, include the genus *Architea*, all possessing simple perforations.

The same may be said of the other features, mostly even in a much higher degree.

This point may be elucidated with a single example for the second most important feature: 1 or 2 types of rays. All the genera of the *Guttiferae* examined by us possess two types of rays. The genera *Calophyllum* and *Cratoxylon* include another type having one kind of rays.

Once a clear statistic outline has been obtained it will appear that in one family this feature is the most constant, in another that feature.

Beforehand, however, the features must be clearly and sharply defined. In the foregoing pages the features of each table have been described as explicity as possible. Under "Selection of subgroups and indices" we give the line of action to be followed in doubtful cases.

B. Descriptions; cards and systems; selection of subgroups and indices.

The system is applied as follows:

Of all the samples under investigation model descriptions are made (see IV D), from which, in a manner to be explained later, the classification scheme is composed. This scheme is printed on the description form under the heading: "Further particulars".

Then two or more cards are made, which are filed in two systems — classed alphabetically and according to the subgroups (see IV C). For the models of these cards see IV E. The cards comprise: the classification scheme, systematic botanical data, the sample numbers and additional remarks, if any.

Evidently, the correct selection of subgroups or index must often take place arbitrarily and intelligently, as nature abhors sharp lines of demarcation. It is exactly rigid delimitation, however, which is a primary necessity in a classification system such as the present one.

For this reason, the limits drawn in the subdivision of each group have been accurately described. It must further be ascertained what general rules have to be observed in the arbitrary selection of the indices. If **quantitative features** * are in question it is advisable, in general, not to search for extreme cases, such as are found in each wood; in determining whether in a certain species the vessels occur in groups of 2—4 or 2-many, for instance, do not try to find somewhere in the back a single group of more than 4 vessels, and if so, do not use at once the index belonging to the second case, but ascertain whether the occurrence of such groups of more than 4 vessels is a constant feature that is easily found in different places. Also, in determining the number of rays, do not look everywhere for an extraordinarily large number of rays over a width of 1 mm, but count about ten times over a distance of 1 mm, preferably, say, over twice 5 mm, and then take the average.

Quite different is the searching for two types of perforation plates,

* See also Desch (1932) and Rendle and Clarke (1934).

two types of rays or the presence of resin canals, etc., in short, **qualitative** features. Then one swallow does make summer, persistent and careful search of all the surfaces being a necessity.

If, in the case of such a feature, identification is very difficult, and if it is necessary to search long, also that index is entered on the card which would have been taken if this particular formation had not been found.

In order to indicate, however, that one index is only a result of erroneous observation, this figure is indicated in r e d or i t a l i c s. If in preparing a collective card for a genus or subgenus, such a formation does occur in some, but decidedly not in other species, both figures are given in b l a c k. If there is a gradual transition between different species (e.g. in *Cyclostemon* fam. *Euphorbiaceae,* some species of which possess exclusively simple perforations, others simple and scalariform, and still others exclusively scalariform ones), the letters and figures are placed, say, as follows: c/d, 6/7.
9/0

If, however, two sharply separated cases are found (e.g. in the genus *Calophyllum* fam. *Guttiferae,* showing rays both in two and one type) the indices might be placed as follows: a—b, 4—9 or a 4 This at the
b 8/9.
same time renders it possible to make more detailed descriptions. As to cutting hardness and grain, e.g. 1 b. 4/5 will signify: the wood (or woods) is straight-grained and has little cross-fibre; b, 4—5, denotes, however, that in some samples cross-fibres are absent and in others present.

If it cannot be ascertained with sufficient certainty whether a given formation has been correctly classified, a note of interrogation is placed over the column containing the index in question. If, as a result of the very fine texture of the wood, it is quite impossible to determine the most probable index, a note of interrogation is placed in the square in question. Exactly the same procedure with quantitative features is followed: in borderline cases, or if different samples show transitions between two headings, this is indicated by means of a dash; otherwise a diaeresis is used.

If one of the subordinate features is particularly characteristic, or especially suitable for distinguishing one wood species from an as to the rest very similar one, then the index belonging to that feature is underlined.

C. Arrangement of the cards; systems of identification.

The cards may be arranged by the following methods:

A r r a n g e m e n t a c c o r d i n g t o P f e i f f e r.

The cards are filed in two systems.

In one system the cards, filled in as completely as possible, are arranged alphabetically according to family and genus. In the second system the cards are arranged according to subgroups, and afterwards according to

indices in the order already described under IV A, care being taken to approximate a "natural" division as far as possible. It may be stated now already, that this will be possible only approximately. In order to prevent the cards of both systems from being mixt up the four types of cards might be chosen of a different colour.

Under either system two colour cards are used, i.e. the collective cards for samples belonging to one and the same genus or subgenus are in one, the cards for completely defined species (either already fully identified and named) being in the other colour.

The second set, which at the same time has to serve as an identification table, always must be kept complete; the first set may be used in tracing generic subfamily and family characteristics, and in collecting statistical data; here it should invariably be possible for the cards to be grouped in different ways. The original order (alphabetical according to families) is always easy to restore again.

In filing the cards in the system according to the subgroups, it is advisable to follow the two rules:

1. Figures or letters, red or in italics, occurring in one and the same square with figured or letters in black, are ignored in the classification.
2. If several black letters or figures occur in one square the lowest number or the foremost letter is taken first.

In order to allow of a proper identification, even when almost unavoidable errors are made, and also in borderline cases, several cards are made, where, in the squares with several letters (and figures, if any), the previous letters, or in the case of red or black letters, the black letters, are omitted. As many cards are made as correspond to the actual number of cases, the other cards being referred to at the foot of the card under the heading "particulars". The completest card, which therefore corresponds to the one occurring in the other system, is regarded as the principal card. From the cards of fully defined species only one card is made for the determination system, which is to be as detailed as possible. If several cards are made for such a species, for the others only genera-cards are used, referring to the primary indices of the complete card. In making extra cards for borderline cases and errors we did provisionally not go further than the letter indices of the above mentioned first series of groups.

Arrangement according to Bianchi.

A. T. J. Bianchi, at the time placed at the disposal of the Head of the Technological Department of the Forestry Experiment Station at Buitenzorg, suggested the following alteration in the arrangement of the cards in practice, which is well worth adopting.

All combinations of the subgroups of the nine groups used for the first division (I A, I B, I C, II A, II B, II C, and III A, III B, III C) are arranged by him according to a table, indicating them by combination of two groups of figures, the former running from 1—36, the latter from 1—432. In this way 12312 different figure combinations are obtained, each indicating one of the possible combinations of the subgroups, e.g. 11/375.

TABLE II.

Table for the transposition of the subgroup combinations into a combination of two figure groups, according to which the arrangement takes place, if vessels are lacking.

First figuregroep				Second figuregroup																
A				B			C	C II	a			b			c			d		
I	II	III		I	II	III	I	C III	a	b	c	a	b	c	a	b	c	a	b	c
a	a	a	1	a	a	a	a		1	2	3	4	5	6	7	8	9	10	11	12
		b	2			b	a		13	14	15	16	17	18	19	20	21	22	23	24
		c	3			c	a		25	26	27	28	29	30	31	32	33	34	35	36
	b	a	4		b	a	a		37	38	39	40	41	42	43	44	45	46	47	48
		b	5			b	a		49	50	51	52	53	54	55	56	57	58	59	60
		c	6			c	a		61	62	63	64	65	66	67	68	69	70	71	72
	c	a	7						73	74	75	76	77	78	79	80	81	82	83	84
		b	8						85	86	87	88	89	90	91	92	93	94	95	96
		c	9						97	98	99	100	101	102	103	104	105	106	107	108

TABLE III.

Table for the transposition of the subgroup combinations into a combination of two figure groups, according to which the arrangement takes place, if vessels are present.

First figuregroup				Second figuregroup																	
A				B			C	C II	a			b			c			d		
I	II	III		I	II	III	I	C III	a	b	c	a	b	c	a	b	c	a	b	c
b	a	a	10	b	a	a	b		1	2	3	4	5	6	7	8	9	10	11	12
		b	11				c		13	14	15	16	17	18	19	20	21	22	23	24
		c	12				d		25	26	27	28	29	30	31	32	33	34	35	36
	b	a	13			b	b		37	38	39	40	41	42	43	44	45	46	47	48
		b	14				c		49	50	51	52	53	54	55	56	57	58	59	60
		c	15				d		61	62	63	64	65	66	67	68	69	70	71	72
	c	a	16			c	b		73	74	75	76	77	78	79	80	81	82	83	84
		b	17				c		85	86	87	88	89	90	91	92	93	94	95	96
		c	18				d		97	98	99	100	101	102	103	104	105	106	107	108
c	a	a	19		b	a	b		109	110	111	112	113	114	115	116	117	118	119	120
		b	20				c		121	122	123	124	125	126	127	128	129	130	131	132
		c	21				d		133	134	135	136	137	138	139	140	141	142	143	144
	b	a	22			b	b		145	146	147	148	149	150	151	152	153	154	155	156
		b	23				c		157	158	159	160	161	162	163	164	165	166	167	168
		c	24				d		169	170	171	172	173	174	175	176	177	178	179	180
	c	a	25			c	b		181	182	183	184	185	186	187	188	189	190	191	192
		b	26				c		193	194	195	196	197	198	199	200	201	202	203	204
		c	27				d		205	206	207	208	209	210	211	212	213	214	215	216
d	a	a	28	c	a	a	b		217	218	219	220	221	222	223	224	225	226	227	228
		b	29				c		229	230	231	232	233	234	235	236	237	238	239	240
		c	30				d		241	242	243	244	245	246	247	248	249	250	251	252
	b	a	31			b	b		253	254	255	256	257	258	259	260	261	262	263	264
		b	32				c		265	266	267	268	269	270	271	272	273	274	275	276
		c	33				d		277	278	279	280	281	282	283	284	285	286	287	288
	c	a	34			c	b		289	290	291	292	293	294	295	296	297	298	299	300
		b	35				c		301	302	303	304	305	306	307	308	309	310	311	312
		c	36				d		313	314	315	316	317	318	319	320	321	322	323	324
					b	a	b		325	326	327	328	329	330	331	332	333	334	335	336
							c		337	338	339	340	341	342	343	344	345	346	347	348
							d		349	350	351	352	353	354	355	356	357	358	359	360
						b	b		361	362	363	364	365	366	367	368	369	370	371	372
							c		373	374	375	376	377	378	379	380	381	382	383	384
							d		385	386	387	388	389	390	391	392	393	394	395	396
						c	b		397	398	399	400	401	402	403	404	405	406	407	408
							c		409	410	411	412	413	414	415	416	417	418	419	420
							d		421	422	423	424	425	426	427	428	429	430	431	432

Now the system is divided into 36 sections by means of simple index cards, bearing the numbers 1—36, the cards being filed in each of these sections in accordance with the order of the figures of the two groups. In this way the cards come to stand in quite the same order as in the system described previously, but it is much easier to arrange them and to find certain combinations.

In subsequent identification the method is as follows: Prepare a card in the manner described before, take the corresponding number from the table below (or numbers, if the card shows several combinations), and find the appropriate card (or cards).

The numbers are placed in the right hand top corner of the cards, over the word "order", in such a way that after the last group of figures enough space is left for a third figure group to be used if a further subdivision should be contemplated.

TABLE IV.

D. Example of a wood description.

Name: *Aleurites moluccana (L.) Willd.* Order: *Geraniales* (sensu Engler)

No.: 1746, 2101 Family: *Euphorbiaceae*
Crotonoideae
Chrozophoreae

A. Structure of the wood.

Vessels:	Plates:	simple perforations.
	Grouping:	majority solitary, only few groups of 2 to many.
	Arrangement:	scattered.
	Size:	moderately large.
	Number:	few in general, sometimes moderately few locally.
	Bordering:	bordered by rays mostly on two, always on one side, for the rest almost invariably surrounded by parenchyma.
	Elements:	1—2 per running mm.
	Contents:	not characteristic.
Fibres:		
Rays:	Types:	clearly in two types.
	Structure:	the narrow rays completely of upright cells; the broader rays, as far as they are simple, composed of only few rows of procumbent cells with 1—3 rows of upright cells. Vertically fused rays very frequent.
	Number:	rather numerous (8—10); ratio of the numbers not to be determined.

TABLE IV (continued).

Width: the broader ones very fine to moderately fine, the narrowest extremely fine to very fine, ratio difficult to determine.

Height: very low.

Parenchyma: Paratracheal parenchyma present as a rather broad mostly complete ring, with numerous outgrowths of scattered parenchyma. Definitely arranged, in extremely short fine bands of diffuse and metatracheal parenchyma, rather regularly arranged but in some places betraying a distinct association with the paratracheal parenchyma, and locally, where the vessels are few, irregular or absent and resembling indefinitely arranged parenchyma. Indefinitely arranged parenchyma, present as diffuse and as extremely short fine bands; scanty.

Particular growths: Included phloem; lacking.
Resin and other ducts: not noticed.
Storied structure: lacking.
Pith flecks: not noticed.
Growth rings: lacking or extremely vague.

B. Other features:

Specific gravity: very light.
Hardness: soft, easily cut.
Grain: straight.
Feel:
Colour: yellowish white.
Gloss: moderate.
Smell:
Taste:
Burning:
Extract:

C. Further particulars.

Literature about the species in question:
Scheme of classification: 17/77

	I		II		III		IV		V	
A	b	2	c	9	b	4	a	1	a	2
B	b	4	a	?	*a*-c	*1*-9	a	1	a	1
C	b	2	b	2	b-*c*	2-*8*	a	1	c	5
D	b	4	b	2/3	b	2-*4*	a	1	a	2

TABLE V.

E. Examples of filled-up cards.

Green:

Species card for the botanical arrangement.

	I		II		III		IV		V	
A	b	2	c	9	b	4	a	1	a	2
B	b	4	a	?	*a*-c	*1*-9	a	1	a	1
C	b	2	b	2	b-*c*	2-*8*	a	1	c	5
D	b	4	b	2,3	b	2-*4*	a	1	a	2

Order: 17/77-78
Geraniales
Family:
Euphorbiaceae
Subfamily:
Crotonoideae
Tribus:
Chrozophoreae
Genus:
Aleurites
Species:
moluccana (L.) *Willd.*

Nos. 1746. 2101.
Particulars: In some samples, the definitely arranged parenchyma may be partly or wholly regarded as indefinitely arranged.

White:

Species card for the arrangement according to classification number.

	I		II		III		IV		V	
A	b	2	c	9	b	4	a	1	a	2
B	b	4	a	?	*a*-c	*1*-9	a	1	a	1
C	b	2	b	2	b-*c*	2-*8*	a	1	c	5
D	b	4	b	2,3	b	2-*4*	a	1	a	2

Order: 17/77-78
Geraniales
Family:
Euphorbiaceae
Subfamily:
Crotonoideae
Tribus:
Chrozophoreae
Genus:
Aleurites
Species:
moluccana (L.) *Willd.*

Nos. 1746. 2101.
Particulars: In some samples, the definitely arranged parenchyma may be partly or wholly regarded as indefinitely arranged.

TABLE V (continued).

Yellow:

Species card for the arrangement in both the systems.

	I		II		III		IV		V	
A	b	2	c	9	b	4	a	1	a/b	2/4
B	b	4	a	?	*a*-c	*1*-9	a	1	a/b	1/4
C	b	2	b	2	b-*c*	2-*8*	a	1	c	4 5
D	b	4	b	2/3	b	2-*4*	a	1	a	2

Order: 17/77-78
Geraniales
Family:
Euphorbiaceae
Subfamily:
Crotonoideae
Tribus:
Chrozophoreae
Genus:
Aleurites
Species:
moluccana (L.) *Willd.*

Nos. 1746. 2101. 2140. 2435.
Particulars: In some samples definitely arranged parenchyma may, although wrongly, be partly or wholly regarded as indefinitely arranged parenchyma.

Reference card for species mentioned twice.

	I		II		III		IV		V	
A	b	2	c	9	b	4	a	1	a/b	2/4
B	b	4	a	?	*a*	*1*	a	1	a b	1/4
C	b	2	b	2	*c*	*8*	a	1	c	4/5
D	b	4	b	2/3	b	*4*	a	1	a	2

Order: 17/6
Geraniales
Family:
Euphorbiaceae
Subfamily:
Crotonoideae
Tribus:
Chrozophoreae
Genus:
Aleurites
Species:
moluccana

Nos.
Particulars: The apparently indefinitely arranged parenchyma is in fact definitely arranged: See also III b-c 9 and III c-b, 2, so 17/77-78.

V. DISCUSSION.

A. Comparison of the decimal system with other systems of classification and identification.

Arrangement of characteristics.

In the literature a number of schemes are to be found intending to give a universal method for the classification and identification of woods. The features mentioned are arranged in the following ways:

a. The features are not all correlated with each other by numbering or lettering, e.g. Lecomte (1923), Record (1934a) and Normand (1934).

b. The features are numbered consequently, so that these systems do not make it clear that certain features are subordinate to each other (Beversluis 1925, Clarke 1938, Record and Chattaway 1939).

c. Non equivalent features are partly classed as subordinate to each other. Besides, however, such features or feature groups are given the same importance. Moll and Janssonius (1906).

In the above decimal system of classification, however, all the features and feature groups are consistently divided in such a manner that only groups of nearly equal importance are placed side by side. These feature-units, which may also more or less be regarded as of equal importance, have been subordinated to greater characteristic units and so forth. The great advantage of this method is that the scheme of classification thus composed automatically yields the possibility of identification, which is not the case in any of the other systems described above.

Systems of identification.

The identification system based on the decimal classification has the same advantages as the systems in which the number of wood species included can be extended at random. Our system also employs loose cards. Drawbacks attaching to the existing method using loose cards have been removed. The advantages thus obtained are as follows:

a. The number of features that can be made use of are not determined by the dimensions of the cards, such as in Clarke's system.

b. Neither is the number of wood species that can be included in the system determined by these dimensions. This is the case in Bianchi's system.

c. The cards do not need to be punched. In punched cards the holes which do not run on to the edge of the card will wear out on prolonged and frequent use, which may give rise to erroneous result. A similar drawback has come to the front when this method was used in another field, viz. for the classification of literature data.

B. Possibilities of the decimal system.

As already appeared from the example of a wood description (see IV, D), it is not our intention to substitute the decimal system of classification of the description of woods by a numerical system. This would

render it impossible to use numerous fine shades. The scheme can, however, give lines of action to be persued with a view to establishing a certain order of description, so that uniformity in the treatment of the woods is guaranteed.

Linking up with morphological systematics.

Apart from the possibility of arriving at a botanically justified classification and identification of woods, and of assisting in discovering their mutual relationships, the common indices of the decimal system also give the basis for a fourth kind of investigation, as they make it possible easily to gain an idea of the distribution of certain features and their variability. In morphological botanical systematics such "feature phylogeny" is very much in the ascendant *) and in wood anatomy the influence of it is clearly noticeable. This appears from the publications of Record (1931, 1934 b, 1936 a and b); Frost (1930 and 1931); Janssonius (1931); Chalk (1937); Kribs (1937) and many others, some of which have already been mentioned. Consequently the systematic anatomic examination of woods can easily adopt itself to the newer trends in botanical systematics.

Extension of the scheme.

On page 439 we discussed the desirability of applying the decimal classification also to features, which can only be observed with sufficient accuracy with the aid of a compound microscope. Far the best plan is to use all available means in the classification of wood species according to their mutual relationship.

A quick and practical method of identification only requires the application of macroscopically perceivable features (hand lens method). As a result we think it advisable that the classifications for macroscopically and exclusively microscopically perceivable features should be kept apart.

They run, however, largely parallel. The most suitable solution of the problem seems, therefore, to design a second classification in which the above features are combined with those which are exclusively perceivable through the microscope. This classification can possibly be arranged in such a way that these last named features are mentioned in the second place so that they may at will be used or not.

A recently provisionally elaborated scheme of microscopical features, using decimal indices includes a division for vascular tracheids, fibretracheids and libriform wood fibres, while, among others, groups have been formed for the nature, the position and the dimensions of pits, striation and stratification of the wall, and the lengths of different elements. This point will be discussed separately in due course.

*) Hayata (1921, 1928 and 1931); Vavilov (1921); Zimmermann (1930); Lam (1938).

VI. SUMMARY.

1. The literature gives various methods to compile a universal scheme for the classification and identification of wood species. To attain this object a new method is now given possessing various advantages over the methods that have been used so far.
2. The wood structure is subsequently described using decimal indices. Each of five sections of features are divided into four groups, and these again in subgroups, which have been worked out by means of indices. In the treatment of various features literature data are discussed.

   The classification of wood species aims at obtaining a grouping which, as far as possible, links up with the botanical groupings according to natural systems.
3. On the grounds given in the introduction and the discussion, the classification has been applied to features which can be perceived both with the unaided eye and a hand lens. The desirability and the possibility of classifying microscopic features in a similar way are dealt with briefly.
4. On the classification scheme an identification method is based employing loose cards. In this way, the number of woods included can be extended at will. Drawbacks attaching to the loose-card methods, used so far, have been obviated.
5. It is suggested that the decimal indexing of features should be normalized internationally.

The authors should greatly appreciate to receive any remarks and suggestions that might improve and supplement the classification system described.

Amsterdam/Delft, August 1944.

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B. Index of authors.

C. Botanical index.

D. Index of terms.