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A Chemotaxonomic Study of the Rutales of Scholz

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ABSTRACT

On the basis of chemical evidence, the order *Rutales* seems to be a homogeneous one, if we consider it to contain the families *Rutaceae*, *Simaroubaceae*, *Burseraceae* and *Meliaceae*.

We know too little as yet of the chemistry of other families of 'our' order (the *Rutales* of Scholz, in Engler, Syll. 12, 1964) to say whether or not they constitute with the above four families a homogeneous group within the *Rutales*. The chemistry of the *Malpighiaceae*, however, is consistent with a position near the *Meliaceae*.

The chemical evidence also supports the creation of two more small families -- *Flindersiaceae* (*Flindersia* and *Chloroxylon*), and *Ptaeroxylaceae* (*Ptaeroxylon* and *Cedrelopsis*) -- which should be placed, perhaps, between *Rutaceae* and *Meliaceae*; and the separation of *Picramnia* (*Picramnioideae*) from the *Simaroubaceae*, *Mundtia* (if our material was genuine) from the *Polygalaceae*, and *Fagara* from *Zanthoxylum*.

A CHEMOTAXONOMIC STUDY OF THE "RUTALES"

OF SCHOLZ (IN ENGLER, SYLLABUS 12, 1964)

by

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TABLE OF CONTENTS

FIGURE AND LIST OF TABLES

CONTENTS OF APPENDIX

INTRODUCTION

The term systematics can be used, as defined by Simpson (1961), as the scientific study of the kinds and diversity of organisms and of any and all relationships between them. Taxonomy is that part of systematics which deals with the study of classification, including its bases, principles, procedures and rules; while classification in a biological sense is the process of ordering plants into groups which are arranged hierarchically.

As stated by Davis and Heywood (1963):

> "Certain disciplines of biology are, of course, so closely tied up with taxonomy that they cannot be practised without the use of a basic classification. These include Cytology, Genetics, Ecology, Phytosociology, Comparative Anatomy, Palynology, Palaeobotany and Plant Geography".

Taxonomy, therefore, is one of the very important biological sciences.

A. History of Taxonomy

In order to survey the field of taxonomy at the present day, it is necessary to have some knowledge of the history of the subject and the development of ideas associated with it.

The early history of botany is largely a history of the uses of plants in medicine, and the root-gatherers and herbalists of the past began, many centuries ago, to group plants having similar "virtues" or medicinal properties, (Gibbs, 1963).

Greene (1909), in his Landmarks of Botanical History, emphasized the major early descriptive developments in taxonomic botany, particularly as related to specific individuals and their contributions to systematics. Beginning with prehistoric time, he recognized as foremost (1) the descriptive contributions of Aristotle and Theophrastus, followed by a long period of lasting quiescence to the fifteenth century, (2) the significance of the observations of the herbalists Tragus, Brunfels, Bauhin, *et al*. of the sixteenth century (3) the first distinction of the monocotyledons and dicotyledons by John Ray in 1703, (4) recognition of sexual characters and their significance by Linnaeus and others in the mid-eighteenth century, and so on.

Lawrence (1951), in an excellent treatment of the history of classification, says:

> "Many different classifications of plants have been proposed. They are recognizable as being or approaching one of three types: artificial, natural and phylogenetic. An artificial system classifies organisms for convenience, primarily as an aid to identification, and usually by means of one or a few characters. A natural system reflects the situation as it is believed to exist in nature and utilizes all information available at the time. A phylogenetic system classifies organisms according to their evolutionary sequence, it reflects genetic relationships, and it enables one to determine at a glance the ancestors or derivatives (when present) of any taxon. The present state of man's knowledge of nature is too scant to enable one to construct a phylogenetic classification, and the so-called phylogenetic systems represent approaches toward an objective and in reality are mixed and are formed by the combination of natural and phylogenetic evidence".

Theophrastus (370-287, B.C.), the "father of Botany", classified plants according to the growth habit. Thus he had four groups: herbs, undershrubs, shrubs, and trees. This was the period of artificial classification, when plants were grouped according to their habit or number of a certain organ.

The natural system came with John Ray (1628-1704) who for the first time recognized the importance of the embryo and the presence of one or two cotyledons. Several outstanding taxonomists during the 1800's classified plants by a "natural" system, they often made no serious or conscious attempt to place the major taxa together according to their evolutionary relationship. For example, such outstanding workers as Bentham and Hooker, in their classic Genera Plantarum, placed the gymnosperms between the Dicotyledons and Monocotyledons instead of placing the latter two together as most phyletic workers have done since that time. None-the-less Bentham and Hooker's work remains to this day a useful system, mostly "natural", but not phylogenetic.

Nearly all systems of classification are based in part, at least, on arbitrary principles as to what constitutes primitiveness or, in turn, advancement. Several such principles have been advanced, some of a contradictory nature depending on the point of view of the systematist (Just, 1948; Constance, 1958). For example, Engler and Diels (1936) considered that the majority of plants with simple unisexual flowers are primitive, while Bessey, Hutchinson and others have considered these same floral types indicative of advancement, the condition having developed by reduction processes from complete, bisexual flowers.

Hutchinson (1959), in setting forth his view on the phylogeny of the angiosperms, adopts the principle that "the spiral arrangement of leaves on the stem and of the floral leaves precedes that of the opposite and whorled type". Cronquist (1955), on the contrary, in considering the phylogeny of the family Compositae, considered opposite leaves to be the primitive condition in that family, but this does not mean necessarily that he considers this to be the primitive condition for angiosperms generally. Similarly, Hutchinson's view that the herbaceous habit is primitive in the Ranunculaceae does not conflict with his supposition that woodiness is the primitive condition for the angiosperms generally.

Several systems of classification, particularly of the flowering plants and usually to the level of family, have been proposed in recent years. These include those of Cronquist (1968), Benson (1957), Hutchinson (1959; 1969 for dicots), Takhtajan (1969) and others. However, only a few systems have gained wide acceptance or attention, the more important being those of Bentham & Hooker, Engler, Bessey, and Hutchinson.

No botanist, however, would claim that any one of the many present systems of classification that have been put forward, represents an ideal or final solution. There are still many problems at all taxonomic levels and, in particular, the interrelations between higher categories such as orders are very unclear. Many difficult taxonomic problems arise from phenomena such as parallel, convergent, and divergent evolution, which may cause botanists to assume closer or more distant genetic relations between plants or groups of plants than those actually existing (Erdtman, 1968). This is argued by Davis and Heywood (1963):

> "Classification, many taxonomists claim, should be based on, or reflect, phylogeny. This aim we believe, is unrealistic in a group with an extremely inadequate fossil record, ... Indeed, the whole conception of phylogenetic classification is, we believe, a mistake except around the species level in favourable and well-studied groups; and even there phyletic relationship often conflicts with genetic relationship as expressed by phenotypic resemblances".

Research is being done to solve this problem of phylogenetic relationships between taxa. Paleobotany, embryology, cytology, and genetics are just a few of the fields. As Cronquist (1957) states

> "Every taxonomic character is potentially important, and no character has inherent, fixed importance; each character is only important as it proves to be in any particular instance in defining a group which has been perceived on the basis of all the available evidence. Experience shows us that some characters are much more stable and thus more likely to be important than others, and that there are many essentially unidirectional evolutionary trends ....."

Despite apparent disagreements over the purpose and interpretation of classifications, it is widely accepted that the most useful assessment of the overall relationships of organisms is obtained by using the largest possible number of similarities and differences. In the original definition of phenetic classification (Cain and Harrison, 1960) it was made clear that it was based on all available observable characters (including genetic data), not just morphological ones. Thus phytochemical characters are included, along with cytological, anatomical, palynological and other attributes, in the best classifications.

Botanical classification rests largely on comparative studies of morphological and anatomical characters. Roads to phylogenetic systems were opened by Darwin, and a deeper understanding of the mechanism of heredity resulted from the fundamental experimental studies of Mendel and his successors. Their work made it abundantly clear that chemical as well as morphological characters of plants are determined by genetic factors by mechanisms the more precise natures of which are now gradually being unveiled.

Morphology is the outward expression of genes. Since genes or chromosomes are biochemical in nature, the study of the chemistry of plants is just another method of investigation. But by no means should this line of research be emphasized to the exclusion of others. This thought is echoed by the words of McNair (1935) who stated that "Plants can be classified chemically in accordance with the substances made by them. Such a chemical classification may be compared with and used as a supplement to morphological classification and may be of some importance in the development of the true natural system of angiosperm phylogeny".

It is evident that systematic investigations of the chemical characters of plants are likely to become of great supplementary value to classical plant taxonomy. Chemical characters of plants have the great advantage that they can be exactly defined.

B. Development of Chemotaxonomy

Chemical plant taxonomy or chemotaxonomy of plants, as defined by Hegnauer (1967), is a scientific investigation of the potentialities of chemical characters for the study of problems of plant taxonomy and phylogeny.

Chemical characteristics of plants have been noted and used by taxonomists for centuries. Gibbs (1965) wrote:

> "Some of the earliest taxonomy was, in a sense, chemotaxonomic. The first groping towards some of our oldest families - oldest, that is, in establishment - was due to the recognition of 'virtues' in common."

De Candolle believed Rudolph Jacob Camerarius to be the first clearly to express the connection between forms of plants and their properties. In some of the writings of A.P. de Candolle, as Hegnauer (1958) has noted, considerable attention was given to the chemical properties of plants as correlated with their morphological characters. Examples from De Candolle cited by

Hegnauer were the observations that all _Cinchona_ species combat fever, all _Pinus_ species produce terpenes, all _Amentifere_ have astringent bark, and all _Convolvulaceae_ are laxative.

Petiver, in 1699, as Gibbs (1965) has noted, recognized the families _Umbelliferae_, _Labiatae_, and what we now call _Cruciferae_, largely on medicinal (chemical) characters.

Lindley, in 1830, as cited by Gibbs (1965), wrote of the _Amygdaleae_ that they are:

> "Distinguished from Rosaceae and Pomaceae by their fruit being a drupe, their bark yielding gum, and by the presence of hydrocyanic acid; from Leguminosae by the latter character, and ... from Chrysobalaneae by their hydrocyanic acid ..."

Abbott (1886) prophesied:

> "There has been comparatively little study of the chemical principles of plants from a purely botanical view. It promises to become a new field of research".

Greshoff (1891) suggested the use of chemistry in taxonomy. He said that a "chemical description" should be part of a formal description of a new genus. At Kew, he looked at plants for tannins, alkaloids, cyanogenic substances, and saponins. In 1909, he emphasized the presence of HCN in plants, and vividly described it in _Platanus_:

> "Indeed, in the ordinary plane-tree of London streets (P. acerifolia), there is so much hydrocyanic acid present that the amount from every London plane-leaf would be enough to kill a London sparrow".

Van Romburgh (1899) studied the occurrence of HCN, methyl salicylate, and acetone in plants, while Treub (1907) studied the role of HCN.

At present, botanists such as Gibbs and biochemists such as Florkin have long been aware that chemical data are potentially of great use to systematics as broadly defined, but it is only in the last ten years or so that biochemical systematics has come to occupy a major role. The two main reasons for this have been the development of rapid and efficient screening techniques such as chromatography and electrophoresis, and, as a result of this the rapid identification of a large number of organic compounds by these methods, and the realization that they have a wide systematic value and can contribute to the solution of many taxonomic problems.

Many constituents are looked for in plants today. Compounds found only in a single species (unique compounds) may only possess taxonomic value at the species level. Many natural products are ubiquitous and are, for that reason, of little of no taxonomic interest. Proteins and nucleic acids are truly ubiquitous but are, nevertheless, of potentially great taxonomic value. In spite of their high molecular weight, compounds such as cellulose, protein and nucleic acids can be assigned definite structures. The lignins are less regularly constructed, probably being mixtures of condensation products. Nevertheless, the lignins appear to possess great taxonomic value. Very recent developments suggest that biochemical data, especially at the "macromolecular" level, may assist in working out some of the evolutionary pathways by which groups have arisen.

Among the more popular small molecular weight compounds investigated in this fashion have been those of amino acids, alkaloids, terpenoids and flavonoids, these four chemical classes are widespread among plant groups but in each may be found certain subclasses which are restricted to closely related taxa.

Distributional surveys for secondary compounds will become much more meaningful after knowledge of their biosynthetic origins has accumulated. This point has been repeatedly emphasized by a number of workers (Swain, 1966), and in at least one recent text on phytochemistry (Mentzer and Fatainoff, 1964) the secondary compounds are arranged according to the metabolic pathways leading to their production; e.g., acetic acid $(C_2)n$ derivatives; isoprenoid $(C_5)n$ derivatives; shikimic acid derivatives, etc. Thus, as H.G.H. Erdtman (1963) writes:

> "Chemotaxonomy is essentially the investigation of chemical compounds or groups of biosynthetically related compounds, in a series of related, or supposedly-related plants".

Therefore, for purposes of classification, knowledge about the genesis of plant constituents is just as important as knowledge of their structures. The general tendencies of evolution for metabolic patterns and for individual categories of constituents of angiosperms, are scarcely known at present. Alkaloids, for instance, have been detected in fungi, pteridophyta, gymnospermae and angiospermae, but it is virtually impossible to indicate evolutionary trends concerning their structure and distribution. Within taxa of lower rank, such as species in a genus, genera in a family, and even families in an order, such tendencies may emerge in the near future, but with regard to the whole plant kingdom such tendencies seem not to exist at all or are still far from being conceived clearly.

At the present time, there are many well developed methods available for both botanists and chemists who are interested in chemosystematic study.

The simple tests used by the present author and others are useful for preliminary surveys of the biochemistry of plants.

The techniques of paper-chromatography, although they require skill, are relatively simple and rapid, and they only need a small amount of leaf material. The author has used 2-way paper chromatography for the separation and subsequent identification of simple phenolic compounds of leaves. Today this method, as well as thin-layer chromatography, is extensively used.

Gas chromatography, where the extracts are volatilized and run as a gas through a liquid column instead of on paper, requires more expensive apparatus but can be largely automated, the results being presented in the form of a graph in which the peaks represent the abundance of molecules with different features. It is employed for the screening of oils as in mints, or terpenes as in the pines.

With the techniques of gel electrophoresis, Boulter and his associates at Liverpool worked on protein bands obtained from the albumin fraction of seeds of various genera of the Leguminosae and they have shown that the technique may be of great value in supporting taxonomic arrangements or suggesting where revision ought to be considered.

Mass spectrometry is increasingly replacing the classical elementary analyses and determinations of molecular weights. The combination of gas chromatography and mass spectrometry makes it possible to investigate products available only in trace amounts and to identify their components by comparing their mass spectra with those of known substances. The fragmentation reactions of organic compounds are being intensely studied and, no doubt, in the future it will become possible to elucidate the structure of many substances by mass spectrometry alone.

One of the most important recently developed techniques is that of nuclear magnetic resonance spectroscopy (NMR). It has opened new avenues of approach to a whole world of problems involving small molecules, including the phenolic and other secondary metabolic substances. The principles and methods involved make its use applicable to the small amounts of substances available in many types of biological experiments.

The UV, IR, and NMR spectra of many substances give valuable information about their structure, configurations, and conformations. Many important but difficult problems concerning the absolute configuration of natural products are now easily solved by examination of their ORD curves.

Structural investigation and studies on the distribution of natural products in the plant kingdom open roads to fields such as taxonomy and, perhaps, plant evolution.

C. Purpose of This Research

The purpose of this research was to gather supplemental (that is, chemical) evidence to reveal (1) Whether the "Rutales" of Scholz (in Engler 12th Syllabus, 1964) is a natural group. (2) The affinities and/or absence of affinities between the families of Scholz's Rutales. (3) Gaps in our knowledge of these families, which might suggest further work to be done on this group.

REVIEW OF LITERATURE

A. The Order "Rutales"

The position of many taxa of Scholz's "Rutales" in the natural system of plants is still highly uncertain. This applies to all levels of taxonomic categories, e.g. species in a genus, genera in a family (e.g. Ptaeroxylon in Ptaeroxylonaceae?), families in an order (e.g. Polygalaceae in Polygalales?; Malpighiaceae in Malpighiales?).

Scholz in the 12th "Syllabus" of Engler and Melchior (1964) classifies the "Rutales" as follows:

Suborder Rutineae:	Rutaceae (204/1600)
	Cneoraceae (2/3)
	Simaroubaceae (26/100)
	Picrodendraceae (1/3)
	Burseraceae (20/600)
	Meliaceae (50/1400)
	Akaniaceae (1/1)
Suborder Malpighineae:	Malpighiaceae (65/800)
	Trigoniaceae (4/35)
	Vochysiaceae (6/200)
Suborder Polygalineae:	Tremandraceae (3/30)
	Polygalaceae (13/800)

The above 12 families have been placed in several different arrangements and groups under various names over the years. The positions attributed to them in some systems of angiosperms are given in Table I. This table does not show all the other families which some of the systematists include, but rather gives the more common ones and the names of the orders under which they have been grouped. I choose a few examples to illustrate this point:

Hutchinson (1969) believes that not all the "Rutales" of the 12th Syllabus are representatives of one line of development (woody). Accordingly, he splits them into no less than eight orders: Rutaceae, Simaroubaceae, and Burseraceae form for him the order Rutales which derives from the Celastrales. His Polygalales includes Polygalaceae, Trigoniaceae, Vochysiaceae (and Krameriaceae). Malpighiaceae and Irvingiaceae (from Simaroubaceae) with some other families form his order Malpighiales. The remaining five families Meliaceae, Akaniaceae, Tremandraceae, Cneoraceae and Picrodendraceae, Hutchinson considers to be members of the Meliales, Sapindales, Pittosporales, Celastrales and Juglandales respectively.

An order "Rutales" has been established by other systematists, too --Lindley (1853),Gunderson (1950), Rendle (1938, 1952), Takhtajan (1959, 1969), Pulle (1952), Benson (1957), and Boivin (1956).

Gunderson (1950) had a "Geranium group", placed between the "Malva group" and the "Dianthiflorae", with Rutales, Juglandales, Sapindales, Celastrales and Geraniales. Included in his Rutales are Burseraceae, Cneoraceae, Simaroubaceae, Rutaceae, and Meliaceae of 'our' Rutales. The Akaniaceae,

TABLE I

Numbers of Taxonomists Assigning the Families of Scholz's Rutales to the Rutales and to other Orders

	FAMILIES	ORDERS								
		Rutales	Geraniales	Terebinthales	Sapindales	Malpighiales	Polygalales	Juglandales	Meliales	Cneorales
SUBORDER 1	Rutaceae	9	3	6	1	0	0	0	0	0
	Cneoraceae	5	2	2	1	0	0	0	0	1
	Simaroubaceae	9	3	6	1	0	0	0	0	0
	Picrodendraceae	1	0	0	0	0	0	2	0	0
	Burseraceae	7	2	4	1	0	0	0	0	0
	Meliaceae	7	3	6	1	0	0	0	2	0
	Akaniaceae	2	0	4	6	0	0	0	0	0
S.O. 2	Malpighiaceae	1	7	1	2	3	3	0	0	0
	Trigoniaceae	1	1	3	1	1	7	0	0	0
	Vochysiaceae	1	1	3	2	1	7	0	0	0
S.O.3	Tremandraceae	1	1	3	2	0	5	0	0	0
	Polygalaceae	1	1	3	3	0	10	0	0	0

Malpighiaceae, Vochysiaceae (including Trigonia), Tremandraceae and Polygalaceae are in the Sapindales.

Rendle (1952) placed four of 'our' families in the Rutales -- Rutaceae, Simaroubaceae, Burseraceae and Meliaceae. He included Polygalaceae doubtfully in the Sapindales, while Malpighiaceae was put in Geraniales. He also believed that Geraniales, Rutales and Sapindales are closely allied to each other.

Pulle (1952) had the following scheme:

Clusiales → Rutales → Polygalales: Tremandr., Polygal.

Rutales → Malpighiales: Malpighi., Trigoni., Vochysi.

Rutales: (Zygophyll.), Cneor., Rut., Burser., Simaroub., Meli., Akani.

Takhtajan (1969) has a Rutales much like Pulle's with Burser., Simaroub., Rut., Cneor., and Meli. He puts Malpighi. in his Geraniales, and Trigoni., Vochysi., Polygal., and Tremandr. in his Polygalales. The Akani. are in Sapindales, and the Picrodendr. in Euphorbiales.

Benson (1957) separated 'our' families into three different orders: Rutales, Polygalales and Geraniales. He regarded Akaniaceae and Tremandraceae to be of uncertain position, but he believed that they are related to the complex of the Geraniales, Rutales and Sapindales.

Boivin (1956) placed the Rutaceae and Simaroubaceae in the Rutales; Meliaceae as the only family of Meliales; Polygalaceae, Trigoniaceae and Vochysiaceae as Polygalales; while Malpighiaceae was raised to ordinal rank again. Akaniaceae, Cneoraceae and Tremandraceae were put in Sapindales, Celastrales and Pittosporales respectively.

The early systematist Lindley (1853) included in the Rutales the Rutaceae, Simaroubaceae and Meliaceae; while Malpighiaceae, Vochysiaceae, Tremandraceae and Polygalaceae were in Sapindales.

On the other hand, Cronquist (1957 ; 1968) does not segregate Rutales from Sapindales as many taxonomists do. He places six of 'our' families -- Akaniaceae, Burseraceae, Simaroubaceae, Cneoraceae, Rutaceae and Meliaceae -- in Sapindales. He refers Polygalaceae, Malpighiaceae, Trigoniaceae, Vochysiaceae, Tremandraceae (and Xanthophyllaceae and Krameriaceae) to the Polygalales.

He says that Picrodendron seems best associated with the Juglandaceae in the Juglandales. Bessey (1951) included all of 'our' families except Picrodendraceae and Akaniaceae in his order Geraniales.

Soó (1953) and Wettstein (1935) included most of the families of the Syll. 12 Rutales in an order Terebinthales, but the family Cneoraceae was placed in Geraniales by Soó, while Cneoraceae and Malpighiaceae were referred by Wettstein to Gruinales.

Skottsberg (1940) included in his order Terebinthales only Rutaceae, Cneoraceae, Simaroubaceae, Meliaceae and Akaniaceae. The Malpighiaceae, Trigoniaceae, Vochysiaceae and Tremandraceae form his Gruinales. Polygalaceae is the only family of his Polygalales.

Chaudefaud and Emberger's (1960) order Terebinthales is essentially the Rutales, but includes other families also. Malpighiaceae was placed by Chaudefaud and Emberger in Geraniales. They raised Cneoraceae to ordinal rank as Cneorales.

Hallier (1912) and Copeland (1957) placed the Malpighiaceae, Trigoniaceae, Vochysiaceae, Tremandraceae and Polygalaceae in the Polygalales. Hallier (1912) placed the other five families: Rutaceae, Cneoraceae, Simaroubaceae, Burseraceae, and Meliaceae in his Terebinthinae. Copeland (1957) referred Rutaceae, Cneoraceae, Simaroubaceae and Meliaceae to Trihilatae. While Warming (1895) included Rutaceae, Simaroubaceae and Meliaceae in Terebinthinae.

Finally, van Tieghem and Constantin (1918) referred Rutaceae, Simaroubaceae, Meliaceae and Malpighiaceae to Geraniales; Trigoniaceae and Tremandraceae to Oxalidales; and Vochysiaceae to Rhamnales.

These placings are summarized in Table I. We see that there are many authors placing Rutaceae, Cneoraceae, Simaroubaceae, Burseraceae and Meliaceae in Rutales or its equivalent order

Terebinthales. On the other hand, Malpighiaceae, Trigoniaceae, Vochysiaceae, Tremandraceae and Polygalaceae are assigned to Polygalales; or the Malpighiaceae, Trigoniaceae and Vochysiaceae are grouped in Malpighiales; while Picrodendraceae and Akaniaceae are put in Juglandales and Sapindales, respectively.

B. Families of the "Rutales"

1. Rutaceae

This family was first made by Jussieu in 1789. Small (1907), Bessey (1915), Van Tieghem and Constantin (1918) and Engler and Diels (11th "Syllabus", 1936) assigned this family to the Geraniales. Scholz (in the 12th "Syllabus", 1964) split the Geraniales, and the Rutaceae became the type family of an order Rutales.

This family has been placed in the Rutales by many other authors (Lindley, 1853; Rendle, 1938, 1952; Gundersen, 1950; Pulle, 1952; Boivin, 1956; Benson, 1957; Hutchinson, 1969, and Takhtajan, 1969), while Cronquist (1968) included this family in the Sapindales. However, several authors (Soó, 1957; Emberger in Chadefaud and Emberger, 1960; Skottsberg, 1940; Wettstein, 1935) placed this family in the Terebinthales. It has also been made a member of Trihilatae (Copeland, 1957) and Terebinthinae (Hallier, 1912; Warming, 1895).

This family is divided into seven subfamilies: Rutoideae, Dictyolomatoideae, Flindersioideae, Spathelioideae, Toddalioideae, Citroideae, and Rhabdodendroideae by Scholz.

Metcalfe and Chalk (1950) stated that the wood anatomy is very uniform and highly-specialized in the whole group.

The placing of the genera Chloroxylon and Flindersia, of Scholz's subfamily Flindersioideae, has proved difficult for botanists (Kribs, 1930). According to Solereder (1908), these two genera have both Rutaceous characters, i.e. secretory cavities in the tissue of the leaf and cortex, and Meliaceous characters, i.e. the secretory cells in the cortical tissue of the axes. Bentham and Hooker (1862) have placed Chloroxylon and Flindersia with the Meliaceae, whereas placement in the Rutaceae was favoured by others (Engler and Prantl, 1897-1964; and Kribs, 1930. The latter view is supported by pollen morphology (Erdtman, 1952). Metcalfe and Chalk (1950) mention that Flindersia should remain with Rutaceae, while Chloroxylon should go to Meliaceae. Because of the homogeneous rays and the non-septate fibres, Harrar (1937) suggested that a separate family, the Flindersiaceae, should be formed. Dadswell (1935) agrees.

Bentham and Hooker took the genus Zanthoxylum to include the subgenus Fagara. The problem of whether or not to consider Fagara L. (with a biseriate, differentiated perianth) as distinct from Zanthoxylum L. sensu stricto (with a uniseriate, undifferentiated perianth) has recently been reviewed and discussed by Brizicky (1962) who concluded that ...

> "the 'simple' perianth of Zanthoxylum is most likely a secondary condition, derived by reduction from that of the Fagara type by abortion of some or all the sepals"

and

> "The occurrence of species of Zanthoxylum which appear in their perianth structure to be transitional to Fagara not only supports this view (of reduction), but also is ample reason to regard Fagara as a subgenus of Zanthoxylum".

Hartley (1966) agreed with these conclusion, except in the formal recognition of Fagara as a subgenus.

The only genus, Rhabdodendron, of the subfamily Rhabdodendroideae is also a problem. Heimsch (1942), on the basis of wood anatomy, concluded that Rhabdodendron does not belong in this family. It has been placed in Rubiaceae by Willis (1960), and in Phytolaccaceae by Record and Hess (1943). Dadswell (quoted by Price, 1963), however, considered it is possibly a mixed genus with species belonging to each of the three families. Recently, Prance (1968) states that Rhabdodendron is shown to differ from Rutaceae in nearly all important features of floral morphology, leaf and stem anatomy and pollen grain structure, and he writes:

> "In these respects, it is closely related to Phytolaccaceae and other families of Centrospermae but sufficiently distinct from them to justify the description of a new family to accommodate it".

2. Cneoraceae

Cneorum L. is the typical genus of this family which many authors have placed in the Rutales (Gundersen, 1950; Pulle, 1952; Benson, 1957; Engler and Melchior, 1964 and Takhtajan, 1969). On the other hand, other systematists have made this family a member of the Geraniales (Bessey, 1915; Engler and Diels, 1936; Soó, 1953). Engler (1931) stated that the carpels are somewhat like those of the Zygophyllaceae, but the single stamen whorl, the absence of stipules and the presence of oil-cells make the genus somewhat distinct from the other members of the *Geraniales*.

Cronquist (1968) placed this taxon in the *Sapindales*; Hutchinson (1959) and Boivin (1956) in the *Celastrales*. Wettstein (1935) had the *Cneoraceae* doubtfully at the end of the *Gruinales*. Bentham and Hooker (1862-1883) included it in the *Simaroubaceae*, while Hallier (1912) placed it near *Simaroubaceae* and *Toddalineae* in the order *Terebinthinae*.

Although Emberger (in Chadefaud and Emberger, 1960) stated that the nucleated albumen, the trinucleated pollen and the ovary are like those of the *Geraniales*, he made this family the only member of an order *Cneorales*.

Erdtman (1952) suggested that there is possibly some resemblance between the pollen grains of *Cneorum* and those of *Rutaceae* and related families.

3. *Simaroubaceae*

Simarouba and the other members of this family were included in the *Rutales* by Scholz, near *Cneoraceae* and *Picrodendraceae*.

Many other authors have also assigned this family to the *Rutales*, amongst them Lindley (1853), Gundersen (1950), Pulle (1952, Rendle (1952), Boivin (1956), Benson (1957), Hutchinson (1956) and Takhtajan (1969). Engler and Diels (1936), however, had this family in the *Geraniales* as did some other authors (Small, 1907; Bessey, 1915). Cronquist (1968) included it in the Sapindales, along with Akaniaceae, Burseraceae, Cneoraceae, Rutaceae and Meliaceae.

This family has also been assigned to their equivalent of the Rutales, that is, the Terebinthales by Wettstein (1935), Skottsberg (1940), Soó (1953) and Emberger (in Chadefaud and Emberger, 1960); the Terebinthinae by Warming (1895), and Hallier (1912); and the Trihilatae (Copeland, 1957).

Emberger stated that the simple leaves of this family have the same phylogenetic origin as those of the Aurantioideae of the Rutaceae.

Scholz divides this family into six subfamilies: Surianoideae, Simarouboideae, Kirkioideae, Irvingioideae, Picramnioideae and Alvaradoideae. Metcalfe and Chalk (1950) stated that there were few anatomical characters common to the group. Jadin (1901), as a result of his anatomical studies of stems, petioles and leaves, excluded the genera Suriana and Holacantha and assigned them respectively to the monotypic families Surianaceae and Holacanthaceae. Small (1907), too, formed a family Surianaceae which he placed near Rutaceae and Simaroubaceae in the Geraniales. Solereder (in Loesener and Solereder 1905) returned Suriana to the Simaroubaceae, recognized the genus Rigiostachys as belonging to it, recommended the re-establishment of the genus Guilfoylia (which had been combined in Cadellia), and included these four genera in the subfamily

Surianoideae. Webber (1936) in her systematic anatomy of the woods of Simaroubaceae, supported Solereder's abolition of the monotypic family Surianaceae, his close grouping of Suriana and Cadellia, and his withdrawal of Guilfoylia from Cadellia. She also claimed that Holacantha and Castela differed markedly from the other genera, but that the differences do not support Jadin's erection of the monotypic family Holacanthaceae, since the woods of both Castela and Holacantha differ from those of other Simarouboideae in the same respects.

Hallier (1908) proposed that the Irvingiaceae and the genera Picrodendron, Picramnia and Alvaradoa be excluded from the Simaroubaceae. Whereas Webber (1936), from the standpoint of wood anatomy, wrote:

> "the distinct type of wood structure characterizing the Kirkioideae, Irvingioideae, Picramnioideae and Alvaradoideae indicated that each of these subfamilies is a natural group. Whether these groups should be ranked as subfamilies of the Simaroubaceae, as distinct families, or as components of other families can be determined only after a consideration of all their characteristics. It is, however, of significance that the exclusion of the Irvingioideae, Picramioideae and Alvaradoideae from the Simaroubaceae has been proposed because of distinctive morphological characteristics other than wood structure".

In the meanwhile, she stated that the Surianoideae showed some diversity, and that the Simarouboideae exhibit rather wide variation, and suggested that the genus Picrodendron be assigned to a new monotypic family Picrodendraceae, since the wood-structure of Picrodendron bears a strong resemblance to that of the Irvingioideae.

In 1923, Hallier reviewed the early taxonomic history of the *Irvingiaceae* and included this group in his account of the *Linaceae*. Hutchinson (1959) formed a family *Irvingiaceae* which he placed in his *Malpighiales*, near *Linaceae* and *Huaceae*. Van Tieghem and Constantin, as early as 1918, assigned a family *Irvingiaceae* to the *Geraniales*, near *Simaroubaceae* and *Leguminosae*.

4. *Picrodendraceae*

The affinities of *Picrodendron* are still obscure. It was placed in the *Geraniales* as part of *Simaroubaceae* by Engler and Diels (Syll. 11, 1936). In the 12th Syllabus, it was raised to familial rank and was assigned to the *Rutales*, near *Simaroubaceae*. Hallier (1923) suggested that *Picrodendron* be referred to the *Bombacaceae* rather than the *Simaroubaceae*. Engler (1931) considered that the carpel morphology of this genus was sufficiently distinctive to outweigh the anatomical evidence presented by Boas (1913) to show that *Picrodendron* should be included in the *Irvingioideae*; whereas, Webber (1936), according to the structure of wood, suggested that the genus *Picrodendron* should be assigned to a new monotypic family *Picrodendraceae*. Record and Hess (1943) had a family *Picrodendraceae* too. Hutchinson (1959) placed this family near *Juglandaceae*, in the *Juglandales*, and Cronquist (1968) stated that *Picrodendron* seems best associated with the *Juglandaceae*.

5. Burseraceae

Scholz, in splitting the Geraniales put Burseraceae in his Rutales.

This family has also been placed in the Rutales by many other authors (Rendle, 1938, 1952; Gundersen, 1950; Pulle, 1952; Benson, 1957; Hutchinson, 1959, and Takhtajan, 1969); and it has been assigned to their equivalent of the Rutales, the Terebinthales, by Wettstein (1935), Soó (1953) and Emberger (1960); and Terebinthinae (Hallier, 1912).

Small (1907) and Bessey (1915) placed this family between Simaroubaceae and Meliaceae in the Geraniales, while Cronquist (1968) assigned it to the Sapindales, along with Akaniaceae, Burseraceae, Simaroubaceae, Cneoraceae, Rutaceae and Meliaceae.

Guillaumin (1909-1910) stated that the most marked affinities of Burseraceae are with Anacardiaceae, Meliaceae, Rutaceae and Simaroubaceae. Webber (1941) and Heimsch (1942), on the basis of wood structure, also concluded that Rutaceae, Simaroubaceae, Meliaceae, Sapindaceae, Burseraceae and Anacardiaceae form a natural group. Heimsch (1942), in his study of the wood anatomy of 1000 species in 37 families including Burseraceae, Meliaceae, Sapindaceae, Rutaceae, Simaroubaceae and Anacardiaceae, concluded that these families are better classified by Wettstein, Hutchinson, and especially Hallier.

Emberger (in Chadefaud and Emberger, 1960) placed this family in the Terebinthales, with affinities with Rutaceae and

Simaroubaceae, but distinguished by certain anatomical feature, such as the secretory schizogenous cortical canals, and the radical or fundamental phloem which is sometimes more medullary or pithy.

Erdtman (1952) stated that the pollen grains in *Burseraceae* are more like those of certain genera of the *Simaroubaceae* than those of *Rutaceae* and *Meliaceae*.

6. *Meliaceae*

Engler and Diels (1936) placed this family in the *Geraniales* as did Small (1907), Bessey (1915) and van Tieghem and Constantin (1918). In the 12th "Syllabus" it is in the *Rutales*, near *Burseraceae* and *Akaniaceae*.

Many other authors have also assigned this family to the *Rutales* (Lindley, 1853; Pulle, 1952; Gundersen, 1950; Rendle, 1938, 1952; Benson, 1957). Cronquist (1957; 1968) included it in the *Sapindales*, along with *Akaniaceae*, *Burseraceae*, *Simaroubaceae*, *Cneoraceae*, and *Rutaceae.* Takhtajan (1954) also assigned this family to the *Sapindales*, but later, in 1959 and 1969, he referred it to *Rutales* which he segregated from the *Sapindales*. Heimsch (1942) stated that *Meliaceae*, *Rutaceae*, *Simaroubaceae*, *Sapindaceae*, *Burseraceae* and *Anacardiaceae* form a more or less natural group.

Hutchinson (1969) and Boivin (1956) made this family the only member of the *Meliales*. It has also been assigned to the *Terebinthales* (Soó, 1953; Emberger in Chadefaud and Emberger, 1960; Skottsberg, 1940; Wettstein, 1935), and *Terebinthinae*

(Hallier, 1912; Warming, 1895). These are essentially rutaceous orders. Copeland (1957) placed this taxon in the order Trihilatae.

The genus Ptaeroxylon was placed in the Sapindaceae by Bentham and Hooker (1862); while Harvey and Sonder (1860) favoured a separate small subfamily, the Ptaeroxyleae, in the Meliaceae. Radlkofer placed this genus in the Meliaceae because of the presence of secretory cells in the leaves. Kribs (1930), on the other hand, having examined the wood of this monotypic genus, suggested that it more closely resembles the Rutaceae. Recently, it was placed with Cedrelopsis in a small family, the Ptaeroxylaceae (Leroy, 1959) and regarded as closely related to the Sapindaceae.

Kribs (1930) argued that Swietenioideae is the only subfamily of Meliaceae in which the genera form a distinct homogeneous group on the basis of its anatomy and morphology and should thus be raised to familial rank as Swieteniaceae. Erdtman (1952), says that pollen morphology, does not support Harms's suggestion that the three subfamilies Cedreloideae, Swietenioideae and Melioideae should rank as separate families, and he also found pollen-grains more or less similar to those in Meliaceae to occur in Rutaceae (e.g. in Aegle, Atalantia, Citrus etc.).

7. Akaniaceae

This is a tiny family with Akania hillii only. Stapf (1912) first proposed this family and placed it in the Sapindales, in which he was followed by many authors (Gundersen, 1950; Boivin, 1956, Hutchinson, 1959; Cronquist, 1968, and Takhtajan, 1969). Scholz places this family in Rutales, and this mainly because of the ovule.

Cronquist (1968) wrote:

> "The Akaniaceae, ... were unique in the Sapindales in their very wide wood rays, and they are somewhat unusual in lacking a floral disk and having endosperm. Their pollen is like that of some of the Sapindaceae, and they commonly have eight stamens and a pentamerous perianth, like the Sapindaceae. Although it has sometimes been included in the Sapindaceae, Akania seems amply to merit status as a separate family. On the other hand, there is nothing to indicate that it would be better placed in any other order".

In fact, in the presence of the very large rays and the absence of uniseriate rays in the secondary wood, this family differs clearly from Sapindaceae.

Benson (1957) says that Akaniaceae and Tremandraceae are of uncertain position, but he believes that they are related to the complex of the Geraniales, Rutales and Sapindales. Emberger (in Chadefaud and Emberger, 1960), although placing this family in the Terebinthales, considers the affinities of this taxon to be unclear.

8. Malpighiaceae

This family was most often placed in Geraniales (Small, 1907; Bessey, 1915; van Tieghem and Constantin, 1918; Rendle, 1938, 1952; Benson, 1957; Emberger, in Chadefaud and Emberger, 1960; and Takhtajan, 1969); less often in Malpighiales (Pulle, 1952; Boivin, 1956; Hutchinson, 1959); or Polygalales (Hallier, 1912; Copeland, 1957 and Cronquist, 1968); while only Scholz (1964) treated it as a family of Rutales, in the suborder Malpighiineae, near Trigoniaceae and Vochysiaceae.

It has also been assigned to the Sapindales (Gundersen, 1950), but Gundersen noted that the twisted seed of the Sapindaceae and other characters make Malpighiaceae distinct from that family.

Erdtman (1952) found the pollen grains of Malpighiaceae to be slightly similar to those of Tremandraceae and Trigoniaceae, but more or less different from those of Vochysiaceae. van Tieghem and Constantin (1918) described the Malpighiaceae as "....
... une famille trés homogéne".

9. Trigoniaceae

This family was included in the Vochysiaceae by Bentham and Hooker (1862-1883). Scholz (in Syll. 12, 1964) has it as a distinct family in the Rutales.

Several authors (Benson, 1957; Hutchinson, 1959; Cronquist, 1968, and Takhtajan, 1969, etc.) made this a family of the Polygalales and placed it near Vochysiaceae. Pulle (1952) assigned this family to the *Malpighiales*, again near *Vochysiaceae*. Warming (1895) assigned this family to *Aesculinae*, again near *Vochysiaceae* (and *Tremandraceae*).

Thus, as one can see, many authors assign this family to a position near *Vochysiaceae*. Metcalfe and Chalk (1950) described it as being conspicuously different from *Vochysiaceae* in the absence of intraxylary phloem and in the presence of bordered pits in the ground tissue elements of the xylem. However, Heimsch (1942) stated that the wood anatomy suggests a relationship with *Polygalaceae*, *Tremandraceae*, *Malpighiaceae*, and *Vochysiaceae*; while Erdtman (1952) says that there is some similarity between the pollen-grains of *Lightia licanioides* (*Trigoniaceae*) and those of some genera of the *Vochysiaceae*.

10. *Vochysiaceae*

Scholz assigned this family to the *Rutales*, and thus placed it near *Malpighiaceae* and *Trigoniaceae*.

Many authors (Small, 1907; Benson, 1957; Hutchinson, 1959; Cronquist, 1968 and Takhtajan, 1969) have preferred to put this family in *Polygalales*. Pulle (1952) made it a member of the *Malpighiales*.

Heimsch (1942) said that this family is related to *Polygalaceae*, *Trigoniaceae*, *Tremandraceae*, and *Malpighiaceae*, but differs from them in the more pronounced development of banded parenchyma and the occurrence of intercellular canals. Erdtman (1952) found that certain pollen types in *Malpighiaceae* and *Trigoniaceae* (*Lightia*) have at least some characters in common with the pollen of *Vochysiaceae*.

11. *Tremandraceae*

Scholz assigns this family to *Rutales* and has it with *Polygalaceae* as the suborder *Polygalineae*. This family has been included in the *Geraniales* (Bessey, 1915) and in the *Sapindales* (Lindley, 1853; Gundersen, 1950), but many authors place it in *Polygalales* (Pulle, 1952; Cronquist, 1968; Takhtajan, 1969; etc.).

Warming (1895) made this family part of the *Aesculinae*, and placed it between *Trigoniaceae* and *Polygalaceae*.

Metcalfe and Chalk (1950), after investigating this family, described it as one in which anatomical structures are uniform and thus do not aid in establishing affinities. According to Erdtman (1952) the pollen grains of *Tremandra* are more-or-less similar to those of *Galphimia* (*Malpighiaceae*).

12. *Polygalaceae*

This family has been variously placed by different systematists. Scholz (Syll. 12, 1964) has it in the *Rutales* near *Tremandraceae*. Warming (1895) also placed this family near *Tremandraceae* but in the *Aesculinae*.

Many authors have it in *Polygalales* (Small, 1907; Pulle, 1952; Benson, 1957; Hutchinson, 1959; Cronquist, 1968 and Takhtajan, 1969 etc.). Others (Lindley, 1853; Gundersen, 1950; and Rendle, 1952) have placed this family in the *Sapindales*, but Rendle calls the *Polygalaceae* a family of doubtful position.

Heimsch (1942) investigated some members of this family and found that the wood anatomy shows affinities with that of Trigoniaceae, Tremandraceae, Malpighiaceae, and Vochysiaceae.

Chodat (1891-1893) describes this family as "a very natural family, not closely allied with any others." The herbs, shrubs, and small trees, he adds, have distinct pollen grains. He remarks that this is the "surest mark of distinction in the family". The grains are ellipsoidal with coarse pitting at the poles and longitudinal bands broken in the center by an equatorial ring.

Some genera have been doubtfully placed here.

Diclidanthera was made the type of a family Diclidanthereae (=Diclidantheraceae) by Agardh (1858). The family has been associated with Ebenales, but also with Polygalales. Metcalfe and Chalk (1950) have it after Polygalaceae and before Vochysiaceae. From pollen-grain morphology and wood anatomy, however, it was referred to Polygalaceae (O'Donell, 1964).

Chodat (1891-1893) noted that Krameria was not a member of Polygalaceae, but the type of a family (Krameriaceae) near Leguminosae-Caesalpiniaceae. Le Maout and Decaisne (1873), however, assigned Krameria to Polygalaceae.

Xanthophyllum Roxb. was raised to familial rank as Xanthophyllaceae (Gagnepain, in Chadefaud and Emberger, 1960). Scholz keeps it in Polygalaceae.

According to Jauch (1918), Xanthophyllum differs in its wood parenchyma from other members of the Polygalaceae, but should remain in the family because of its floral anatomy and pollen-grain structure.

C. Some Useful Chemistry in Plant Taxonomy

There has been a fever of intellectual activity in botanical chemosystematics during the past 10 years. Chemical characters are ideally suited to be used, together with morphological criteria, in a numerical approach to taxonomy. Many books on chemotaxonomy have appeared since 1962 (Swain, 1963, 1966; Alston and Turner, 1963; Hegnauer, 1962, 1963a, 1964, 1966a, 1969; Harborne, 1967; Harborne and Swain, 1969), Reviews have been written for both books (Davis and Heywood, 1963; Alston, 1967; Harborne, 1968) and journals (Bate-Smith and Swain, 1965; Hegnauer, 1965) and many papers have appeared in journals such as Phytochemistry and Lloydia.

Many samples of plant material can be quickly and efficiently surveyed for a particular class of compound by one or other of the many chromatographic procedures available today. Terpenoids are usually separated and identified by gas-liquid chromatography and mass spectrometry; phenolic compounds by paper or thin-layer chromatography and absorption spectroscopy; amino acids by electrophoresis and ion-exchange chromatography, and so on.

The contributions of chemosystematics to plant taxonomy will be discussed under two general headings, micromolecules and macromolecules, depending on the relative molecular weights of the compounds under consideration.

1. Micromolecules

Most of the early chemosystematic literature, and much of the present, has concerned itself with the mere notation of the distribution of relatively simple compounds from only one or, less often, several collections of a given taxon.

In this review, it is proposed to consider the various classes of micromolecular plant constituents, to outline their present contribution to taxonomy, and to estimate their future potential in this field.

a. Phenolic Constituents

Some phenols present in plant tissue are characteristic of the species, and thus they are of taxonomic value. Analysis of coumarins, flavonoids and other phenolic compounds in the study of taxonomic relationships, hybrids, ecological differentiation, etc. in various botanical taxa, has been receiving increased attention. The popularity of using this group of compounds as a criterion is partly due to the advent of thin-layer chromatography (Dedio, et al, 1969) which enable one to analyze rapidly a large number of samples.

i. Coumarins

In the plant kingdom, coumarins are widely but by no means universally distributed. That coumarins may be useful in chemotaxonomy will be clear from Price (in Swain, 1963) who says:

> "Further support for the view that the Rutaceae is a distinct and homogeneous group is provided by its essential oils and coumarins ... within the Rutaceae coumarins are distributed throughout the four sub-families Aurantioideae, Rutoideae, Toddalioideae

> and Flindersioideae ... On the other hand, though it is negative evidence, there is not one report of the isolation of a coumarin from the Meliaceae, Burseraceae, Simaroubaceae, Zygophyllaceae, or Cneoraceae"

However, Cedrelopsis, Ptaeroxylon and Ekebergia, three genera of the Meliaceae (Scholz) have been reported to contai: coumarins (Eshiett et al., 1968; Dean and Taylor, 1966; Bevan et al., 1965). Especially, two botanically very close genera -- Cedrelopsis and Ptaeroxylon -- both contain Ptaeroxylin which has an unusual seven-membered ring structure not encountered elsewhere. This would seem to be good evidence in support of Airy Shaw (in Willis, 1966), who places the two genera in a little family Ptaeroxylaceae somewhat intermediate between Meliaceae and Rutaceae.

Ellagic acid and its derivatives are in almost all families of Myrtiflorae, except Hippuridaceae (Hegnauer, 1964, 1966). In addition, members of Rhizophoraceae, Combretaceae and Myrtaceae are well-known sources of ellagitannins (Bate-Smith, 1962a). Ellagic acid is also found as an occasional constituent throughout the Archichlamydeae. It is of rare occurrence in the Sympetalae; plants containing it here (e.g. some Ericaceae) are those with close affinities with the Archichlamydeae (Bate-Smith, 1962b). Bate-Smith (1968) says it is absent from Monocotyledons. Its close association in occurrence with "woodiness" in plants indicate that it is more of phylogenetic rather than of practical interest to the systematist (Harborne, 1968).

Another aspect of coumarins in plants which shows promise of being of systematic interest is the study of their metabolism. Harborne and Corner (1961) and Harborne (1964) have noted differences in metabolic pathways of cinnamic acids and coumarins. Datura, for example, was the only genus among some dozen genera of the Solanaceae studied with the ability to convert caffeic acid into the coumarin scopolin. Again, while the more primitive angiosperms convert 6,7-dihydroxycoumarin (aesculetin) into the 6-glucoside, the more advanced plants (e.g. the Compositae, Solanaceae, etc.) change it into a mixture of 6- and 7-glucosides.

ii. Flavonoids

There has recently been considerable interest in the range of plants in which flavonoids occur (Harborne, 1967). This has been due, in part, to their significance as taxonomic and evolutionary markers (Bate-Smith, 1963).

To date flavonoids have been isolated from or identified in a wide range of the lignin-containing Angiosperms, Gymnosperms and ferns (Harborne, 1967). Of the plants normally considered to be non-ligniferous, only the Mosses have so far been proven to contain flavonoids (chiefly flavone C-glycosides and anthocyanins) (Harborne, 1967; Markham and Porter, 1969a). However, several existing reports (Harborne, 1967; Reznik and Wierman, 1966) indicate that flavonoids might also occur in the Liverworts (Hepaticae) and this occurrence has recently been confirmed by Markham and Porter (1969b). The flavonoid data do not help us to establish the phylogenetic relationship between mosses and other plants although it is interesting, of course, to know that flavonoids occur among liverworts.

The flavonoid pigments of plants vary chemically according to class or according to number and position of extra skeletal substituents (e.g. hydroxyl, methoxyl, O-glycosyl, C-glycosyl, or isoprenoid residues). Lebreton (1964) set forth some rules by which one may presumably judge primitive versus advanced features of flavonoids. Saturation of the heterocyclic ring (as in catechins, leucoanthocyanins, flavanones, dihydrochalcones and flavononols) is regarded as a primitive character. Thus, anthocyanins, flavones and flavonols are more advanced than are the leucoanthocyanins. Hydroxylation of the B-ring is primitive; thus the evolved types are characterized by lack of B-ring hydroxyls or by methylation or glycosylation. Alston (1968), in discussing the C-glycosyl flavonoids, wrote:

> "Indeed, if the implications of this fragmentary chemical data were accepted at face value, we might reconsider the question of which types of flavonoids are 'primitive' as opposed to 'advanced'. Although this question of chemical primitiveness among flavonoids has not apparently been considered comprehensively on biogenetic grounds, it seems to be generally regarded that anthocyanidins such as cyanidin, and O-glycosides of flavonoids are representatives of more primitive flavonoids. Primitive, as used here, signifies that such compounds may have appeared early among the flavonoids following the appearance of the characteristic C_{15} structural unit".

These criteria may be valid if applied as broad generalizations, although it is doubtful that they have any significance at all when applied as specific criteria in individual situations.

To the taxonomist, variation in flavonoid class appears to be of most significance, since there is good evidence that some classes act as "replacement" characters. For instance, the betacyanin/anthocyanin criterion has been useful in supporting the inclusion of the Cactaceae and the Didiereaceae in the order Centrospermae, and for indicating that the affinities of the Caryophyllaceae (and Molluginaceae?), the only families to retain anthocyanin pigmentation, should be re-examined.

Flavones and flavonols do not often co-occur in the leaves of higher plants. Flavones instead tend to replace flavonols, a change which is correlated with evolutionary advancement (Bate-Smith, 1962b). Harborne (1967), for example, has shown that the occurrence of flavones versus flavonols is correlated with tribal division in the main subfamily of Umbelliferae, the Apioideae. The eight tribes can be divided into three groups according to whether the species have only flavonols, mainly flavonols or mainly flavones. Again, Crowden (1969), in a study of 52 per cent of the genera of Umbelliferae discovered that nearly all species have either flavonols or flavones, but not both. Furthermore, he also found that flavones were almost entirely in taxa generally considered to be more specialized or advanced (e.g. Daucus, Torilis), while flavonols predominated in the less advanced genera (e.g. Hydrocotyle). Thus, the replacement of flavonol by flavone appears to have an evolutionary significance with the family, as it probably has among the angiosperms generally. (Harborne, 1967; Bate-Smith, 1962b).

From the taxonomic viewpoint, a difficulty is the disconcerting habit of some types of flavonoids which had seemed to characterize a certain group appearing sporadically in quite unrelated taxa. Thus the value of biflavonyls for defining the Gymnosperms in chemical terms is lessened by the recent discovery of their presence in two widely different Angiosperms (Casuarina and Viburnum); in two lower plants (Selaginella and Psilotum); and their absence from the Pinaceae (one of the largest families of gymnosperms).

A similar situation exists in the case of isoflavones. It is well known that they occur quite characteristically in one subfamily of the Leguminosae, the Faboideae, and are rarely found elsewhere. But recently they have been found also in related (Rosaceae) and unrelated (Iridaceae) taxa.

The inheritance of flavonoids in the leaves of plants is usually straight-forward in that hybrids normally contain all or most of the constituents of the two parents. For example, in Baptisia the flavonoid patterns of hybrids were identical with those obtained by superimposing the pattern of one species on the other (Alston and Turner, 1962).

iii. Other Simple Phenols

There is a vast number of papers published on the phenolic acid contents of plants in which the presence or absence of certain hydroxycinnamic acids or even, sometimes, of a particular acid has been considered to be of taxonomic value. For instance, gentisic acid appears to be associated with woody habits and is perhaps associated with lignification or some associated process (Griffiths, 1959). In contrast, syringic acid was found in 35 per cent of the species investigated by Ibrahim (1961) and was more frequently found in Monocotyledons. More recently, Harborne (1968) chose the distribution of seven of the many systematically interesting simple phenols to illustrate the point that phenolic substances are useful at all levels or hierarchies of classification. However, since the assumption that phenolic acids are metabolically inert (Bate-Smith, 1958) is no longer valid, before any taxonomic use can be made, more studies are needed to determine to what extent genetical factors and environmental factors are responsible for the types and amounts of the phenolic acids accumulating in plants.

b. Alkaloids

Alkaloids are of very many different kinds and not a chemically natural group. Higher plants are the chief source of alkaloids, yet alkaloids are also known from club mosses (*Lycopodium* spp.), horsetails (*Equisetum* spp.), and fungi (Robinson, 1968). Although between two and three thousand different alkaloids have been isolated from plants, some are taxonomically quite restricted in occurrence and others are found widely in unrelated plants. A statistical analysis of 3600 alkaloid plants by Willaman and Li (1963) showed caffeine occurring in the largest number of families (14), lycorine in the largest number of genera(30), and berberine in the largest number of species (89).

Henry, as early as 1949, reviews a number of instances where alkaloids were used to contribute to taxonomic problems, and Manske (1949) considered them in relation to the whole phylogenetic scheme of the angiosperms. Some authors are of the opinion that generalizations as to their phylogenetic significance may be of little value (Alston and Turner, 1963; Hegnauer, 1962, 1963b) or that "there does not appear to be any facile generalization to be made about alkaloid distribution" (Robinson, 1963). However, alkaloids are frequently treated as a related group of substances for both theoretical and practical purpose, and studies on their general patterns of distribution and occurrence have been attempted in the past (Manske, 1949; McNair, 1941, 1945; Willaman and Li, 1963). Their value in interrelating families is limited because of parallelism and convergence (Hegnauer, 1966b). Nevertheless, they have been shown to be of systemic interest in several families, particularly in the _Amaryllidaceae_ (Hegnauer, 1963b), _Liliaceae_ (Hegnauer, 1963b), _Papaveraceae_ (Hegnauer, 1966b) and _Rutaceae_ (Price, in Swain, 1963).

In recent reviews by Alston and Turner (1963), Hegnauer (1963b), and Stermitz (1968), on the use of alkaloid content in biochemical systematics or chemotaxonomy, considerable emphasis was placed on interfamily and intergeneric relationships. Rather few alkaloid surveys have been carried out at the species level but Kuck et al. (1967) worked on the bark alkaloids of 7 Argentinian species of Fagara.

Li and Willaman (1968), in studying 7,740 alkaloid plants, suggested that presence or absence of alkaloids (as well as their relative abundance in the families and orders) may have both taxonomic and phylogenetic significance. Within the dicotyledons, there is a high incidence of alkaloid occurrence in the morphologically primitive Magnoliales-Ranales complex and related groups, a lower incidence in various phylogenetically intermediate groups, and a progression of high incidence in all of the phylogenetically advanced but unrelated groups. Notably, the generally wind-pollinated "Amentiferous" families, as well as the wholly aquatic families, are either alkaloid-free or show very low incidence. High incidence of alkaloid occurrence appears as a general character for some families or orders. In Ranunculaceae, Berberidaceae, Menispermaceae, Piperaceae, Cactaceae, Papaveraceae, and Gentianaceae, alkaloids occur in over 90% of the species tested. On the other hand, in Fagaceae, Betulaceae, Casuarinaceae, and Juglandaceae the alkaloid occurrence is almost zero. Thus, the presence or absence of alkaloids can be treated as a general family characteristic. At the ordinal level, high or low incidence may appear uniformly in all component families of a single order or sometimes pronouncedly in one of the component families.

McNair (1941) digressed from taxa and considered the size of alkaloids as it might be reflected in the habitat of the families containing them. For example, he deduced that the average molecular weight of alkaloids was greater in temperate than in tropical families; that the average number of nitrogen and carbon atoms was the same in the two groups, but that the number of oxygen atoms was greater in the temperate.

Alkaloids biogenesis and distribution even now are of considerable use, but as Hegnauer points out:

> ".... because of this structural diversity, the biosynthetic origin of an alkaloid should be known before reliance is placed on its use as a taxonomic marker"

and Gibbs (MSS) says:

> "When we do know enough of the biogenesis of alkaloids it will be possible to group them more naturally and to use the distribution of the groups as an important taxonomic character".

c. Terpenoids

This name has been applied to a group of compounds distinguished by a singular chemical composition. Chemically, terpenoids all have carbon skeletons based on two or more isoprene (C_5) units. Thus there are monoterpenes (C_{10}), sesquiterpenes (C_{15}), diterpenes (C_{20}), triterpenes (C_{30}), tetraterpenes (C_{40}) and polyterpenes.

There is probably no living organism which does not contain at least one isoprenoid compound -- such as carotenoids, phytol or steroids -- belonging, respectively, to the tetra-, di- and mixed terpene groups. The occurrence of mono-, sesqui- and polyterpenes seems to be confined to the plant world, and there only to a limited number of species.

The distribution of terpenoids with respect to taxonomic classification can be found in Klein's Handbuch der Pflanzenanalyse (1932), in Guenther's Essential Oils (1948-1952) and in several recent reviews (Ponsinet *et al*., 1968; Harborne, 1968; Weissmann, 1966).

As early as in 1920, Baker and Smith published the chemotaxonomic investigations of the essential oils or terpenes of *Eucalyptus* species. In recent years, gas chromatographic separation of terpenes has proved valuable in taxonomic studies. Mirov (1948) studied the terpenes of *Pinus*, Von Rudloff (1966) the essential oils of *Picea*, and chromatographic analysis for chemotaxonomic purposes relating to the genus *Abies* were also reported by Zavarin and Snajberk (1965). Other workers in the field have tried to find genetic relationships based upon the chemical composition of the essential oils (Haagen-Smit, 1953).

The contributions of these various terpenoid classes to taxonomy will be briefly considered.

i. Monoterpenes

These are most abundant in the *Pinaceae*, *Labiatae*, *Umbelliferae*, *Rutaceae*, *Lauraceae*, *Myrtaceae*, and *Compositae*, but occur in at least 50 other families. The most extensively studied group at the present time are the members of the *Pinaceae*. (Mirov *et al*., 1966; Von Rudloff, 1966; Zavarin & Snajberk, 1965).

The exact nature of these variants is still in some doubt although some writers, e.g. Flück (1963), have suggested that the variation may be purely quantitative and not qualitative. Recently, Hellyer and coworkers (1969), in an examination of the oils from four "physiological forms" (chemical varieties) of *Eucalyptus dives*, established that the oils of *Eucalyptus dives* "type" all contain the same constituents, but in markedly varying proportions. These results tend to support Flück's hypothesis and indicates that monoterpene variation known in other *Eucalyptus* may be of the same type.

Harborne (1968) writes:

"Perhaps the most striking correlation between terpene distribution and taxonomy has been found in a group quite unrelated to the Pines, in the angiosperm genus Hypericum (Guttiferae). In a survey of over 35 species, Mathis and Ourisson (51, 52a) found that the eight volatile constituents present varied both qualitatively and quantitatively. The result confirmed the existing classification at the sectional level. Species fell clearly into groups, those rich in limonene (12) and myrcene (13), and those poor in these substances (Table 3). Interestingly enough, the distribution of monoterpene alcohol, sesquiterpenes, and quinones also fitted in with these results".

Monoterpenes are also proving of value in taxonomic studies of plants of the family Rutaceae. Recent studies of the essential oils of the 12 genera in the Aurantioideae (Scora et al., 1969) indicate that the essential oils conform to the botanical groupings, except for Pleiospermium in the Citrinae and Murraya in the Clauseneae.

ii. Sesquiterpenes

The sesquiterpenes are the class of terpenoids with 15 or fewer carbon atoms, the members of which originate from farnesyl pyrophosphate. The hydrocarbons ($C_{15}H_{24}$-$C_{15}H_{18}$), related alochols, ketones and a few other types have been commonly isolated from essential oils.

Bisset and Cowokers (1966), in analysing seventy-eight samples of resin which belong to 42 different species of the genus Dipterocarpus found that the sesquiterpenes are very variable, and defined six groups in the genus on the basis of the composition of the sesquiterpene fraction of their resin.

Sesquiterpene lactones may be useful for chemotaxonomic markers as will be clear from the following:

Novotný *et al.*, (1966) say:

> "The occurrence of sesquiterpenoid lactones (compounds of the santonine, guaianolide, ambrosanolide, germacranolide and eremophilanolide type) may be taken for a new chemotaxonomic character"

Steelink and Spitzer (1966), in a paper on sesquiterpene lactones in chemotaxonomy, say:

> "The guaianolides, a class of sesquiterpene lactones with the guaiane skeleton (I) appear to possess potential application in the chemotaxonomy of higher plants".

In fact, a number of workers (Steelink and Spitzer, 1966; Herz, 1968) have suggested that the distribution of sesquiterpene lactones, C_{15} compounds which occur frequently in plants belonging to the *Compositae* tribes *Heliantheae*, *Ambrosieae*, *Anthemideae*, and *Helenieae*, might prove useful in understanding the evolutionary relationships among such genera as *Ambrosia*, *Parthenium*, *Iva*, and others.

The variation of chemical constitution within a plant species is commonly encountered. Perhaps the most striking examples of the diversity between morphological characterization and chemical constitution are found in the genus *Ambrosia* (fam. *Compositae*, trib *Ambrosiaceae*). The distribution of sesquiterpene lactones in *Ambrosia* species has been reviewed by Herz, 1968); its possible utility for clarifying evolutionary relationships has been discussed by Miller *et al.*, 1968);

while Geissman and co-workers (1969), in examining and isolating sesquiterpene lactones of three distinct populations of *Ambrosia psilostachya* and four species of *Ambrosia acanthicarpa* (two of them being seedling and mature plants from a single location), found that different populations vary markedly in lactone content, and the seedling and mature forms show a wide qualitative difference.

Novotny *et al.*,(1966), in a systematic study of the chemical components in representatives of the *Compositae*, revealed the occurrence of sesquiterpenoid substances of the less usual *eremophilane type* and found that these compounds can also be used as an important distinguishing character of the taxa of *Petasites*. They also noted that eremophilanolides have been found in two other genera -- *Ligularia* and *Euryops* -- of the *Senecioneae* and suggested that this shows the possibility of putting all three genera -- *Ligularia*, *Euryops*, and *Petasites* -- into the one tribe *Senecioneae* which can be distinguished chemically from other tribes of *Compositae* as mentioned above.

iii. *Diterpenoids*

Erdtman (1956, p. 453) has already pointed out the possible taxonomic importance of diterpenoids if it becomes feasible to distinguish specific patterns of their distribution in the different genera and sub-genera. In view of the difficulties involved in the isolation and separation of the diterpene hydrocarbons by classical methods, the gas-liquid chromatographic (GLC) technique appeared to offer the most satisfactory method for investigation of the problem (Eglinton et al., 1962a).

Aplin and co-workers (1963), using the GLC method, have applied their results to clarify anomalies connected with the occurrence and to determine the taxonomic value of the diterpene hydrocarbon content of twenty-eight species of the Podocarpaceae and nine related gymnosperms. They quote the example of Podocarpus spicatus to show that variation of the diterpene constituents could occur regardless of the geographical location, and suggest that the diterpenes of Podocarpaceae are of little value for taxonomy.

iv. Triterpenoids

The common structural characteristic of triterpenes has been recognized as proceeding from squalene.

The genetic origin of the triterpenes may be explained by the action of specific enzymes that impose on the acyclic precursor a particular conformation that, upon cyclization, yields the observed basic carbon skeletons. Most triterpenes arise from further reactions of these skeletons such as rearrangement, degradation, oxidation and reduction.

Many genera of Cucurbitaceae contain bitter principles derived only from Cucurbitacin B, or only from Cucurbitacin E, but Rehm (1960) reported that both series are represented in Cucurbita. Ponsinet et al. (1968) considered that more primitive species contain only *Cucurbitacin* B, whereas the more highly evolved species contain B and E, or only E. They said that

> "derivatives of the related euphane and elemane skeletons are of great taxonomic interest since they are found in certain families considered to be closely related from a morphological point of view (Table 9)(...). Morover, among these substances there are a large number of bitter principles that possess great homogeneity in respect to degradation and oxidation patterns (Table 10)".

Examples of restricted distribution at sub-family, genus, or species level are discussed below. Dreyer (1966) found triterpenoids of interest at the sub-family level when examining plants of *Rutaceae* for limonoids. He detected limonin or related structures in 26 Citrus species, in 3 related genera, *Poncirus*, *Microcitrus* and *Fortunella* (all *Aurantioideae*), and in 6 genera of two other sub-families, *Toddalioideae* and *Rutoideae*. By contrast, they have not been reported in the four other sub-families, members of which are morphologically distinct from those mentioned above.

Steroidal sapogenins appear to be of interest at the genus level. Akahori (1965) analysed the steroidal sapogenins of 12 Japanese *Dioscorea* spp. and considered that the chemical composition of the sapogenins they contain corresponds to their morphological features.

At the species level, Ponsinet and Ourisson (see Ponsinet *et al.*, 1968), in studying the latex of more than 70 species of *Euphorbia*, found that various morphological types of Euphorbias produce different tetracyclic triterpenes, i.e.

1) Herbaceous Euphorbias all contain cycloartenol (IV).

2) Cactus-like Euphorbias contain euphol (V) and euphorbol (VI).

3) Coral-like Euphorbias contain euphol and tirucallol (VII).

d. Alkanes

Despite an early adverse prognostication by one of the pioneers in the field of chemotaxonomy (Erdtman, 1956), the universal presence of normal alkanes as constituents of leaf cuticular-waxes is well established and both their biogenesis and their value as a taxonomic criterion have been extensively discussed (Eglinton and Hamilton, 1967).

Herbin and Robins (1968b) have shown, in a survey of a large number of leaf cuticular waxes from a range of families in the Angiosperms, that in the homologous series of n-alkanes present, nonacosane (C_{29}) and hentriacontane (C_{31}) are the most frequent major components among the predominating odd carbon number constituents and the C_{28} and C_{30} are the most frequent major components among the, usually, less significant even carbon number constituents.

Castillo *et al.* (1967), in analysing the alkanes of thirty-two *Podocarpaceae* and other related species, considered that

> "the alkane constituents would appear to be a better guide to the botanical classification though there are a number of exceptions. Thus, of the twenty-one *Podocarpus* species only three cannot be grouped with

> the others by their alkane distribution. In a number of species, it was possible to note that both alkane and diterpene contents were unusual, for example, Libocedrus plumosa and Podocarpus latifolius. It would again appear that the alkane distribution in plant waxes would not be sufficiently diagnostic by itself."

The constituents of plant cuticular waxes have been shown by Eglinton and co-workers (1962a) to have significance in the study of interrelationships within a group of closely related genera in the sub-family Sempervivoideae of the Crassulaceae. In Eglinton's study gas-liquid chromatographic analysis of the alkane fraction of leaf cuticular waxes gave distribution patterns of normal and branched chain alkanes which could be correlated with the accepted taxonomy based on morphological characters.

In a further study of a number of New Zealand species drawn from different families, Eglinton and co-workers (1962b) found that in four species of the genus Hebe (Scrophulariaceae) a much wider variation in alkane pattern existed within a single genus than had been found by the earlier work within a sub-family. This variation within a genus indicates that, while alkane distribution patterns may be valid criteria for distinguishing related plants, difficulties might be encountered in any attempt to correlate less closely related groupings.

Herbin and Robins (1968a) confirmed, in studying the alkanes of cuticular waxes from 6 species in the genus Aloe (Liliaceae), the species specificity in composition. They subsequently examined (1968b), on the basis of large numbers of leaf wax alkanes from many orders, Hutchinson's sub-division of the Angiosperms into '*Herbaceae*' and '*Lignosae*'. Their results showed that, with the limited samples employed, there is no apparent distinction between the '*Lignosae* and the '*Herbaceae*' on the basis of leaf alkane pattern.

e. *Sulphur Compounds*

The secondary sulfur compounds of plants have been considered in general articles by Kjaer (1963, 1966) and Ettlinger and Kjaer (1968). Harborne (1968), in his review of Biochemical Systematics, says:

> "of the various groups of natural products containing the element sulphur, only two, thioglucosides and sulphides, are at present of taxonomic interest".

Thioglucosides appear to be of interest at the order level, i.e. Kjaer (1963) has reported them in 300 of the 1500 species of the *Cruciferae* and in all species examined of the *Capparidaceae*, *Resedaceae*, and *Moringaceae*. They are, by contrast, clearly absent from the *Papaveraceae*, a family sometimes placed in the same order (Wettstein, 1935).

Saghir *et al*. (1966), using the gas chromatographic technique, determined the amount of methyl, n-propyl, and allyl sulphides in the volatile fractions of 25 North American species of *Allium* and compared the results with the sectional groupings of species based on cytology and morphology. Unfortunately, they found that a classification based entirely on chemical characters would not only place clearly unrelated species such as *Allium cernuum* and *A. haematochiton* together but would separate otherwise very similar taxa like *Allium campanulatum* and *Allium membranaceum*.

2. Macromolecules

In some cases, the macromulecular data support the micromolecular data in confirming generic separation. In 1968, Harborne said

> "that macromolecular data is more 'fundamental' or more phyletically significant than data obtained from studying secondary constituents. ... One real advantage of macromolecular data is that they will provide a means of chemically comparing widely separated taxa, an operation which is rarely possible by any other means. They may also, by means of amino acid sequences in proteins or DNA-DNA hybridization data, provide taxonomists with an objective means of drawing lines between the larger units of classification (family, order, class, etc.)".

At the present time, some macromolecules in plants have received attention with respect to taxonomic significance and these are discussed briefly below:

a. Polysaccharides

The distribution of polysaccharides in plants has been reviewed by Percival (1966). From the view point of chemotaxonomy, the more complex polysaccharides may eventually yield characters of use in systematic work. However, complete structures are not available and data on the sugar units present within complex polysaccharides are only available for relatively few plants. Therefore, only a few examples of their contribution to taxonomy follow:

Whistler and Gaillard (1961), in studying the xylans from the hemicellulose-A fractions of several annual plants, found the species of Leguminosae, unlike those of the Gramineae, contained no arabinose at all. The uronic acid content of the polymers, on the other hand, is higher in the hemicellulose-A fraction from the *Leguminosae*. Later Gaillard (1965), in examining the composition of corresponding linear and branched polymers from the hemicellulose-B fraction of three members of the *Gramineae* and three of the *Leguminosae*, found the corresponding polymers from the former were very similar as were those from the latter. However, there was a distinct difference between the two plant families. The linear polymers of the *Gramineae* contained more arabinose and less glucuronic acid than those from the *Leguminosae*. The greatest difference between the two plant families was found in the branched polymers, those from the *Gramineae* containing a high percentage of xylose and rather small amounts of arabinose, galactose and uronic acid, whereas those from the *Leguminosae* contained relatively large amounts of uronic acid, galactose and arabinose and little xylose. In the branched polymers from the *Gramineae* the uronic acid was linked to xylose, whereas in those from *Leguminosae* it was linked to arabinose. However, it is still not clear whether or not the differences in hemicellulose composition between the *Gramineae* and the *Leguminosae* are a reflection of differences between *Monocotyledons* and *Dicotyledons*, rather than between the families.

b. *Lignins*

Lignins are found in vascular plants such as lycopods, ferns, gymnosperms and angiosperms, whereas it is absent from plants such as fungi, and from all other organisms. The mosses are an exceptional group which do not have the cells characteristic of xylem tissue but which do contain lignin-like materials. These "moss lignins" have been discussed by Freudenberg (1968), and some doubts have been expressed as to whether or not they are true lignins.

There are, in general, differences between the lignins of gymnosperms and angiosperms. The woods from angiosperms give a rose-red color, whereas gymnospermous woods usually give only a brown colour with Maüle's test. A suggestion by Gibbs that the red coloration of the Maüle test is correlated with the presence of syringyl groups in lignin was verified by the work of Creighton, Gibbs and Hibbert (1944); Towers (1951); and Towers and Gibbs (1953).

That the angiosperms universally have lignins containing the syringl group is strongly suggested by the work of Gibbs (1958, and unpublished), he has carried out Maüle's test and got positive reactions from 207 families of dicotyledons. Only a few have given negative or doubtful results and these were mostly aquatics or very lightly lignified plants. At least 35 families of monocotyledons also gave positive results, the few exceptions being again largely aquatics.

c. <u>Serology</u>

Alston and Turner (1963) reviewed the contribution of serology to systematics and concluded that, while catalytic to positive thinking in some instances, the extravagant claims made for it apparently created more disinterest in "chemistry" as an approach to plant taxonomy that it did enthusiasm.

However, quantitative serological methods have been applied for many years to taxonomic investigations and are useful for the differentiation of plant species since they may offer an overall picture of the similarity of the proteins (Leone, 1964). In recent years the more qualitative methods of immunoelectrophoresis, which offer the possibility of distinguishing different proteins without the need of previous separation, are recognized to be exceptionally well suited for comparison of protein patterns from different origins, and have been successfully applied to selected problems. For instance, Klozova and Kloz (1964) have used immunochemical methods to detect the hybrid Phaseolus vulgaris x P. coccineus, the F_1 possessing a complementation of the distinctive parental protein lines, much as was found in the flavonoids in hybrid Baptisias. But Turner (1967) says:

> "The detection of interacting macromolecular bands by immunogenetic techniques reflects the activity of relatively few genes and, viewed in this light, it is doubtful that this approach, taken alone, will contribute significantly to problem of plant phylogeny, although it has high value for distinguishing among presumably homologous proteins."

d. Proteins

In recent years, a number of investigators have shown a correlation between protein composition and systematics in higher plants. Using electrophoretic techniques, Johnson and

Hall (1965) investigated relationships in the *Triticineae* (*Gramineae*) and Boulter *et al.* (Fox *et al.*, 1964; Boulter *et al.*, 1967; and Thurman *et al.*, 1967) examined separately the systematic relationship of albumin and globulin fractions in seeds of certain *Legumes*, and of two dehydrogenase enzymes within the same family, while Vaughan and Denford (1968) surveyed the albumin and globulin fractions of the seeds of a number of species of *Brassica* and *Sinapis*, correlating the results with the established taxonomy. Other workers (Gell *et al.*, 1960) have used immunochemical techniques to demonstrate taxonomic affinities between species.

More recently, Crowden (1969), using acrylamide gel electrophoresis, surveyed soluble proteins and the enzymes peroxidase and esterase, present in the seed of selected species from all tribes in the *Apioideae* (*Umbelliferae*) and found distinct differences in patterns to be present at the tribal and generic levels.

It has been suggested (Wilson and Kaplan, 1962) that enzymes are better suited for taxonomic investigation than other proteins, and that a comparison of enzymes may allow assessment of genetic relations in and between taxa.

Numerous investigations have been performed which have demonstrated that isoenzyme staining patterns are dependent upon several variables. In interspecific comparisons, many patterns are reported to be species-specific and of diagnostic utility (Schwartz *et al.*, 1964; Clements, 1966; Bhatia *et al.*, 1967). Many authors (Shaw, 1965; Boulter *et al.*, 1966) have expressed the desirability of a more complete knowledge of the extent of genetically-based protein variations in natural populations in order to insure proper usage of isoenzyme pattern data for systematic purposes. However, Scogin (1969), in surveying natural populations of three species of *Baptisia* (*Leguminosae*), found no species-specific patterns and suggested that there is no way to predict, *a priori*, the possible taxonomic or physiological implications of a given isoenzyme pattern until possible intraspecific variation has been evaluated.

EXPERIMENTAL

A. Material

Mainly, fresh leaves and stems of mature plants were used in this investigation. Specimens were obtained from the McGill University greenhouse, Montreal Botanical Gardens, and some important botanical gardens all over the world. Imported specimens were flown to Montreal, packed in polyethylene bags to ensure freshness.

B. Methods

As mentioned in the Introduction, there are many methods which have been well developed for chemotaxonomic study. They may be said to belong either to an intensive or to an extensive approach. Although most people prefer the intensive approach, they can with this study only a few plants and chemical constituents in years of work. We have chosen the extensive approach, which means doing as many simple tests as possible on as many species as possible in the time available. It precludes detailed chemical work, except at rare intervals.

Gibbs has spent many years, using simple tests as devised by others or modifications of these (Gibbs, 1962, and MSS). I have used these tests and in addition have done chromatography for phenolics as outlined below.

1. Cigarette and Hot-Water Tests

Dagmar Dykyj-Sajfertová (1958), in a paper on respiration pigments, described two simple tests which probably reveal the presence or absence of polyphenolases and their substrates. These tests were adopted by Gibbs and they are described below. I have included Miss Dykyj-Sajfertova's results, those of Gibbs (MSS), and my own in Appendix I.

Fresh leaves (mature, but not senescent) are used for the tests.

a. Hot-Water Test: The leaf is dipped halfway into hot water (85-90^{o}C) for five seconds and then removed. Rapid darkening along the water-line (and sometimes of the whole dipped portion) is designated by I. If, after a minute or more, a dark line should appear, the result is classified as II. Any formation of a dark line after 30 minutes is classed as III, and if no reaction occurs within that time, it is recorded as IV. In addition Dykyj-Sajfertova noted an "oxalis-reaction" (because first seen in Oxalis) -- a yellowing of the dipped portion. This particular result is perhaps due to highly-acid cell-sap; however, it has also been obtained in young leaves of other plants. It was observed doubtfully in two or three of our species.

b. Cigarette Test: A lighted cigarette is pressed gently against the underside of the leaf for three seconds. The results are classified as follows:

I. -- an immediate reaction (formation of a dark ring around the heated area)

II. -- a slower reaction

III. -- a very slight reaction

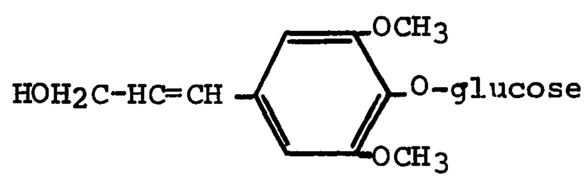
IV. -- no reaction

o.r. -- "oxalis reaction"

The results of both tests are similar, but the reaction in the cigarette test is more rapid. These tests have been found to be good chemotaxonomically. Some groups give constantly positive (I-II) reactions, others are negative (IV). While yet others are mixed.

2. Syringin (1:1 H_2SO_4/H_2O) Test

Freshly-cut transverse-sections of stems, or sometimes petioles, are used for this test. Two sections are placed on separate microscope slides. To one, a drop of 50% aqueous sulphuric acid is added and the preparation is examined under the microscope at intervals during about thirty minutes. A blue color in the xylem, lignified fibres, etc. is recorded as a positive "Syringin test". It is said to be due to the presence of syringin (Tunmann, 1931). Syringin, which was first found in Syringa, is the glucoside of 5-methoxy-coniferyl alcohol.



Syringin

Other colors may appear in the xylem and fibres. A yellowish color often appears. The development of a pink to red color in the lignified tissue is closely correlated with positive HCl/methanol and positive leuco-anthocyanin reactions. Purpling, or darkening, especially in the cortex, is associated with the presence of aucubin or aucubin-like substances.

The other section, in a drop of water, is used as a control. The presence or absence of raphides and/or other crystals is noted in this section too. Most plants are negative to the syringin test.

3. Raphides

These are bundles of needle-shaped crystals of calcium oxalate, occurring in special raphide-sacs (Gibbs, 1962). He, in 1963, says that the taxonomic importance of raphides was recognized by Robert Brown who considered its presence or absence as a diagnostic character. Gulliver (1866) remarks that raphides are restricted in distribution and that they may be used as taxonomic characters. Metcalfe and Chalk (1950) write:

> "Other types of crystalline secretion such as raphides and crystal-sand are more restricted in distribution and therefore of still greater taxonomic importance."

We have included our own observations, made on control sections when doing the syringin test (above), observations of Gibbs (MSS), and others from the literature.

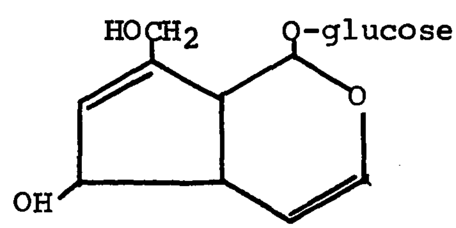
4. Ehrlich Tests (A and B)

Gibbs got this test from G.H.N. Towers but we do not know the original source of it.

About 0.5 gm of fresh leaf-blade material is chopped, placed in a test tube, and extracted with a little boiling 50% aqueous ethanol. The extract is then concentrated by evaporating it to a small volume.

Three spots of the concentrated extract are built up on a 9 cm. filter paper (Whatman No. 1) and allowed to dry. To the second spot is added a drop of acid alcohol (5 ml conc. HCl in 200 ml of 95% ethanol) as a control, to the third spot is added a drop of Ehrlich's reagent (1 gm p-dimethylamino-benzaldehyde; 5 ml conc. HCl: 200 ml 95% ethanol), and again the spots are allowed to dry. Often no marked change of colour occurs but the third spot may become blue (a positive reaction) or magenta. The filter paper is then placed in a preheated oven (100^{o}C) for one minute. This sometimes causes the development of a blue color where it has not previously appeared.

A blue (positive) reaction is caused by the presence of aucubin or aucubin-like substances.



Aucubin

A magenta colour is very closely correlated with the red colour observed in the syringin test, with a magenta (positive) HCl/methanol reaction, and with a "carmine" (positive) leucoanthocyanin reaction. In the absence of a blue or magenta colour, yet other colours -- such as yellow -- may be observed.

To the first spot a drop of dilute aqueous (10%) ammonia is added (Test B). Usually a pale yellow colour is produced, but sometimes a bright yellow colour appears, and although this has not been tested, this colour may be indicating flavonoids. Rarely a red or other off-beat reaction is developed. Such colours are recorded, since they may prove to be of taxonomic significance.

5. The HCl/Methanol (or Isenberg/Buchanan) Test

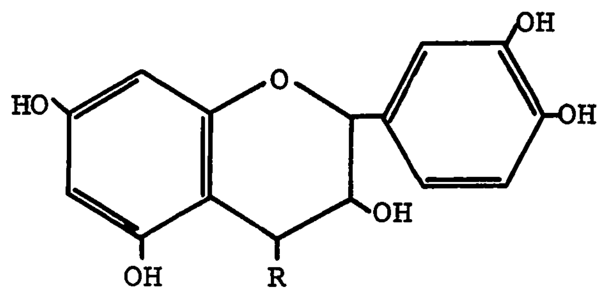
This test seems first to have been described by Isenberg and Buchanan (1945), and they found it to have some taxonomic significance. Gibbs verified this, and has adopted and modified it. I include, again, my own and his (MSS) observations. It is carried out as follow:

Fresh chips of wood (usually sapwood, and often obtained with a pencil-sharpener from pencil-sizedtwigs) are placed in a test tube and covered by a few millilitres of HCl/methanol solution (25 ml conc. HCl : 1000 ml methanol) and left for some hours, usually overnight.

A magenta colour (positive test) may develop, or no colour to a pale yellow colour may result (negative test). Using Ridgway's "Color Standards and Color Nomenclature' (1912), the specific colour is recorded. The positive reactions are also rated:

Purple 1 ..... very pale purple
2 ..... pale purple
3 ..... magenta
4 ..... darker than magenta

Adler (1951) concluded that this magenta colour (positive) is due to the presence of catechol tannins. These condensed tannins, according to Swain (1965), are formed by the condensation of two or more molecules of flavan-3-ols, such as catechin, or flavan-3,4-diols, such as leucocyanidin, or mixtures of the two.



Catechin : R=H

Leucocyanidin : R=OH

and he writes:

> "The hydroxylation patterns of the monomers vary depending on the source, but are generally related to the commonly occurring flavonols and anthocyanins."

Thus they are very closely correlated with the leuco-anthocyanin test. Gibbs has observed a very rare orange reaction with the HCl/Methanol test (Gibbs, *et al.*, 1967). We have not seen it in any of our material.

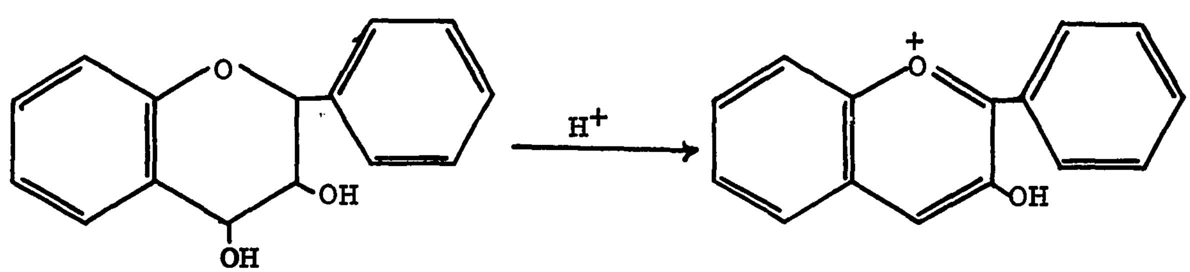
6. Leucoanthocyanin Test A

This useful test is due to Bate-Smith. He demonstrated it to Gibbs, who has adopted and used it extensively. It is carried out as follows.

Freshly-chopped leaves (ca. 0.5 gm) are placed in a 150 x 25 mm test tube which is etched at the 5 and 10 ml points. 2N HCl is added to the 5 ml level; the test tube is immersed in a boiling water bath for 20 minutes; after which it is removed and cooled. Isoamyl-alochol is then added to the 10 ml mark, and the solution is vigorously shaken.

On standing, the mixture separates into two layers. A red colour in the upper (isoamyl-alcohol) layer is a positive reaction, while a yellow, buff or green colour is negative. We usually match the colour against Ridgway and record it.

In this test, a positive reaction is considered to be due to the presence of leucoanthocyanins, which are colorless and water-soluble, but which are hydrolysed and oxidized to the corresponding isoamyl-alcohol-soluble anthocyanidins (Bate-Smith, 1954).



A leucoanthocyanidin An anthocyanidin

The results of this test are usually distinctly positive or negative. Sometimes, however, because of the small amounts of leucoanthocyanin or the presence of interfering substances (such as aucubin or aucubin-like compounds which give black or bluish colours) the results are doubtful. Catechins also obscure the test, especially in acid solution. They may form red-brown polymers known as phlobaphenes which are isoamyl alcohol soluble.

According to Bate-Smith (1965), the leucoanthocyanins are prevalent in woody plants, and the presence of these compounds are regarded as being a less advanced character.

7. HCN Test A

About one gm of fresh leaf and stem material, including young tips if possible, is ground in a mortar with a few drops of water, a speck of emulsin (which hydrolyses cyanogenic glycosides and releases HCN), and a drop or two of chloroform. The mixture is poured into a glass-stoppered tube (ca. 150 x 25 mm). To the glass stopper has been fixed with wax an almost triangular piece of picric acid paper freshly dipped in 10% sodium carbonate (Na_2CO_3) and blotted.

A strongly positive reaction is one in which the yellow sodium picrate paper turns a deep rust colour within minutes to hours; while a weakly positive reaction is one in which the colour change may not show up clearly for several days and even then is not deep. In the absence of HCN the paper remains yellow (negative reaction). The test tubes are left in a rack for at least a week before being discarded.

Bohm (1803) first reported the presence of HCN or prussic acid in plants. Later, various authors, Lindley (1830), Dillemann (1958), Gibbs (1963), and others considered that HCN is taxonomically interesting.

8. Juglone Tests A-C

This old test is thus named because it was first described for juglone itself. Other naphthaquinones also give colour reactions with it. Only Test A, however, is for juglone and other naphthoquinones. Tests B and C are for other compounds but are conveniently included here.

"Juglone Test A" is carried out as follows. A little finely-chopped material (from leaves, root or stem, but preferably the root, and where possible bark material) is placed in a test tube. It is then covered in chloroform and left, with some shaking, for hours or overnight. The chloroform extract is evaporated to dryness on a water-bath, the residue is taken up in a few ml of ether and a few ml of 10% aqueous ammonia (NH_4OH) added.

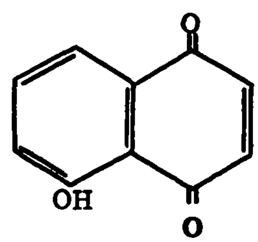
On shaking, a brilliant purple colour is a positive reaction and is due to the presence of juglone or some closely-related naphthaquinone. An orange or wine colour may be indicative of other naphthoquinones also.

In the absence of naphthoquinones, it was seen that not infrequently the ammonia layer is yellow. This probably indicates the presence of flavonoids and is recorded as "Juglone Test B".

By using a long wave ultraviolet lamp any notable fluorescence of the ammonia layer is recorded as "Juglone Test C." Bright blue or green fluorescence is probably due to coumarins.

Gibbs (1965) finds that some plants develop, in the ammonia layer, slowly a green to blue-green colour from above. He suggests that it may prove to be of definite taxonomic interest. In order to be sure that one does not miss this slow reaction, the tubes from "Juglone Test A" are allowed to stand for several days before discarding.

Juglone (below) has been known to be present in the walnut for over a century (Thomson, 1957). I have included with my results some from Gibbs (unpub'd.).



Juglone

9. Tannin Test A

Gibbs first met this test in a thesis by Miss Harney. He has adopted it and carries it out as follows:

The reagent for tannins is 2.5% aqueous ferric ammonium citrate, freshly-prepared or kept under refrigeration. A small (we use 7 cm) Whatman No. 1 filter paper is dipped into the solution and blotted. A piece of clean leaf material is placed on the filter paper which is folded around it. It is then squeezed with a pair of pliers.

A positive reaction is one in which a grey to purple colour is seen at once on the filter paper. The intensity of the colour is rated by positive (+, ++, +++) signs.

A negative reaction is one in which no such colour develops.

As a control we squeeze another piece of the same leaf with the filter paper dipped only in water. This enables us to distinguish colour reactions due to "Tannins" from those which may develop otherwise.

10. Saponin Test A

Following the methods of Amarasingham and his co-workers (1964), a small amount (0.5 gm ±) of finely-chopped fresh leaves is placed in a 150 x 15 mm glass-stoppered tube which is marked at 5 ml and 10 ml levels. Distilled water is added to the 5 ml mark. The mixture is boiled briskly for 1 minute and cooled. It is then vigorously shaken, and left standing for five minutes. The amount of foam is then noted. We record our results as follow:

If a deep (> 2 cm) layer of foam has persisted it is assumed that saponins are present (+); if rather less foam persists we record the result as doubtfully positive (+?); if a little foam remains we class the result as probably negative (-?); and if there is no foam, as negative (-). The tubes with their contents are then used for the test below.

11. "Saponin Test B (NH_3)"

This is not a test for saponins but is conveniently included here since we use the tubes with their contents from Saponin Test A (above). Ammonia (10% aqueous) is added to the 10 ml mark. The test tube is shaken and the initial colour is recorded. Some samples give almost no colour, others a pale yellow or a very deep yellow.* On standing for 3 days, the colour may remain unchanged or may even fade somewhat, or may deepen to orange-brown or even almost black. At present, it is not known why aqueous ammonia causes darkening of the solution, but darkening is closely correlated with occurrence of tannins. The colour deepens from above, thus indicating that oxygen is necessary for the reaction. Therefore, we remove the stoppers and shake gently from time to time to facilitate oxidation. Using Ridgway we record our results.

0 -- no change in colour, or fading

1 -- about "yellow ocher" to "ochraceous orange"

2 -- "tawny" to "hazel"

3 -- "liver brown"

4 -- deeper than "liver brown"

This test has evidently some taxonomic value (Gibbs, 1965).

12. Paper Chromatography for Phenolic Constituents

The application of chromatographic techniques to the analysis of phenolic mixtures in higher plants has opened a new

* but see Picramnia (p. 101)

era in the study of these substances and their distribution in plant tissues. By means of chromatographic methods a large number of plants have been screened for phenolic constituents and many phenolic substances infrequently detected in the past, such as chlorogenic acid, have been shown to be almost ubiquitous in higher plants.

Paper chromatography was first employed for the separation of phenolic pigments by Bate-Smith (1948) and has been widely used since with all types of phenolic compounds. Many methods have been developed and data for the separation of various phenolic substances have been summarized by Block *et al.* (1958) and Harborne (1961, 1967). Lists of R_f values in several solvent systems of most of the known, naturally-occurring phenols and related compounds are available (Harborne, 1958, 1959; Block *et al.*, 1958; Reio, 1960).

a. Preparation of plant extracts

Phenolic acids occur in plants largely as esters and glycosides (Bate-Smith, 1962a). The common practice for their extraction from plant tissue involves the use of diethyl ether, hot aqueous ethanol, methanol or isopropanol. Boiling *N* NaOH has also been used (Pearl *et al.*, 1957). The method described by McCalla and Neish (1959) has been found to be very satisfactory by other workers (Ibrahim and Towers, 1960).

The present writer followed this method (slightly modified) for phenolic acid analysis. The fresh plant material is homogenized during extraction with aqueous ethanol and the ethanolic extract is evaporated to dryness. The residue thus obtained is re-extracted in a small volume of boiling water and washed with petroleum ether. The filtrate is extracted with ether, to remove the free acids, and then subjected to either alkaline or acid hydrolysis to release the phenolic acids bound in either ester or glycosidic linkages. The acids released on hydrolysis are subsequently extracted with ether under acidic conditions. The detailed extraction procedure is shown in Fig. 1.

b. Chromatographic Techniques and Equipment

i. Paper: Large sheets (18 1/2" x 22 1/4") of Whatman's No. 1 chromatography grade filter paper were used for two-dimensional separation of plant extracts fractionated as mentioned under a.

ii. Tanks: Air-tight, chromatographic chambers containing glass troughs suitable for development of large chromatograms by the descending methods were employed.

iii. Solvents: One of the best solvent systems for chromatographing the phenolic aglycones is that of Ibrahim and Towers (1960), but we used aqueous formic acid (2% by volume) (Bohm and Towers, 1962) instead of their mixture of Sodium Formate: Formic Acid: Water (10 : 1: 200) for the second direction.

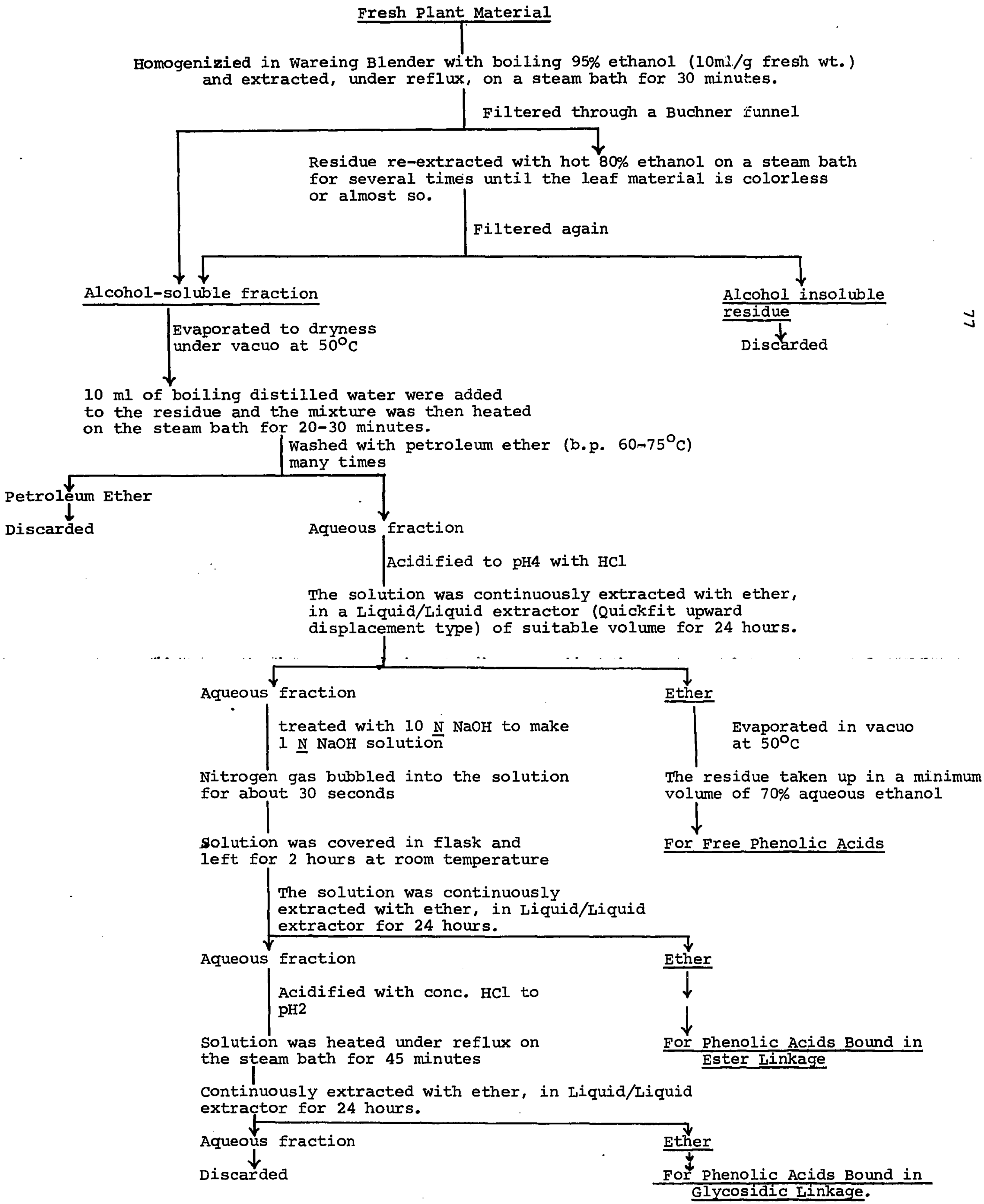


Fig. I Extraction of Phenolic Acids

Two solvents were prepared with analytical grade reagents and distilled water as follows:

(1) Benzene-Acetic Acid-Water (10:7:3 by volume). This is prepared by shaking for a few minutes in a separatory funnel and then allowed to stand for at least 1 hour (and often overnight).

This two-phase solvent was used for the first direction in the chromatographic separation of the phenolic acids. In a tank (well-saturated by leaving for 4 hours with the aqueous phase) 70 ml of the organic phase were found adequate to irrigate two chromatograms at 21.1°C in 4 to 4.5 hours. Complete removal of the solvent from chromatograms required from 2 to 3 hours in the fume hood with the fan running.

(2) Aqueous formic acid (2% by volume) (Bohm and Towers, 1962). This solvent was used for the development of the chromatograms for phenolic acids in the second direction. Development time was 3 to 3.5 hours using 65 ml of solvent for irrigation of two chromatograms at 21.1°C. Chromatograms were dried subsequently for 4 to 6 hours.

c. Identification of Phenolic Acids

The identification of the phenolic acids was carried out by examining the paper chromatograms under ultraviolet lamps, both longwave and short wave, before spraying. The fluorescence was examined again after exposure to ammonia vapor. Chromatograms were then sprayed with one of the following reagents.

i. <u>Diazotized p-nitroaniline</u> (Bray *et al*., 1950)

The following stock solutions were prepared:

(1) p-Nitroaniline; (2) 5% Sodium Nitrite solution;

(3) 20% Sodium Acetate solution; (4) 5% Sodium Hydroxide solution.

Chromatograms were sprayed with a mixture of stock solutions 1, 2 and 3 in a 5:1:15 ratio by volume, followed by overspraying with solution 4.

ii. <u>Diazotized Sulfanilic Acid Spray</u> (Evans *et al*., 1949)

The spray reagent was prepared from the following stock solutions:

(1) Sulfanilic acid solution prepared by dissolving 9 gm of sulfanilic acid in 90 ml conc. HCl and diluting to one litre with distilled water.

(2) 5% Sodium Nitrite solution; (3) 20% Sodium Hydroxide solution.

The spray reagent was freshly prepared prior to use by mixing the 3 stock solutions in a 2:1:2 ratio by volume.

iii. <u>1% Ferric chloride solution</u>

Since reference compounds had been run by earlier workers, and a chart had been prepared giving the colour and position of each known compound, the spots on the chromatograms were thus identified.

RESULTS

For convenience in comparing and contrasting the systematic relationships of Rutales, all results are represented by tables 2-10.

The data have been collected (1) through work done in the laboratory by myself, (2) a survey of literature, up to September, 1969* and (3) the information cards of Dr. R. D. Gibbs (most unpublished).

Classes of chemical constituents as delimited in this thesis are those of Gibbs (MSS). For the writer's summary of her results, consult the tables in the appendix.

*A few later items are included.

	FAMILIES	TESTS: H.W. and CIG.	SYRINGIN	RAPHIDES	EHRLICH	HCN (TEST A)	HCl/METHANOL	L.A. (TEST A)	JUGLONE (TEST A)	FLUORESCENCE	TANNIN (TEST A)	SAPONIN (TEST A)	[illegible]
SUBORDER 1	Rutaceae	(∓)	(-)(NR)	(-)	-(ot/M)	(-)	(∓)	(∓)	-	(+)	(±)	-	(
	Cneoraceae	(∓)	-(NR)	-	-ot	-	-	-	-	-	-	-	
	Simaroubaceae	(±)	-(NR)	-	-(ot)	-	(-)	(-)	-	(±)	+	-	
	Picrodendraceae	-	-(R)	-	-M	-	+		-	+			
	Burseraceae	(∓)	-(NR)	-		-	(∓)		-	±	+		
	Meliaceae	(∓)	-(R)	-	-(M/ot)	(-)	(+)	±	-	+	(±)	(∓)	
	Akaniaceae	+	-(R)	-	-M	?	+	+	-	+	+		
S.O. 2	Malpighiaceae	(∓)	-(R)	-	-(M)	(-)	(+)	(+)	-	(±)	(±)	-	
	Trigoniaceae												
	Vochysiaceae						±		-	-			
S.O. 3	Tremandraceae	-	-(R)	-	-(M/ot)	(+)	+		-	+	+		
	Polygalaceae	(∓)	-(NR)	-	-(ot)	-	(∓)	(∓)	(-)	(∓)	±	(-)	

Comments: This is merely a summary chart. It is subjective in part. Thus for more detailed results, the tables on the following pages and in the Appendix should be consulted.

TABLE 2

Chemical Characters of "Rutales"

FLUORESCENCE	TANNIN (TEST A)	SAPONIN (TEST A)	"SAP. TEST B" (NH_3)	PHENOLIC ACIDS	Benzoic	Phenylacetic	Cinnamic	Ellagic	COUMARINS	Simple coumarins	6,7-Furocoumarins	7,8-Furocoumarins	Chromanocoumarin	FLAVONOIDS	Anthocyanins	Leucoanthocyanins	Flavanoes	Flavanonols
+)	(±)	–	(∓)	(+)	(+)	(–)	(+)	(+)	(+)	(+)	(+)	(–)	(+)	+	(–)	(∓)	(∓)	(-
-	–	–	–	(+)	(+)	–	(+)	–	(+)					+		–		
±)	+	–	+	(+)	(+)	–	(+)	(+)						+		–		
+																		
±	+			(+)	(+)	–	(+)	(+)						+		(+)		
+	(±)	(∓)	±	(+)	(+)	(–)	(+)	(+)	(+)	(∓)	–	(–)	(–)	+		(–)		
+	+			(+)	(+)	–	(+)	(+)										
±)	(±)	–	±	(+)	(+)	–	(+)	(+)	(–)					+		(+)		
–																		
+	+			(+)	(+)	–	(+)	(+)						+		–		
∓)	±	(–)	±	(+)	(+)	–	(+)	(+)						+		–		

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Key to symbols:
+ = all positive
– = all negative
(+) = majority are positive
(–) = majority are negative
(±) = more positive than negative
± = half positive, half negati
(∓) = more negative than positive
NR = no red
R = red
ot = other than magenta
M = magenta

.es"

Leucoanthocyanins	-	-	(+)		(-)	(+)	-	-	(±)
Flavanoes									(±)
Flavanonols									(-)
Flavones									(±)
Flavonols	(±)	(∓)	∓		(+)	(+)	(±)	(∓)	(∓)
TERPENOIDS					+	+	+		+
Monoterpenoids					+	(+)	-		(+)
Sesquiterpenoids					∓	(+)	-		(∓)
Diterpenoids					∓	(+)	-		-
Triterpenoids	(+)				(+)	(+)	+		(+)
Tetraterpenoids					-	-	-		(±)
ALKALOIDS	∓	∓	(±)	+	(±)	(-)	∓		(∓)
Acridines					-		-		∓
Alkaloidal amines					-		-		∓
Imidazoles					+		-		(-)
Indoles					-		∓		∓
Isoquinolines					-		-		∓
Oxazoles					-		-		(-)
Pyridines					-		-		(-)
Pyrrolidines					-		-		(-)
Quinazolines					-		-		(-)
Quinolines					-		∓		+

tive
tive
n negative
lf negative
n positive
a

Families, etc. No. of genera bracketed		H.W. & Cig. Tests I		II		III		IV	or	Syringin Test +	−	?
Rutaceae	(204)	10/14	4/4 ↔	2/2	6/7 ↔	15/15	2/2 ↔	20/30		1/1	29/46NR 18/10R	2/2R 1/1NR
Rutoideae	(142)	4/5		1/1		7/7	2/2 ↔	4/6		1/1	16/26NR 3/3R	2/2R
Dictyolomatoideae	(4)											
Flindersioideae	(2)		1/1								1/1R	
Spathelioideae	(3)											
Toddalioideae	(24)	1/3	1/1		2/3			3/5			5/6NR 2/3R	1/1NR
Citroideae	(30)	1/1	2/2		4/4			6/14			8/14NR 2/2R	
Rhabdodendroideae											1/1NR	
Cneoraceae	(2)						1/1 ↔				1/1NR	
Simaroubaceae	(26)	1/1		1/1	↔	1/1					1/1R 5/5NR	
Surianoideae	(4)			1/1							1/1R	
Simarouboideae	(5)										3/3NR	
Kirkioideae	(1)							1/1			1/1NR	
Irvingioideae	(4)											
Picramnioideae	(1)	1/1									1/1NR	
Alvaradoideae	(1)											
Picrodendraceae	(7)							1/1			1/1R	
Burseraceae	(20)					2/2					2/2NR 1/1R	
Meliaceae	(50)	4/6						6/6			4/5R 2/2NR	
Cedreloideae	(4)	1/1						2/2			1/1R 1/1NR	
Swietenioideae	(8)	1/1						1/1			2/2R	
Melioideae	(28)	2/4						3/3			1/2R 1/1NR	
Akaniaceae	(1)			1/1							1/1R	
Malpighiaceae	(65)	1/1						3/4			2/2NR 4/8R	
Trigoniaceae	(4)											
Vochysiaceae	(6)											
Tremandraceae	(3)							1/4			1/1NR 1/3R	
Polygalaceae	(13)				1/1			1/3			2/6NR	
Xanthophylleae	(1)											
Polygaleae	(8)				1/1			1/3			2/6NR	
Moutabeae	(4)											

Key to symbols: NR = no red; R = red; ot(in Ehr.) = color other than magenta or blue
M = magenta; bk = bark

*Fraction represent numbers of genera/species

TABLE 3

A list of plants tested (by families and subfamilies) in "Rutales"

Test		Raphides		Ehrlich		HCN			HCl/Meth.			L.A.		
	?	+	−	+	−	+	−	?	+	−	?	+	−	?
6NR	2/2R				16/28ot									
0R	1/1NR	3/3	34/44		16/23M	2/4	34/53	1/1	9/12	29/46	4/6	13/17	21/30	2/
6NR					7/8ot									
R	2/2R	3/3	19/29		11/18M	1/3	18/27		3/5	18/27	2/3	8/12	12/15	
R			1/1		1/1M		1/2		1/1			1/1		
R					3/5ot									
	1/1NR		5/8		2/2M		6/8		3/3	6/9	1/1		4/6	2/
NR					6/15ot									
			9/16		2/2M	1/1	9/16	1/1	2/3	5/10	1/2	4/4	5/9	1/
R			1/1		1/1M		1/1							
R			1/1		1/1ot		1/1			1/1			1/1	
					4/4ot									
R			6/6		1/1M		5/5		1/1	4/4			6/6	
			1/1		1/1M		1/1		1/1				1/1	
R			3/3		2/2ot		1/1			3/3			3/3	
R			1/1		1/1ot		1/1						1/1	
							1/1							
R			1/1		1/1ot		1/1			1/1			1/1	
			1/1		1/1M		1/1		1/1					
R														
			2/3				2/2		2/3				1/1	
					3/3ot									
R			7/7		4/5M	1/1	9/11		7/10	1/1		4/5	4/4	
					1/1 ot									
R			2/2		1/1M		2/2		2/2			1/1	2/2	
			2/2		2/2M		2/2		2/2			2/2		
					2/2ot									
R			3/3		1/2M	1/1	5/7		3/6	1/1		1/2	2/2	
			1/1		1/1M			1/1	/1/1			1/1		
R					1/1 ot									
			7/10		4/6M		4/7	1/2	7/10	2/2		4/6	1/1	
									1/1	1/1				
NR					1/1 ot									
			2/5		1/2M	2/2	1/3		2/5				1/1	
					1/4ot									
NR			2/6		1/1M		3/5		1/1	2/4		1/1	1/2	
NR			2/6		1/4ot		3/5		1/1	2/4		1/1	1/2	
					1/1M									

or

utales"

.A.		Juglone		Fluorescence			Tannin			Saponin Test A			"Sap.Test B" (NH_3)	
-	?	+	-	+	-	?	+	-	?	+	-	?	+	-
21/30	2/3		27/36 11/14 13/19	27/42	7/10	1/1	13/20	8/11	4/4		13/4	2/2	4/4	10/15
12/15			6/7Y	16/26	1/1		9/15	7/9	3/3		4/6		2/2	3/5
			1/1	1/1			1/1				1/1			1/1
4/6	2/2		5/5	4/4	1/3		3/4	1/2	1/1		3/5	1/1	1/1	2/4
5/9	1/1		1/1PY 8/11 4/6Y	6/11	5/6	1/1	5/6	5/6	1/5		5/9	1/1	1/1	4/5
1/1			1/1Y 1/1Y		1 1/1						1/1			1/1
6/6			5/5	4/4	2/2		3/3				2/2	1/1	1/1	
1/1			1/1		1/1						1/1			
3/3			3/3	3/3			1/1							
1/1			1/1	1/1			1/1				1/1			
1/1			1/1		1/1		1/1					1/1	1/1	
			1/1	1/1										
1/1			2/4	1/2	1/2		1/1							
4/4			8/9	7/8		1/1	5/6	2/2		2/2	2/2	2/2	4/4	4/4
2/2			2/2	2/2			1/1	1/1		1/1	(bk)		2/2	2/2
			2/2	1/1		1/1	2/2			1/1		2/2	2/2	
2/2			4/5	4/5			2/3	1/1			2/2			2/2
			1/1	1/1			1/1							
1/1			5/7 1/1Y	5/5	3/3		5/6	3/3			3/4		2/2	2/2
			2/2		2/2									
1/1			1/1	1/1			2/2							
1/2		1/1												
1/2		1/1	1/2 2/2Y	1/1	2/2	1/1	1/1	1/1		2/3	1/2	1/1	1/1	1/1

TABLE 4

Occurrence of groups of phenolic acids by families and subfamilies in "Rutales" (see Appendix II)*

		Benzoic acids	Phenyl-lacetic acids	Cinna-mic acids	Coumarins	
Rutaceae	(204)	27/33	2/2	30/27	27/33	20/20**
Rutoideae	(142)	15/20		17/22	14/18	10/10**
Dictyolomatoideae	(1)					
Flindersioideae	(2)					
Spathelioideae	(3)					
Toddalioideae	(24)	5/5		5/6	5/6	4/4**
Citroideae	(30)	7/8	2/2	8/9	8/9	6/6**
Cneoraceae	(2)	1/1		1/1	1/1	1/1**
Simaroubaceae	(26)	2/2		2/2	2/2	
Simarouboideae	(15)	1/1		1/1	1/1	
Kirkioideae	(1)	1/1		1/1	1/1	
Picrodendraceae	(1)					
Burseraceae	(20)	1/1		1/1	1/1	
Meliaceae	(50)	4/5	1/1	6/7	6/7	1/1**
Cedreloideae	(4)			1/1	1/1	
Swietenoideae	(8)	2/2	1/1	2/2	2/2	
Melioideae	(28)	2/3		3/4	3/4	
Akaniaceae	(1)	1/1		1/1	1/1	
Malpighiaceae	(65)	1/2		2/3	1/2	1/1**
Trigoniaceae	(4)					
Vochysiaceae	(6)					
Tremandraceae	(3)	2/2		2/2	2/2	
Polygalaceae	(13)	1/2	1/1	1/2	1/1	

* Fractions represent numbers of genera/species

**Coumarins other than Ellagic Acid

TABLE 6

A list of plants (by genera) tested by wr

(see Appendix I)

		Hot Water and Cig. test I	II	III	IV	or +	Syrin-gin –	Raph-ides	Ehrlich +	–	+
RUTACEAE											
I. Rutoideae											
Choisya	(7)										
Evodia	(120)	1			1		2NR	-2		1	
Geijera	(7)	1					1NR	-1		1M	
Melicope	(50)				1		1NR	-1		1	
Orixa	(1)						1NR	-1			
Zanthoxylum	(15)	2					2NR	-2			
Cneoridium	(1)				1		1R	-		1M	
Dictamnus	(2)			III?-IV-1			1NR	-1		1	
Ruta	(60)				3		3NR	-3		2	
Acradenia	(1)				1	1?R	5NR	-1		1M	
Boronia	(20)				1	2?	1R	-5		5M	3
Correa	(11)				1	1?R	1NR	-1		1M	
Chorilaena	(3)				1		1NR	-1		1M	
Crowea	(4)				1		1NR	-1		1M	
Diplolaena	(8)			1?			1NR	-1		1	
Eriostemon	(30)	1					2NR	-2		2M	
Nematolepsis	(2)			1			1NR	-1		1M	
Phebalium	(36)		1	1?			1R	-1		1M	
Barosma	(20)			1			1NR	-1		1M	
Calodendron	(2)			1			1R	-1		1	
Coleonema	(6)			1			2NR	-2		2M	
Diosma	(15)										
Pilocarpus	(20)			1			1NR	-1		1	
Galipea	(8)							+1			
Erythrochiton	(5)			III-IV-1		1		+1		1M	
Raputia	(5)							+1			
II. Dictyolomatoideae											
III. Flindersioideae											
Flindersia	(20)	I-II-1					1R	-1		1M	
IV. Spathelioideae											
V. Toddalioideae											
Acronychia	(40)		II-III-1		1		1NR				
Amyris	(20)										
Casimiroa	(60	I-II-1					1NR	-1		1	
Halfordia	(4)				1					1M	

Key to symbols:

NR = no red		Sd = seed	
R = red		Bk = bark	
M = magenta		Rt = root	
PY = pale yellow		Ot = other	
Y = yellow		Tr = trace	

by writer, Gibbs and others

Lich	HCN		HCl/Meth		L.A.		Juglone		Fluores.		Tannin		Saponin Test A		"Sap. Test B" (NH_3)	
-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-
						1										
1		2	1	2	1	1		2	3		1	1				
1M		2	1?			1										
1		1		1		1		1PY	1			1		1		1
		1		1				1	1		1(Tr)					
				5	1	1		2/3Y	3		1	1				
1M		1	1		1			1		1	1			1	1	
1		1		1				1	1		1	1				
2		3		3		3		1/3PY	3			3		3		3
1M		1	1		1											
5M	3	3		2?	4			4	4		4			1		
1M		2		1												
1M		1		1				1	1		1?					
1M		2		1		1										
1		1		1		1		1	1			1				
2M		1		2	2			1	1		2					
1M		1		1	1			1	1		1					
1M		2		1				1PY	1							
1M		1		1	1			1Y		1	1				1	
1		1		1?		1		1	1			1				
2M		2		2		2		2	2		2					
1		1		1		1		1Y	1		1			1		1
1M				1	1			1	1		1?					
1M		2	1		1			1	1		1			1		1
		2	2											1		
				1												
1		1		1		1		1	1		1		1		1	
1M		1		1												

TABLE 6 (cont'd.)

		Hot Water and Cig. test I	II	III	IV	or	Syrin- gin +	-	Raph- ides	Ehrlic +	-
RUTACEAE (cont'd.)											
Oricia	(8)										
Phellodendron	(10)	3	II-III-2				1?NR	2NR	-4		3
Ptelea	(3)				1			1NR	-1		
Skimmia	(10)				1	1?		1NR	-1		1
Teclea	(25)				1			1R	-1		1M
Toddalia	(1)										
VI. Citroideae											
Aegle	(1)	1	II-III-1					1NR	-1		1M
Atalantia	(30)		II-III-1		1			1NR	-1		1
Citrus	(60)				8			6NR	-6		6
Clausena	(30)	I-II-1II-III-1						2R	-2		2
Eremocitrus	(1)										
Feronia	(1)		II-III-1					1NR	-1		1M
Fortunella	(6)				1			1NR	-1		1
Glycosmis	(40)				1			1NR	-1		1
Limonia	(1)										
Murraya	(9)	I-II-1			2			{1R? 1NR	-2		3
Poncirus	(1)							1NR	-1		
Triphasia	(2)				1			1NR	-1		1
VII. Rhabdodendroideae											
Rhabdodendron	(2)							1NR	-1		1M
CNEORACEAE											
Cneorum	(2)			III-IV-1				1NR	-1		1
SIMAROUBACEAE											
I. Surianoideae											
Suriana	(1)		1					1R	-1		1M
II. Simarouboideae											
Ailanthus	(10)		II-III-1		1			1NR	-1		1
Hannoa	(4)							1NR	-1		
Picraena	(2)										
Picrasma	(17)				1			1NR	-1		1
III. Kirkioideae											
Kirkia	(5)				1			1NR	-1		1
IV. Irvingioideae											
Irvingia	(5)										
V. Picramnioideae											
Picramnia	(40)	1						1NR	-1		1
PICRODENDRACEAE											
Picrodendron	(3)				1			1R	-1		1M
BURSERACEAE											
Bursera	(100)			1?							

yrin- gin +	-	Raph- ides	Ehrlich +	-	HCH +	-	HCl/Meth +	-	L.A. +	-	Juglone +	-	Fluores. +	-	Tannin +	-
NR	2NR	-4		3		2	1	3 1?	1?	2		2/3PY		3	2	
	1NR	-1						1		1		1	1		1	
	1NR	-1		1		1		2		2		1	1			2
	1R	-1		1M		1	1		1?			1	1		1Tr	
	1NR	-1		1M 1Tr?				1	1			1Y	1		1	
	1NR	-1		1		1		1		1		1		1		1
	6NR	-6		6		6	2?	4	1	3		2/6Y	5	2	1	1 5?
	2R	-2		2		2	2		1	1?		1/2Y	1?	1	2	
						1										
	1NR	-1		1M		-1		1	1			1	1		1	
	1NR	-1		1	1?			1		1		1Y		1		1
	1NR	-1		1		1	1			1		1		1		1
	{1R? {1NR	-2		3		3		3		3		2/3Y	2	1	1	2
	1NR	-1				1						1	1			
	1NR	-1		1		1		1		1		1Y		1		1
	1NR	-1		1M		1								1		
	1NR	-1		1		1		1		1		1Y		1		
	1R	-1		1M		1	1			1		1		1		
	1NR	-1		1		1		1		1		1	1			
	1NR	-1						1		1		1	1		1	
	1NR	-1		1				1		1		1	1			
	1NR	-1		1		1				1		1	1		1	
						1 (Sd.)										
	1NR	-1		1		1		1		1		1 "carmine"		1	1	
	1R	-1		1M		1	1					1PY	1			
						1	2					2		2		

/Meth	L.A.		Juglone		Fluores.		Tannin		Saponin Test A		"Sap. Test B" (NH_3)	
−	+	−	+	−	+	−	+	−	+	−	+	−
3 1?	1?	2		2/3PY		3	2			3		3
1		1		1	1		1			1		1
2		2		1	1			2				
	1?			1	1		1Tr					
1	1			1Y	1		1					
1		1		1		1		1		1		
4	1	3		2/6Y	5	2	1	1 5?		4		
	1	1?		1/2Y	1?	1	2			1 1?		
1	1			1	1		1					
1		1		1Y		1		1		1	1	
		1		1		1		1		1		1
										1?		
3		3		2/3Y	2	1	1	2		2		2
				1	1							
1		1		1Y		1		1		1		1
						1						1
1		1		1Y		1				1		
		1		1		1				1		
1		1		1	1							
1		1		1	1		1					
1		1		1	1							
		1		1	1		1			1		
1		1		1 "carmine"		1	1		1?		1 "carmine"	
				1PY	1							
				2		2						

TABLE 6 (cont'd.)

		Hot water and Cig. test I	II	III	IV	or	Syrin-gin +	-	Rap ide
								1NR	
Commiphora	(100)		II-III-1					1R	-
Pachylobus	(21)							1NR	-
MELIACEAE									
I. Cedreloideae									
Cedrelea	(7)		III-IV-1						
Toona	(15)				1			1R	-
Ptaeroxylon	(1)	1						1NR	-
II. Swietenoideae									
Entandrophragma	(20)				1			1R	-
Khaya	(10)								
Swietenia	(5)	I-II						1R	-
III. Melioideae									
Carapa	(15)	2						2R	-
Cipadessa	(4)				1			1NR	-
Melia	(9)		III-IV-1		1			1NR	-
Dysoxylum	(100)	2							
Owenia	(5)								
Sandoricum	(10)								
Trichilia	(20)								
AKANIACEAE									
Akania	(1)		1					1R	-
MALPIGHIACEAE									
Tristellateia	(22)				1?			1NR	-
Acridocarpus	(20)				1			1R	-
Gaudichaudia	(15)	I-II-1						1NR	-
Heteropterys	(90)				1?			2NR	-
Hiptage	(25)								
Malpighia	(30)		III-IV-1					4R	-
Byrsonima	(105)							1R	-
Galphimia	(12)				1			1R	-
Stigmaphyllum					1			2R	-
Thryallis									
TRIGONIACEAE									
VOCHYSIACEAE									
Vochysia	(100)							1?R	
Salvertia	(1)								
TREMANDRACEAE									
Platytheca	(1)							1NR	
Tetratheca	(25)				4			3R	
POLYGALACEAE									
I. Xanthophylleae									
II. Polygaleae									
Polygala	(500)		III-IV-1		2			5NR	
Securidaca	(30)								
Bredemeyera	(60)								
Mundtia	(1)	II-III-1						1NR	
III. Moutabeae									

		Syrin- gin		Raph- ides	Ehrlich		HCN		HCl/Meth		L.A.		Juglone		F:
IV	or	+	−		+	±	+	−	+	−	+	−	+	−	+
			1NR												
			1R	-2				1	1			1		2	2
			1NR	-1											
									1			1			
1			1R	-1		1M		1	1		1			1	1
			1NR	-1		1		1				1		1	1
1			1R	-1		1M		1			1				
									1					1	1
			1R	-1		1M		1	1		1			1	1:
			2R	-2		2M		2	2		2			2	2
1			1NR	-1		1M		1	1		1			1	1
1			1NR	-1		1		1		1		1		1	1
						1	1Tr	1	2					1	1
								2							
								1							
									2						
			1R	-1		1M	1?		1		1			1	1
1?			1NR	-1				1		1				1	1
1			1R	-1		1M		1	1		1			1	1
			1NR	-1		1M					1				
1?			2NR	-2		1	2?		1	1		1		1Y	
									1					1	
			4R	-3		3M		3	3		3			3	1
			1R	-1					1						
1			1R	-1		1M		2	2					1	1
1			2R	-2		2M		2	3		2			3	
									1					1	
			1?R	-1										1	
									1					1	
			1NR	-1		1	1		1					1	1
4			3R	-4		2M	1	3	4						
2			5NR	-1		4	1Tr.	3		3		2		1/3Y	1
										1				1Y	
			1NR	-1		M		1	1		1		1		1

/Meth	L.A.		Juglone		Fluores.		Tannin		Saponin Test A		"Sap. Test B" (NH_3)	
−	+	−	+	−	+	−	+	−	+	−	+	−
		1		2	2		1					
		1										
	1			1	1		1Tr.					
		1		1	1			1	1 (Bk)			
	1						1			1		
				1	1				1		1	
	1			1	1?		1			1	1	
	2			2	2		2					
	1			1	1		1			1		1
1		1		1	1			1		1		
				1	1					1		1
	1			1	1		1					
1				1	1		1Tr.					
	1			1	1		1			1	1	
	1							1				
1		1		1Y		1		1		1		1
				1		1						
	3			3	1	2	2	1		2		2
							1					
				1	1							
	2			3		3	2			2	2	
				1		1						
				1		1						
				1		1						
				1	1		1?					
							1?					
3		2		1/3Y	1	2		1	1 (Rt) 1 (Ot)	2	1	1
1				1Y		1						
									2 (Plt)			
	1		1		1?		1?					

TABLE 7
Coumarins of "Rutales" (see Appendix III)*

		Simple Coumarin	6,7-Furo-Coumarin	7,8-Furo-Coumarin	Chromano-Coumarin
RUTACEAE					
I. Rutoideae					
Evodia	(120)	1/1	2/1		
Fagara	(200)	3/5	2/2		2/2
Geijera	(17)	3/2			
Melicope	(50)		1/1		1/1
Zanthoxylum	(15)	5/3	3/3		3/1
Cneoridium	(1)	1/1	3/1		
Dictamnus	(2)	1/1	2/1		
Ruta	(60)	9/5	9/4		2/2
Thamnosma	(6)			1/1	
Phebalium	(36)		3/1		
III. Flindersioideae					
Flindersia	(20)	3/3	1/1		2/2
Chloroxylon	(1)	1/1			2/1
V. Toddalioideae					
Casimiroa	(6)	1/1	4/1		
Halfordia	(4)		2/2		1/1
Helietta	(1)		1/1		
Ptelea	(3)	1/1	9/2		
Skimmia	(10)	3/3	2/2		1/2
Toddalia	(1)	3/1			
VI. Citroideae					
Aegle	(1)	5/1	4/1		
Aeglopsis	(5)	1/1	3/1		
Citrus	(60)	10/7	11/7		1/1
Clausena	(30)		1/1		4/2
Limonia	(1)				1/1
Luvunga	(12)	1/1	2/1		
Micromelum	(10)	1/1			
Murraya	(9)	4/3			
Poncirus	(1)		3/1		
Severina	(1)	1/1	3/1		2/1
MELIACEAE					
I. Cedreloideae					
Cedrelopsis	(7)	1/1			
Ptaeroxylon	(1)	1/1		2/1	2/1
III. Melioideae					
Ekebergia	(15)	1/1			

* Fractions represent numbers of compounds/species

TABLE 8

Flavonoids of "Rutales" (see Appendix IV and IX)*

		Anthano-cyanins I	Leuco-antho-cyanins II	Flavan-ones III	Flavano-nols IV	Flavones V	Flavonols VI
RUTACEAE							
I. Rutoideae							
Choisya	(7)		-				2/1
Evodia	(120)		2/1				3/1
Fagara	(200)			1/1		1/2	
Melicope	(50)						7/3
Zanthoxylum	(15)		1/2	1/4			3/5
Boenninghausenia	(1)						1/1
Ruta	(60)						2/2
Boronia	(60)		1/1				3/1
Correa	(11)		2/1				3/1
Crowea	(4)		2/1				3/1
Eriostemon	(30)		-				-
Coleonema	(6)		1/1				3/1
III. Flindersioideae							
Flindersia	(20)						1/1
V. Toddalioideae							
Phellodendron	(10)		-		1/1		2/2
Ptelea	(3)		-				2/2
Skimmia	(10)		-				
Teclea	(25)					4/1	
Casimiroa	(6)					6/1	
VI. Citroideae							
Citrus	(60)	2/1	-	14/16		13/15	5/2
Glycosmia	(40)		-				-
Murraya	(9)		-			1/1	-
Poncirus	(1)		-	4/1		1/1	
Fortunella	(6)					1/3	
CNEORACEAE							
Cneorum	(2)		-				2/1
SIMAROUBACEAE							
Quassia	(40)		-				-
Ailanthus	(10)		1/1?				2/3
BURSERACEAE							
Protium	(60)		1/2				2/2
MELIACEAE							
Cedrea	(7)		1/2				2/2
Ptaeroxylon	(1)						1/1
Melia	(9)		-				2/1
Aitonia	(1)		-				1/1
MALPIGHIACEAE							
Heteropteris	(90)		-				2/2
Hiptage	(25)		1/1				-
Malpighia	(30)		1/1				-
Tristellatlia	(22)		1/1				1/1
TREMANDRACEAE							
Platytheca	(1)		-				2/2
Tetratheca	(25)		-				1/1
POLYGALACEAE							
Polygala	(500)		-				2/5

*Fractions represent numbers of compounds/species.

TABLE 9

Terpenoids of "Rutales" (see Appendix V)*

		I. Monoterpenoids	II. Sesquiterpenoids	1. Bsiaboiene Group	2. Cadienene Group	3. Eremophilone Group	4. Guaianolide Group	5. Selinene Group	III. Diterpenoids	IV. Triterpenoids	1. Triterpenoid saponins and sapo-genins	2. Triterpenoids other than Saponins and Sapogenins	V. Tetraterpenoids
RUTACEAE													
I. Rutoideae													
Evodia	(120)	1/1								+3/3		+3/3	
Zanthoxylum	(15)	7/3								+2/4	+2/4		
Medicosma	(1)	1/1											
Dictamnus	(2)									+3/1		+3/1	
Ruta	(60)	3/1											
Boronia	(60)	1/1	+1/1				+1/1						
Eriostemon	(30)	+2/2	+1/1				+1/1						
Phebalium	(36)	+2/2	+1/1				+1/1						
Zieria	(15)	+2/1											
Agathosma	(170)	+1/1											
Barosma	(20)	+5/4											
Calodendrum	(2)									+2/1		+2/1	
Empleurum	(2)	+1/1											
III. Flindersioideae													
Flindersia	(20)									+3/4	+1/1	+2/3	
V. Toddalioideae													
Acronychia	(40)									+1/1		+1/1	
Amyris	(20)		+1/1		+1/1								
Casimiroa	(6)									+2/2		+2/2	
Phellodendron	(10)	+1/2								+2/1		+2/1	
Skimmia	(10)	+1/1								+2/1		+2/1	
Vepris	(20)									+1/1	+1/1		
VI. Citroideae													
Aegle	(1)	+4/1								+1/1	+1/1		
Atalantia	(20)	+3/2											
Citrus	(60)	+25/10	+4/2	+1/1		+2/2		+1/1		+9/14	+2/2	+7/13	+5/3
Clausena	(30)	+1/1											
Fortunella	(6)									+2/1		+2/1	
Glycosmia	(40)									+2/1		+2/1	
Luvunga	(12)	+1/1								+1/1		+1/1	
Microcitrus	(5)									+2/1		+2/1	
Murraya	(9)		+3/2	+1/1	+2/1								+2/1
Poncirus	(1)									+4/1		+4/1	
Triphasia	(2)												+2/1
SIMAROUBACEAE													
II. Simarouboideae													
Eurycoma	(4)									+1/1		+1/1	
Quassia	(40)									+2/1		+2/1	
Simaba	(40)									+2/1		+2/1	
Simarouba	(40)									+5/2		+5/2	
Samadera	(40)									+4/1		+4/1	
Ailanthus	(10)									+8/4		+8/4	
Brucea	(10-12)												
Castela	(12)									+1/1		+1/1	
Perriera	(1)									+1/1		+1/1	
BURSERACEAE													
Boswellia	(24)	+5/1							+1/1	+1/2		+1/2	
Bursera	(100)	+8/2								+1/1		+1/1	
Commiphora	(100)	+1/1	+1/1	+1/1					+1/1				
Canarium	(75)	+2/1	+4/2					+4/2		+8/4	+2/1	+6/4	
MELIACEAE													
I. Cedreloideae													
Cedrela	(7)		+2/1		+2/1				+2/1	+11/ −1/5		+11/ −1/5	
Ptaeroxylon	(1)									+1/1	+1/1		
II. Swietenoideae													
Entandrophregma	(20)									+6/9		+6/9	
Khaya	(10)									+16/5		+16/5	
Pseudocedrela	(1)									+5/1		+5/1	
Swietenia	(5)									+3/1		+3/1	
III. Melioideae													
Carapa	(15)									+6/2		+6/2	
Xylocarpus	(5)									+1/1		+1/1	
Turraeanthus	(6)									+1/1		+1/1	
Melia	(9)								+2/1	+11/2		+11/2	
Aglaia	(300)	+3/2	+1/1			+1/1							
Aphanamixis	(22)									+1/1		+1/1	
Dysoxylum	(100)		+1/1		+1/1								
Guarea	(160)									+6/2		+6/2	

	I. Monoterpenoids	II. Sesquiterpenoid	1. Bsiaboiene Grou	2. Cadienene Group	3. Eremophilone Gr	4. Guaianolide Gr	5. Selinene Group	III. Diterpenoids	IV. Triterpenoids	1. Triterpenoid saponins and s genins	2. Triterpenoids than Saponins Sapogenins	V. Tetraterpenoid
RUTACEAE												
I. Rutoideae												
Evodia (120)	1/1								+3/3		+3/3	
Zanthoxylum (15)	7/3								+2/4	+2/4		
Medicosma (1)	1/1											
Dictamnus (2)									+3/1		+3/1	
Ruta (60)	3/1											
Boronia (60)	1/1	+1/1				+1/1						
Eriostemon (30)	+2/2	+1/1				+1/1						
Phebalium (36)	+2/2	+1/1				+1/1						
Zieria (15)	+2/1											
Agathosma (170)	+1/1											
Barosma (20)	+5/4								+2/1		+2/1	
Calodendrum (2)												
Empleurum (2)	+1/1											
III. Flindersioideae												
Flindersia (20)									+3/4	+1/1	+2/3	
V. Toddalioideae												
Acronychia (40)									+1/1		+1/1	
Amyris (20)		+1/1		+1/1								
Casimiroa (6)									+2/2		+2/2	
Phellodendron (10)	+1/2								+2/1		+2/1	
Skimmia (10)	+1/1								+2/1		+2/1	
Vepris (20)									+1/1	+1/1		
VI. Citroideae												
Aegle (1)	+4/1								+1/1	+1/1		
Atalantia (20)	+3/2											
Citrus (60)	+25/10	+4/2	+1/1		+2/2		+1/1		+9/14	+2/2	+7/13	+5/3
Clausena (30)	+1/1											
Fortunella (6)									+2/1		+2/1	
Glycosmia (40)									+2/1		+2/1	
Luvunga (12)	+1/1								+1/1		+1/1	
Microcitrus (5)									+2/1		+2/1	
Murraya (9)		+3/2	+1/1	+2/1								+2/1
Poncirus (1)									+4/1		+4/1	
Triphasia (2)												+2/1
SIMAROUBACEAE												
II. Simarouboideae												
Eurycoma (4)									+1/1		+1/1	
Quassia } (40)									+2/1		+2/1	
Simaba } (40)									+2/1		+2/1	
Simarouba } (40)									+5/2		+5/2	
Samadera } (40)									+4/1		+4/1	
Ailanthus (10)									+8/4		+8/4	
Brucea (10-12)												
Castela (12)									+1/1		+1/1	
Perriera (1)									+1/1		+1/1	
BURSERACEAE												
Boswellia (24)	+5/1							+1/1	+1/2		+1/2	
Bursera (100)	+8/2								+1/1		+1/1	
Commiphora (100)	+1/1	+1/1	+1/1					+1/1				
Canarium (75)	+2/1	+4/2					+4/2		+8/4	+2/1	+6/4	
MELIACEAE												
I. Cedreloideae												
Cedrela (7)		+2/1		+2/1				+2/1	+11/ -1/5		+11/ -1/5	
Ptaeroxylon (1)									+1/1	+1/1		
II. Swietenoideae												
Entandrophregma (20)									+6/9		+6/9	
Khaya (10)									+16/5		+16/5	
Pseudocedrela (1)									+5/1		+5/1	
Swietenia (5)									+3/1		+3/1	
III. Melioideae												
Carapa (15)									+6/2		+6/2	
Xylocarpus (5)									+1/1		+1/1	
Turraeanthus (6)									+1/1		+1/1	
Melia (9)								+2/1	+11/2		+11/2	
Aglaia (300)	+3/2	+1/1				+1/1			+1/1		+1/1	
Aphanamixis (22)												
Dysoxylum (100)		+1/1		+1/1								
Guarea (160)									+6/2		+6/2	
Lansium (7)		+2/1	+1/1		+1/1				+1/1		+1/1	
Trichilia (230									+6/4		+6/4	
POLYGALACEAE												
Xanthophyllum (40)									+1/1		+1/1	
Monnina (80)									+1/1		+1/1	
Polygala (500)									+8/4		+8/4	

*Fraction represent numbers of compounds/species

		I. Acridine Group	II. Alkaloid amines	III. Imidazole Group	IV. Indole Group	1. Simple indole base
RUTACEAE						
I. Rutoideae						
Choisya	(7)					
Evodia	(120)	9/2			4/1	
Fagara	(200)		2/6			
Geijera	(7)					
Medicosma	(1)					
Melicope	(50)	4/1				
Orixa	(1)					
Platydesma	(3)					
Pentaceras	(1)				3/1	
Balfourodendron	(1)	1/1				
Lunasia	(10)					
Xanthoxylum	(15)	1/1	1/1		3/3	
Boenninghausenia	(1)					
Dictamnus	(2)					
Ruta	(60)					
Thamnosma	(6)	1/1				
Haplophyllum	(70)					
Boronia	(60)					
Eriostemon	(30)					
Phebalium	(36)					
Geleznowia	(3)					
Cusparia	(25)					
Galipea	(8)					
Pilocarpus	(20)		1/1	4/4		
Ravenia	(18)	1/1				
II.Dictyolomatoideae						
Dictyoloma	(2)				1/1	1/1

TABLE 10

Alkaloids of "Rutales" (see App

IV. Indole Group	1. Simple indole base	2. Carboline alkaloids	3. The Quinazoline carboline	4. Canthin-6-ones	5. The Carbazole group	V. Isoquinoline group	1. 1,1-Benzyliso-quinolines	2. The Aporphine group	3. Protoberberine	4. Protopine group
4/1			4/1			1/1 19/16	1/6	9/8	1/1 2/1	3/1
3/1				3/1						
3/3			2/1	1/2		20/15	1/1	6/8	4/5	3/2
1/1	1/1									

TABLE 10

: "Rutales" (see Appendix VI)*

2. The Aporphine group	3. Protoberberine	4. Protopine group	5. Phthalide-isoquinalines	6. The x-Naphtha-phenanthridines	VI. The Oxazole group	VII. Pyridines	VIII. Pyrrolidines	IX. Quinazolines	X. Quinoline group	1. Simple Quinolones	2. Furoquino-lines	3. Quinolyl-quinuclidines
									4/1		4/1	
	1/1								9/5	1/1	8/4	
9/8	2/1	3/1		4/6					4/4	2/2	2/2	
									4/1		4/1	
									1/1		1/1	
									2/1		2/1	
									8/1		8/1	
									6/1	1/1	5/1	
									13/1	1/1	12/1	
									19/4	5/2	14/4	
6/8	4/5	3/2		6/8					4/3		4/3	
						1/1			1/1		1/1	
									3/2		3/2	
									7/1	3/1	4/1	
									2/1		2/1	
									14/9	2/2	12/9	
									2/1	1/1	1/1	
									2/5		2/5	
									5/1		5/1	
									1/1		1/1	
									2/2	1/1	1/2	
									13/3	13/3		
									1/1		1/1	

TABLE 10 (cont'd.)

		I. Acridine	II. Alkaloid amines	III. Imidazole group	IV. Indole group	1. Simple indole base	2. Carboline alkaloids	3. The Quinaz-oline carboline
RUTACEAE								
III. Flindersioideae								
Chloroxylen	(1)							
Flindersia	(20)							
V. Toddalioideae								
Acronychia	(40)	7/3						
Casimiroa	(6)		1/1	3/1				
Phellodendron	(3)							
Ptelea	(3)							
Skimmia	(10)							
Teclea	(25)	2/2	1/1					
Toddalia	(1)							
Vepris	(20)							
Halfordia	(1)							
Hortia	(10)				4/2			4/2
VI. Citroideae								
Agele	(1)		1/1					
Citrus	(60)		8/5		2/2	2/2		
Clausena	(30)		1/1		1/1			
Glycosmis	(40)	1/1			2/1			
Murraya	(9)				2/1			
Poncirus	(1)							
SIMAROUBACEAE								
II. Simarouboideae								
Picrasma	(17)				3/2			
Picrolemma	(3)							
MALPIGHIACEAE								
Banisteria	(75)				3/1		3/1	
Cabi	(1)				1/1		1/1	
Banisteriopsis	(100)				3/3	2/2	1/1	

*Fraction represent numbers of compounds/species.

IV. Indole group	1. Simple indole base	2. Carboline alkaloids	3. The Quinaz-oline carboline	4. Canthin-6-ones	5. The Carbazole group	V. Isoquinoline group	1. Isoquinoline group	2. The Aporphone group	3. Protoberberine	4.	5. Phthalide-isoquinalines	6. The x-Naphtha-phenanthridines	VI. The Oxazole group	VII. Pyridines
						5/1		1/1	4/1					
						5/1			1/1			4/1		
													4/1	
4/2			4/2											
2/2	2/2					1/2					1/2			
1/1					1/1									
2/1					2/1									
2/1					2/1									
3/2				3/2										
3/1		3/1												
1/1		1/1												
3/3	2/2	1/1												

cies.

1. Isoquinoline group	2. The Aporphone group	3. Protoberberine	4.	5. Phthalide-isoquinalines	6. The x-Naphtha-phenanthridines	VI. The Oxazole group	VII. Pyridines	VIII. Pyrrolidines	IX. Quinazolines	X. Quinoline group	1 Simple Quinolones	2. Furoquinolines	3. Quinolyl-quinuclidines
										1/1		1/1	
										9/13		9/13	
										7/3	1/1	6/3	
										9/1	6/1	3/1	
	1/1	4/1											
										7/3	1/1	6/3	
										3/3		3/3	
										1/3		1/3	
		1/1			4/1					1/1		1/1	
										4/1		4/1	
						4/1							
										5/2	1/1	4/2	
									2/1	3/1		3/1	
				1/2				1/1		3/3	1/1	2/2	
									4/1	2/2		2/2	
										1/1		1/1	
										1/1		1/1	
										1/1		1/1	
										1/1			1/1

DISCUSSION

A. The individual families of "Rutales"

1. Rutaceae

Many chemotaxonomists and phytochemists have intensively investigated the various chemical constituents which may prove useful for taxonomic study of the Rutaceae (e.g. Dreyer's series of "Chemotaxonomy of Rutaceae" (1966-1969)). However, there is still some disagreement as to which genera should belong to this family and which sub-families should be raised to familial rank. Let us first of all discuss the general distribution of substances within the family.

Cigarette and Hot-Water Test -- I-IV. Polyphenolases, as judged by this test, seem to be absent in most species tested but a few are found randomly present among all four sub-families species.

Syringin -- as indicated by the Syringin (1:1 H_2SO_4/H_2O) Test (p.64). Most members of this family are characterized by the absence of syringin. Only one member of the Rutoideae was recorded as being positive with syringin test. A few doubtfully positive species were found in the Rutoideae, Toddalioideae and Citroideae (Aurantioideae). Most of the species did not develop any red colour in the lignified tissue of the treated sections.

Raphides -- are probably absent from all the genera investigated except for a few members of the Rutoideae where they are said to occur in the subtribe Cusparineae. These were not available to us.

The usual correlation of results of Ehrlich, HCl/Methanol, and Leucoanthocyanin tests (p.64) was inconsistent. Many species gave a negative HCl/Methanol result, but a magenta spot in the Ehrlich test, a positive Leucoanthocyanin result, and a non-red reaction in the syringin test (this could indicate presence of leucoanthocyanins in leaves but not in stems).

Aucubin-like substances -- were found to be completely absent from all the plants tested as judged by Ehrlich tests (p. 65)

Cyanogenic glucosides -- were usually absent, too, but one genus -- Boronia (Rutoideae) -- was recorded as having at least two species yielding HCN with HCN (Test A) (p. 70).

Leucoanthocyanins -- using L.A. (Test A) (p.68) our results were more often negative than positive. This is consistent with the findings of Bate-Smith (1957; 1962).

HCl/Methanol test -- results were largely negative. However, it was interesting to find that most of the positive results were correlated with positive Tannin tests; but the reverse is not always true, since tannins were found in some species, as Bate-Smith found (1957) which did not give a positive HCl/Methanol test.

Naphthoquinones -- as judged by the Juglone Test (p.71)--were absent, but most species showed blue fluorescence in the aqueous layer ("Juglone Test C"). These results are consistent with those found in the literature (Table 5 and 7) and with the results of paper chromatography done in our laboratory (Table 4), i.e. coumarins (excluding ellagic acid) occurred in 20 genera of the plants analysed. It should be mentioned here, that although ellagic acid is structurally a coumarin, according to the biogenetic synthesis, it should be considered to be one of the benzoic acids.

Saponin Test A -- results, except for one recorded as doubtfully positive in *Casimiroa edulis* (Toddalioideae) and one doubtfully negative in *Clausena lansium* (Citroideae), were negative. However, Amarasingham *et al.* (1964) found several genera of the Citroideae (Aurantoideae) to contain saponins, and from Table 9, we know Rutoideae, Flindersioideae, and Citroideae to contain triterpenoid saponins and sapogenins.

"Saponin Test B", (NH_3) -- results, from the limited data available, seem to correlate with tannin test A. This is consistent with Gibbs' (MSS) findings.

Terpenoids -- are, except for diterpenoids, widely distributed in Rutaceae (Table 9). To the best of my knowledge, the limonoids (triterpenoids) are characteristic of this family (see also Simaroubaceae, Burseraceae, and Meliaceae).

Alkaloids -- the Rutaceae are possibly the most versatile of all families from the point of view of alkaloid synthesis. At least ten structural classes of alkaloids have been found in Rutaceae (Table 10). Acridine alkaloids are prominent in the family, all but one being derivatives of acridone rather than acridine. However, the most characteristic alkaloids are the furoquinolines such as skimmiamine, which have been found in 56 species of the 30 genera recorded (Appendix VI).

Flavonoids -- in Rutaceae, they show very beautifully the replacement of flavonol by flavone at the generic level (Table 8). There was one exception from Citrus, but only two out of 15 species have been surveyed (Citrus limon and aurantium) which contain both types of compound. Furthermore, in most cases, the flavonols were present together with leucoanthocyanins, and flavonanols; while flavones were present with flavanones. This suggests that they may have evolutionary significance in the family Rutaceae, as probably among the angiosperms generally (Bate-Smith, 1962; Harborne, 1967).

Phenolic acids -- were found to occur widely in Rutaceae (Appendix II). The major compounds included Group I: gentisic acid; Group II: p-coumaric, caffeic, ferulic and sinapic acids; Group IV: ellagic acid. However, this is not completely consistent with Bate-Smith's (1969) idea. He said:

> "The occurrences of these phenolic acids, associated in the cases of caffeic and ellagic acid with the presence of flavonols and flavandiols, and in the cases of ferulic and sinapic acid with their absence, reinforce the indications provided by the flavonoid constituents (I-V) themselves regarding the evolutionary status of particular plants or families, ...".

The genera Flindersia and Chloroxylon, from a botanical viewpoint, have proved difficult for botanists to classify. Scholz (1964) included just these two genera in his third sub-family, Flindersioideae. Our results (Tables 3 and 5) show that there are three possibilities: the two genera may go into Rutaceae; they may go with Cedrela, etc. into Meliaceae (Cedreloideae); or they may constitute a family Flindersiaceae, intermediate between Rutaceae and Meliaceae.

In spite of the fact that Flindersia and Chloroxylon both contain the typical Rutaceous furoquinolines, they do not have the acridine alkaloids which are prominent in the Rutaceae, occurring widely in Rutoideae, Toddalioideae and Citroideae. Simple coumarins and chromano-coumarins, characteristic of the Rutaceae, are known to occur in these two genera, but they are also in three genera of the Meliaceae (Cedrelopsis, Ptaeroxylon and Ekebergia). Flavonoid data show that the Flindersioideae contain only flavonols, whereas the other Rutaceous sub-families (Rutoideae, Toddalioideae and Citroideae) have both flavones and flavonols. Flindissol, isolated from two species of Flindersia, is structurally midway between epoeuphol (a limonoid of the Rutaceae) and the meliacins of the Meliaceae. We feel, therefore, that the chemical evidence supports the placing of Chloroxylon and Flindersia in a small family Flindersiaceae between Rutaceae and Meliaceae.

Should Zanthoxylum and Fagara be maintained as distinct genera? The principal compounds so far isolated from these plants are very closely related alkaloids, coumarins, terpenoids, and even the phenolic aldehydes - parvifloral from (Zanthoxylum) and zanthoxylol (from Fagara). On the other hand, these two genera have completely different types of flavonoids, Fagara has flavone and Xanthoxylum has flavonols. We suggest that these two genera are closely related but distinct.

Is the family Rutaceae homogeneous or heterogeneous? Paris and Etchepare (1968) concluded that it is heterogeneous for flavonoid pigments, since it contains not only flavones and flavonones, but also methylated derivatives, and some with hydroxy-methyl groups and or isoprene chains. On the other hand, Price (1963) has concluded, from the distribution of alkaloids and coumarins in the Rutaceae, that the major sub-families constitute a highly homogeneous group. Later, this conclusion was supported by Dreyer (1966) who found that there was botanically uniform distribution of limonoids throughout the Rutaceae. He said:

> "The uniformity is further emphasized by the fact that structural variation(s) of these limonoids that occur in the Rutaceae are rather slight (excepting flindissol which appears to occur only in a further removed botanical group) .... The homogeneity of the Rutaceae is attested to by the slight structural variation in the limonoids while the clear definition between subfamilies is attested to by the uniform difference in oxidation levels of their limonoids".

On the basis of the still limited data available, this family would be relatively homogeneous if the sub-family Flindersioideae were removed and made a family Flindersiaceae.

2. Cneoraceae

This family (as we have seen) has been assigned to the Rutales, Geraniales, and Sapindales. It also has been made the type of an order Cneorales.

It has only three species belonging to two genera, and all our information is derived from but one of these -- Cneorum tricoccon.

Cigarette and Hot-Water Tests -- III-IV (negative?)

Syringin -- negative, no red in lignified tissue which agrees with the negative Ehrlich, HCl/Methanol and leuco-anthocyanin tests.

Raphides -- absent.

Saponins -- absent.

Naphthoquinones -- presumably absent (negative with Juglone Test A), but blue fluorescence was observed. This is consistent with paper chromatographic results -- which showed that scopoletin is present.

Phenolic Acids -- the major phenolic acids are Group I: gentisic acid; Group II: p-coumaric, caffeic, ferulic and sinapic acids, but no ellagic acid.

Flavonoids -- the presence of flavonols but no flavone, has been reported.

3. Simaroubaceae

As mentioned in the review of literature, many authors have raised the sub-families and even some genera to familial rank. We may, therefore, expect it to be chemically heterogeneous.

Polyphenolases -- as judged by Cigarette and Hot Water Tests, occur in sub-families Picramnioideae, Surianoideae, and probably also in Simarouboideae, but Kirkia acuminata of the Kirkioideae gave a IV (negative) reaction with the hot water test.

Syringin -- appears to be absent from the whole family. Only Suriana gave a red colour in the xylem. These results are consistent with those obtained from the Ehrlich, HCl/Methanol, and leucoanthocyanin tests.

Raphides -- no raphides were seen in the control sections of the syringin test, and none have been reported in the literature, but solitary and cluster crystals (Appendix XI) have been reported. The size and distribution of the cluster crystals in Castela, Holacantha, and Picramnia are said to be of value in the identification of the genera (Metcalfe and Chalk, 1950). Styloids have been reported in one genus -- Alvaradoa.

Naphthoquinones -- as judged by the Juglone test are absent. Blue fluorescence was noted in Simarouboideae and Kirkioideae, but no coumarins have been detected (ellagic acid is not fluorescent).

It was interesting to note, during the course of the Juglone test, that Picramnia pentandra (Picramnioideae) gave a "carmine" colour (Ridgway) in the ammonia layer under visible light. This may be due to the presence of a naphthoquinone, but, following the method of Chen and Bohm (1966), the unknown was compared with authentic samples of juglone, lapachol, lawsone, lematiol, 7-methyl-juglone, plumbagin and dunnione in different kinds of solvents. Unfortunately, this attempt to identify the compound proved unsuccessful.

In "Saponin Test B" (NH_3), Picramnia pentandra also gave immediately a "carmine" colour reaction in the ammonia layer. Could the substance responsible be an aurone?

2,6-Dimethoxy-1,4-benzoquinones have been reported from genera of the Simarouboideae (Ailanthus, Eurycoma, Picrasma and Quassia.). Unfortunately, we have no records from these genera with the Juglone test comparing with genus Picramnia. A specimen of 2,6-dimethoxy-1,4-benzoquinone (from Dr. R. G. Cooke) gave a bluish colour changing to yellow in Juglone Test B.

Tannin tests -- tannins were present in Kirkioideae and Picramnioideae, and this is consistent with the results of "Saponin Test B" (NH_3).

Saponins -- were recorded as probably present in Picramnia pentandra.

Phenolic acids -- the major phenolic acids were: Group I: gallic acid and Group IV: ellagic acid. Compounds of Group III -- p-coumaric, caffeic and ferulic acids were identified in Ailanthus but not in Kirkia.

Flavonoids -- Ailanthus is reported to have flavonols, too. This result is not consistent with the conclusions of Bate-Smith (1969).

Triterpenoids -- have been reported from several genera of this family, especially in the sub-family Simarouboideae. Simarolide is an acetate of a C_{25} compound and its occurrence in the Simaroubaceae (Simarouba amara) may be of biogenetic significance, since the other bitter substances (C_{20} compounds) of this family (quassin, chaparrin, glaucarubin. ... etc.) are closely related. Polonsky (1964) suggested that the biogenetic precursor of simarolide may be a tetracyclic triterpene of the tirucallol or possibly of butyrospermol (Δ^7-euphol) type, and that its biogenesis might then follow the path proposed for limonin and lead later to the basic skeleton of simarolide. Therefore, Simaroubaceae may have affinity with Rutaceae in this context.

Alkaloids -- have been reported in 50% of the species tested (Appendix VIII), but only two classes of alkaloids, indole and quinoline, are known to occur in this family.

Fatty Acids -- the fatty acid composition of the seeds is interesting. Shorland (1963) stated that:

> "the members of the family Simaroubaceae thus show such wide variation in composition of their seed fats as to prompt further inquiry into their botanical classification".

We have the following:

Genus	Chief Fatty Acids
Ailanthus	Oleic, linoleic
Picrasma	petroselinic
Picramnia	tariric
Irvingia	myristic, lauric

These four genera are distributed among three sub-families. Each contains a different major fatty acid.

Chemical evidence would seem to support the view, that the Picramnioideae should be excluded from the Simaroubaceae. The presence of myristic and lauric acids in Irvingia and other genera, links this family with Vochysiaceae.

4. Picrodendraceae

This family is treated by Scholz as having Picrodendron only with 3 spp. Airy Shaw (in Willis, 1966) includes 5 other genera from the Euphorbiaceae of which we know nothing.

The information below comes from Picrodendeon baccatum only (Gibbs, MSS).

Cigarette & H.W. Tests -- IV
Syringin-- -ve (red in xylem; no raphides).
HCl/Methanol Test -- positive (2-3) consistent with red in xylem in syringin test (above) and magenta in Ehrlich test (below).

Ehrlich Test -- negative (Ehrlich spot magenta)

Juglone Tests -- -ve, but with blue fluorescence.

Cyanogenic Glycosides -- absent? (negative result with HCN Test A).

Tannins, flavonoids, alkaloids and saponins may be absent (Table 2).

5. Burseraceae

This family is said to have affinities with Anacardiaceae, Meliaceae, Rutaceae, and Simaroubaceae.

Few members of this family were available to us for testing.

Cigarette and Hot-Water Tests -- II-III

Syringin (1:1 H_2SO_4/H_2O) Test -- Syringin appears to be absent, red color was seen in xylem of *Commiphora trothai*.

Raphides -- No raphides were seen, nor have they been recorded by others; however, solitary and cluster crystals were found in this family by Metcalfe and Chalk (1950).

Juglone Tests -- negative results from Juglone Test A suggest that naphthoquinones are absent. Blue fluorescence was observed in *Commiphora* and *Pachylobus*.

HCN Test A -- results negative, suggesting absence of cyanogenic glycosides.

Tannin Test A -- the leaf of *Commiphora merkeri* gave a strong positive result (+++) with tannin test A.

Phenolic acids -- members of this family are known to contain gallic, *p*-coumaric, caffeic, and ellagic acids. According to Bate-Smith (1969), these results might suggest that flavonols should be present in this family, and in fact *Protium* is reported to have flavonol (Bate-Smith, 1962). We have no other information on this point.

Terpenoids -- are widely present in this family. *Diterpenoids*, as in *Meliaceae*, are present. Acetates of triterpenes -- derivatives of *euphone* and *elemane*, which occur in *Rutaceae*, *Meliaceae* and *Simaroubaceae*, are found in *Burseraceae*, too (Ponsinet *et al.*, 1968).

Alkaloids -- have been reported in 20% of the plants tested.

The chemical evidence above, and the reported presence of stearic acid as a major fatty acid of the seeds, links this family with the Meliaceae.

6. Meliaceae

As discussed in the review of literature there is no general agreement as to which genera should belong to this family, which sub-families should be raised to familial rank and which families it should be allied with. Hutchinson (1969) further complicated things by making this family the sole member of its order.

Cigarette and Hot-Water Tests -- variable, I-IV.

Syringin test -- only negative results were obtained. The majority of species showed some red colour in the xylem and/or fibres. These results are consistent with those obtained from the Ehrlich, HCl/Methanol, and leucoanthocyanin tests.

Tannin Test -- results were mostly positive and agreed with positive results of HCl/Methanol tests.

"Saponin Test B" (NH_3) -- the few results were mostly consistent with the results of the tannin test.

Raphides -- appeared to be absent,

Cyanogenic Glycosides .. except for Dysoxylum fraseranum (Melioideae), all species investigated contained no cyanogenic glycosides.

ob

Saponin Test A -- Amarasingham et al. (1964) found the majority to give a negative result, but Chisocheton and Dysoxylum of the Melioideae gave positive tests.

Juglone Tests -- results were negative, but blue fluorescence was observed. So far, however, coumarins are known only from three genera belonging to Cedreloideae (Cedrelopsis and Ptaeroxylon) and Melioideae (Ekebergia). These two sub-families, again, were reported to contain flavonols but no flavones.

Terpenoids -- Diterpenoids, to the best of my knowledge, have been isolated, in the Rutales, only from two genera of the Burseraceae and from Cedrela (Cedreloideae), Melia and Aphanomyxis (both of Melioideae). Triterpenoids occur here, as in the Rutaceae, Simaroubaceae, and Burseraceae. Dreyer (1966) wrote:

> "Limonoids have been found in genera belonging to each of the three subfamilies of Meliaceae but in this case there seems to be no general correlation between the limonoid structure and the botanical distribution within the family. ... The known compounds of this series in the Meliaceae show, in general, much wider structural variation than those in Rutaceae. These variants range from members whose position is fairly low on the biogenetic ladder, such as, gedunin, cedrelone, and anthothecol, to those with extensive structural alterations, for example, andirobin, swietenine, nimbin, mexicanolide and methyl angolensate".

However, recently, three structurally close relatives of flindissol -- aphanomixin, melianone and turraeanthin -- were isolated from the Melioideae. These seem to be useful as taxonomic markers on a sub-family level and perhaps even as phylogenetic markers for the whole family, as in Rutaceae.

Alkaloids -- are said to be present in 40% of the plants tested (Li and Willaman, 1968).

The monotypic genus *Ptaeroxylon*, which has given great difficulty to systematists, has been variously placed in *Sapindaceae*, *Rutaceae* and *Meliaceae*, but it is now considered to form (with *Cedrelopsis*) a separate family, the *Ptaeroxylaceae*. Its chemistry has recently been shown to be distinct from the usual pattern both of the *Meliaceae* and the *Rutaceae* (e.g. absence of degraded *triterpenes* in the timber), and in the remarkable range of *chromones*, and some unusual *coumarins*. The results of our simple tests (Appendix I) strongly support this new classification. Unfortunately we did not have *Cedrelopsis*.

Cedrelopsis and *Ptaeroxylon* both contain *coumarins* and *ptaeroxylin* which has an unusual seven-membered ring-structure not encountered elsewhere. There would thus seem to be good evidence for removing *Cedrelopsis* with *Ptaeroxylon* into the new family, *Ptaeroxylaceae*.

The sub-family *Swietenioideae*, in many ways, seems chemically to be very distinct from the *Cedreloideae* and *Melioideae*, as it is on the basis of its anatomy and morphology. However, it is unsafe to draw definite taxonomic conclusions at this junction.

7. *Akaniaceae*

Although many authors placed this family in the *Sapindales*, Scholz considered it to be a family of the *Rutales*. The sole member is *Akania hillii* and Gibbs (MSS) obtained most of the following results.

Cigarette and hot-water tests -- II.

Syringin Test 4:1 H_2SO_4/H_2O) -- negative, but a red color was present in the lignified tissues. Correspondly, it gave positive HCl/Methanol and leucoanthocyanin results. The positive HCl/Methanol result was also consistent with positive tannin tests.

HCN Test A -- doubtfully positive reaction was obtained.

Raphides -- no raphides present.

Juglone Tests -- negative, suggesting that naphthoquinones are absent; but blue fluorescence was observed.

Phenolic Acids -- the major phenolic acids according to Galang (thesis, unpub'd. Material described as "*A. lucens*") are: gentisic, *p*-coumaric, caffeic, ferulic and ellagic, but Bate-Smith (1962) lists of these only *p*-coumaric as present in "*A. hillii*". Are these, in fact, the same plant?

Alkaloids -- are present in this family (Appendix VIII).

More information is required, and particularly, knowledge about terpenoids and flavonoids, before the affinities of this family can be decided.

8. Malpighiaceae

Only Scholz (1964) placed this family in Rutales. If it is properly placed by him it should have many chemical characteristics in common with the Rutaceae.

Cigarette and Hot-Water Tests -- mostly IV, but *Stigmaphyllon tomentosum* was recorded as I.

Syringin Test (1:1 H_2SO_4/H_2O) -- all plants gave a negative syringin test, but in contrast to Rutaceae, the majority of the species showed some red colour in the lignified tissue. These results correlated with those obtained with leucoanthocyanin, HCl/Methanol, and Ehrlich tests.

HCN Test A -- the majority of the plants seem to contain no cyanogenic substances. Heteropterys (2 spp.) gave doubtfully positive results with HCN (Test A).

Raphides -- are absent from the species investigated.

Tannin Test A -- most of the few plants tested were tanniniferous. Thus results were consistent with "Saponin Test B" (NH_3) and also some of the results correlated with positive HCl/Methanol tests.

Juglone Tests -- were negative, so naphthoquinones probably are absent. Blue fluorescence was observed. This is in keeping with the finding that umbelliferone is present in Malpighia (paper chromatography),

Phenolic Acids, etc. -- major phenolic acids are: gentisic, p-coumaric, caffeic, ferulic and ellagic.

Flavonoids -- two classes of flavonoids, leucoanthocyanins and flavonols, have been found in this family.

Alkaloids -- of indole type are reported to occur in Malpighiaceae.

9. Trigoniaceae

No material of this family was available to us, and we have found no information as to its chemistry from the literature.

10. Vochysiaceae

Very little information was found in the literature as to the chemistry of this family. Fortunately, two species were available for investigation.

HCl/Methanol Tests -- gave one strong positive result (Vochysia) and one negative (Salvertia).

Juglone Tests -- naphthoquinones seem to be absent and no blue fluorescence was observed.

Raphides -- none have been reported, but solitary and cluster crystals have been seen (Appendix XI).

Fatty Acids -- we learn from the literature that the major fatty acids of the seeds are myristic and lauric acids. Many genera of the Simaroubaceae also contain these two acids.

11. Tremandraceae

This family has been placed in various positions. The relationships of this family to others remains unestablished.

A few species belonging to two genera, Tetratheca and Platytheca, were tested by Gibbs (unpub'd.)

Cigarette and Hot-Water Test -- IV for 4 spp. of Tetratheca.

Syringin Test (1:1 H_2SO_4/H_2O) -- negative results were obtained. A red colour has been seen only in Tetratheca. These results correlate with those obtained for the related tests.

Raphides -- no raphides were seen in the Syringin Test Controls. Solitary and cluster crystals have been reported to occur.

HCN Test A -- Gibbs got positive HCN Test A results for Platytheca and one species of Tetratheca.

Juglone Tests -- naphthoquinones seem to be absent. Blue fluorescence was recorded.

Tannins -- doubtfully present (Galang, thesis, unpub'd.)

HCl/Methanol Test -- positive (1-4) in all tested.

12. Polygalaceae

The Polygalaceae is said to be a very natural family. Many genera, however, such as Xanthophyllum, Krameria, and Diclidanthera have been doubtfully placed in this family. Unfortunately, material of these genera were not available for investigation.

Cigarette and Hot-Water Tests -- were recorded as IV for Polygala, but as II-III for Mundtia.

Syringin Test -- the species of Polygala tested gave negative with no red reactions in the lignified tissue.

Ehrlich Test -- Polygala negative. Mundtia negative (but a magenta Ehrlich spot).

HCl/Methanol Test -- Polygala and Securidaca negative. Mundtia positive (2).

Tannin Test A -- Polygala negative; Mundtia positive (++).

Leucoanthocyanin Test -- Polygala negative; Mundtia positive.

Juglone Tests -- Polygala negative (some fluorescence); Securidaca negative; Mundtia positive.

Cyanogenic Glycosides -- as judged by HCN Test A -- seem to be absent.

Saponins -- have been recorded in some species. Amarasingham *et al.* (1964) reported that one species of *Xanthophyllum* contains saponin. Four genera (*Xanthophyllum*, *Monnina*, *Bredemeyera* and *Polygala*) are reported to contain triterpenoid saponins and sapogenins. Two tests made by us with *Saponin Test A* were recorded as negative or doubtfully positive.

Raphides -- none have been recorded or observed by us.

Flavonoids -- many species of *Polygala* are reported to have *flavonols*.

Phenolic Acids -- the major phenolic acids appear to be gentisic, *p*-coumaric, caffeic, and ferulic.

Alkaloids -- are said to be present in 50% of the species tested, but none have been identified.

Mundtia spinosa, on the basis of the chemical evidence, seems to be out of place in this family, but there is the possibility that our material was wrongly labelled. Obviously this should be checked. Obviously, too, we need to know much more about the family as a whole.

B. The order Rutales

This is obviously a very diverse and unnatural order. Thus the chemical reactions and other results obtained were mixed (Table 2,3,4,and 5).

Polyphenolases (as judged from Cig. & H.W. Tests) were present in *Akaniaceae*; absent from both *Picrodendraceae* and *Tremandraceae*; but mixed results were obtained from members of the other families.

Except for one subtribe (Cusparineae) of the Rutaceae, raphides as well as syringin are absent. Other calcium oxalate crystals, for example, the widely distributed solitary and cluster crystals, are present. These crystals varied in their distribution, and are possibly familial rather than ordinal characters. In the syringin test, the presence or absence of a red colour in lignified tissues was mixed. Some families usually showed no red while others usually did so.

The results of HCl/Methanol tests were mixed. In most families, the majority of the species were positive in their response. The results were usually closely correlated with the red or magenta colours in syringin, leucoanthocyanin and Ehrlich tests. But, as previously mentioned, this correlation failed in the Rutaceae. The positive results of the HCl/Methanol test were also consistent with positive tannin tests in most of the plants tested.

Mixed results were obtained for the tannin test. Many were positive. These results were also correlated with those of "Saponin Test B"(NH_3).

Saponins -- as judged from Saponin Test A were generally absent, being present only in a few members of the Meliaceae. However, from the literature reported, there are saponins in Polygalaceae, Meliaceae, Rutaceae, and Burseraceae.

HCN was absent from or rare in most families. Boronia (Rutaceae), Platytheca and Tetratheca (Tremandraceae) appear to contain cyanogenic glycosides. Three further genera Dysoxylum (Meliaceae), Akania (Akaniaceae) and Heteropterys (Malpighiaceae) gave doubtfully positive HCN Test A results. Obviously more testing is needed.

The sole positive Juglone test was obtained in the case of Mundtia spinosa (Polygalaceae) but see above. Naphthoquinones seem to be absent from all families. Some blue fluorescence was observed in most of the families investigated (not in Cneoraceae and Vochysiaceae). Paper chromatographic results, however, showed that coumarins (excluding ellagic acid)(Table 4) are present in Rutaceae, Meliaceae, Malpighiaceae, and strikingly enough also in Cneoraceae. From the literature, we have reports of their occurrence only in Rutaceae and Meliaceae.

The number of triterpenes characteristic of members of the Rutales is forever increasing. The biogenetic and close structural relationships of elemolic acid, the limonoids and the simaroubolides parallel the close taxonomic relationships of the Rutaceae, Burseraceae and Meliaceae with the Simaroubaceae. In these four families other terpenoids also occur widely.

Flavonoids, especially the flavonols, are also widely spread in most families of the Rutales. The co-occurrence of flavons and flavanones has been found only in Rutaceae. This family also shows the replacement of flavones by flavonols.

Some of the families are alkaloid-containing, especially the family Rutaceae. However, there are no recorded alkaloids from Cneoraceae, Picrodendraceae, Trigoniaceae and Vochysiaceae, families which have been little investigated.

15

The fatty-acid compositions of the seeds vary, but those of the Simaroubaceae and Vochysiaceae are similar, and so are those of the Burseraceae and Meliaceae. This could link them taxonomically.

Group II phenolic constituents were rarely found in the families. The other compounds of Group I and III were found in varying degrees. While ellagic acid was very widely distributed in the families of this order.

SUMMARY AND CONCLUSION

The Rutales seems to be a homogeneous order, if we consider it to contain the families Rutaceae, Simaroubaceae, Burseraceae and Meliaceae. These appear to be correctly grouped by Scholz in his suborder Rutineae. We are less sure about the correctness of placing of the remaining families of his suborder, the Cneoraceae, Picrodendraceae, and Akaniaceae.

We know too little as yet of the chemistry of the Trigoniaceae and Vochysiaceae to say whether or not they constitute with the Malpighiaceae a homogeneous group (Scholz's Malpighiineae) within the Rutales. The chemistry of the Malpighiaceae, however, is consistent with a position near the Meliaceae.

The two families Tremandraceae and Polygalaceae (Scholz's suborder Polygalineae) seem to differ greatly from each other in their chemistry, but the inclusion of Mundtia (see above) contributes to this. We do not feel in a position, at this stage of our knowledge, to pass judgement on the placing of these families.

There are some systematists who would have the chemotaxonomist deposit in a herbarium a voucher specimen of every plant tested. This is not practicable in extensive investigations, but it would obviously be very worth while to have a voucher specimen of the "Mundtia spinosa" referred to above, for comparison with any later material that becomes available. Unfortunately we do not have this.

The creation of two more small families Flindersiaceae (Flindersia and Chloroxylon) and Ptaeroxylaceae (Ptaeroxylon and Cedrelopsis) is supported by chemical evidence. They should be placed, perhaps, between Rutaceae and Meliaceae.

The data also support the separation of Picramnia (Picramnioideae) from the Simaroubaceae; Mundtia (if our material was genuine) from the Polygalaceae; and Fagara from Zanthoxylum.

Appendix I A list c

	H.W. I	II	III	IV	Or	Cig. I	II	III
RUTACEAE								
I. Rutoideae								
Zanthoxylum americanum	+					+		
Zanthoxylum martinicence	+							
Zanthoxylum simulans								
Evodia Danielli								
Evodia Henryi	+							
Evodia micrococea				+				
Orixa japonica								
Malicopa ternata				+				
Ruta Bracteosa				+				
Ruta chalepensis				+				
Ruta graveolens				+				
Dictamnus albus				+				
Dictamnus albus var. *turkestanicus*			III-IV					
Cneoridium dumosum				+				
Boronia denticulata					+?			
Boronia lanagmusa?								
Boronia pinnata				+				
Boronia purdiana								
Boronia viminea					+?			
Eriostemon spicatum								
Eriostemon myoporoides	+							
Phebalium billordierii				+?				
Phebalium phylicifolium		+						
Crowea dentata				+				
Correa harrisii								+?
Correa laurenciana								
Correa turnbullii								
Diplolaena angustifolia			+?					
Calodendron capense				+				
Barosma Scoparia				+				
Diosma appositifolia								
Pilocarpus pennatifolius				+				
Erythrochiton brasiliensis			III?-IV					
II. Dictyolomatoideae								
III. Flindersioideae								
Flindersia australis	I-II							
IV. Spathelioideae								
V. Toddalioideae								
Phellodendron amurense		II-III				+		
Phellodendron japonicum								
Phellodendron lavallei		II-III						
Phellodendron sachalinense	+							
Ptelea trifoliata				+				
Oricia eurynnertonii								
Acronychia imperforata		II-III		+				
Acronychia suberosa								
Skimmia foremanii					+?			
Skimmia japonica				+				
Teclea simplicifolia				+				
Casimiroa edulis	I-II							

Appendix I A list of all plants tested (by the writer, Gibbs and others)

			Cig.											Jug.	
I	IV	Or	I	II	III	IV	Or	Syr.	Rap.	Ehr.	HCN	HCl/M	L.A.	A	B
			+					-NR	-			-	-	-	+Y
												-		-	+PY
								-NR	-			-		-	-
								-NR	-			-		-	-
								-NR	-	-Y	-	-	-	-	-
	+										-	+1	++		
								-NR	-		-	-		-	-
	+							-NR	-	-Y	-	-	-	-	+PY
	+							-NR	-	-GY	-	-	-	-	-
	+					+		-NR	-	-GY	-	-	-	-	-
	+							-NR	-		-	-	-	-	+PY
	+					+							-		
								-NR	-		-	-	-	-	-
I-IV								-R		-OB	-				
	+								-	-M	-	+3	+	-	-
		+?						-NR	-	-M	+	-?	+	-	
								-NR	-	-M	-	-?	+	-	
	+							-NR	-	-M	-	+1			
								-R	-	-M	-	+3	+	-	
		+?						-NR	-	-M	+	+3	+	-	
								-NR	-	-M		-	+	-	
								-NR	-	-M		-	+		
	+?											-		-	-PY
								-R	-			-			
	+							-NR	-	-DM	-	-			
					+?									-	-BY
											-				
								+?R		-DM	-	-			
?								-NR	-	-G	-	-	-	-	
	+							-R	-	-Y	-	-?	-	-	
	+							-NR	-	-M	-	-	+	-	+Y
												-			
	+							-NR	-	-Y	-	-	-	-	+Y
I?-IV								+	+	-M		-	+	-	
								-R	-	-M	-	+2-3	+	-	-
I			+					-R	-	-PY	-	-?	-	-	-
								-NR	-			-		-	+Y
I								-R	-	-Y	-	-	-		+PY
								-NR	-	-PkB		-	+?		
	+					+		-NR	-C			-	-	-	
												+3			
I	+											+1			
												+2			
		+?						-NR	-	-Y	-	-	-	-	
	+					+						-	-		
	+							-R	-	-M	-	+4	+?	-	
								-NR	-	-Y	-	-	-	-	+Y

tested (by the writer, Gibbs and others)

.	Rap.	Ehr.	HCN	HCl/M	L.A.	Jug. A	B	C	T.T.	S.T.A.	S.T.B.
NR	–			–	–	–	+Y	+	+		
				–		–	+PY	+			
NR	–			–		–	–	+			
NR	–			–		–	–	+			
NR	–	–Y	–	–	–	–	–	+			
			–	+1	++				+		
NR	–		–	–		–	–	++	tr.		
NR	–	–Y	–	–	–	–	+PY	+	–	–	0
NR	–	–GY	–	–	–	–	–	++	–	–	0
NR	–	–GY	–	–	–	–	–	++	–	–	0
NR	–		–	–	–	–	+PY	+	–	–	0
					–						
NR	–		–	–	–	–	–	++	+		
R		–OB	–								
	–	–M	–	+3	+	–	–	–	+++	–	1
NR	–	–M	+	–?	+	–		++	+		
NR	–	–M	–	–?	+	–		+	+		
NR	–	–M	–	+1						–	
R	–	–M	–	+3	+	–		++	tr.		
NR	–	–M	+	+3	+	–		++	tr.		
NR	–	–M		–	+	–		+++	+++		
NR	–	–M		–	+				+		
				–		–	–PY	+			
R	–			–							
NR	–	–DM	–	–							
						–	–BY	+			
			–								
PR		–DM	–	–							
NR	–	–G	–	–	–	–		+++	–		
R	–	–Y	–	–?	–	–		+	–		
NR	–	–M	–	–	+	–	+Y	–	+++	–	2
				–							
NR	–	–Y	–	–	–	–	+Y	+	+?	–	0
+	+	–M		–	+	–		+	++?		
R	–	–M	–	+2–3	+	–	–	+	+++	–	0
R	–	–PY	–	–?	–	–	–	–	++	–	0
NR	–			–		–	+Y	–		–	0
R	–	–Y	–	–	–		+PY	–	++	–	0
NR	–	–PkB		–	+?						
NR	–C			–	–	–		+++	+	–	0
				+3							
				+1						–	
				+2						–	
NR	–	–Y	–	–	–	–		+++	–		
				–	–				–		
R	–	–M	–	+4	+?	–		+	tr.		
NR	–	–Y	–	–	–	–	+Y	+	+	+?	1

Appendix I (cont'd.)

	H.W. I	H.W. II	H.W. III	H.W. IV	H.W. Or	Cig. I	Cig. II	Cig. III	Cig. IV	Cig. Or
RUTACEAE (cont'd.)										
VI. Citroideae (Aurantioideae)										
Glycomis pentaphylla				+						
Murraya exotica				+					+	
Murraya koenigii	I-II									
Murraya paniculata				+						
Clausena lansuim		II-III								
Clausena lumulata	I-II									
Atalantia ceylaniea				+				III-IV		
Poncirus trifolia										
Citrus aurantifolia				+					+	
Citrus Limetta				+					+	
Citrus limoxia				+						
Citrus mascina				+					+	
Citrus medica				+					+	
Citrus nobilis				+						
Citrus simensis				+						
Citrus sp. ("otasheite orange")				+						
Aegle marmelosa	I						II-III			
Fortunella margarita				+						
Triphasia trifolia				+						
VII. Rhabdodendroideae										
Rhabdodendron										
CNEORACEAE										
Cneorum tricoccon			III-IV							
SIMAROUBACEAE										
I. Surianoideae										
Suriana maritima		+								
II. Simarouboideae										
Hannoa klaineana										
Ailanthus altissima		II-III							+	
III. Kirkioideae										
Kirkia acuminata				+						
IV. Irvingioideae										
V. Picramnioideae										
Picramnia pentandra	+									
VI. Alvaradoideae										
PICRODENDRACEAE										
Picrodendron baccatum				+						
BURSERACEAE										
Bursera simarouba										
Bursera simplifolia			+							
Commiphora merkeri		II-III								
Commiphora trothai										
Pachylobus klaineana										
MELIACEAE										
I. Cedreloideae										
Cedrela odorata			III or IV							
Toona ciliata				+						+
Ptaeroxylon obliquum	+									
II. Swietenioideae										
Khaya nyasica										
Entandrophragma candatum				+						
Swietenia mahogni	I-II									

IV	Or	Syr.	Rap.	Ehr.	HCN	HCl/M	L.A.	Jug. A	B	C	T.T.	S.T.A	S.T.B.
		-NR	-	-G	-	+4	-	-	-	-	-	-	0
+		-R?	-	-Y	-	-	-	-	+Y	+	-	-	0
		-NR	-	-YB	-	-	-	-	-	-	++	-	0
			-	-GB	-	-	-	-	+	+	-		
		-R	-	-GB	-	+1	-?	-	-	+	++	-?	1
		-R	-	-GB	-	+3	+	-	+Y	-	++	-	1
-IV		-PK	-	-YB	-	-	-	-	-	-	-	-	0
		-NR	-			-		-	+	+			
+		-NR	-	-Y	-	-	-	-	+Y	+	-?	-	0
+		-NR	-	-PkY	-	+1?		-	-	+	-?		
		-NR	-	-Y	-	-	-	-		+	-		
+													
+													
		-NR	-	-Pk	-	+1?	-	-	+Y	+	-?	-	0
		-NR	-	-Y	-	-	+	-	-	-	-?	-	0
		-NR	-	-Y	-	-		-	-	+	-?	-	0
		[illegible]								+			
		-NR	-	-M	-	-	++	-	+Y	+	++		
		-NR	-	-Y	-	-	-	-	+Y	-	-	-	1
		-NR	-	-GY	-	-	-	-	+Y	-	-	-	0
		-NR	-	-M	-			-		-			
		-NR	-	-Y	-	-	-	-	+	-	-	-	0
		-R	-	-M	-	+4		-	-	-		-	
		-PK	-			-		-		+			
+		-NR	-	-Y	-	-	-	-		+			
		-NR	-	-Y	-		-	-		+	+++?	-	
		-NR	-	-Y	-	-	-	-	-	-	+	+?	4
		-R	-	-M	-	+2		-	-PY	+			
						+4		-	-	-			
						+2		-	-	-			
		-NR	-		-		-	-		+	+++?		
		-R	-			+4		-		+			
		-NR	-			-		-		+			
					-	+4	-						
	+	-R	-	-M	-	+3	+	-		++	tr.		
		-NR	-	-B	-	-	-	-		+	-		
						+3		-	-	-			
		-R	-	-M	-		+				++	-	+3
		-R	-	-M	-	+4	+	-	-	+?	+++	-	+4

Appendix I (cont'd.)

	H.W. I	II	III	IV	Or	Cig. I	II	III	IV	Or
MELIACEAE (cont'd.)										
III. Melioideae										
Carapa guianensis	+									
Carapa procera	+									
Cipadessa cinerascens				+						
Melia azodaroch				+				III-IV		
Trichilia emetica										
Dysoxylum fraseranum	+									
Dysoxylum spectabile	+									
AKANIACEAE										
Akania hillii		+								
MALPIGHIACEAE										
Hiptage benghalensis										
Tristellateia australasiae				+?					+?	
Heteropterys chrysophylla										
Heteropterys umbellata					+?					
Malpighia coccipera				+						
Malpighia cubensis				+						
Malpighia glabra			III-IV							
Malpighia punicifolia										
Byrsonima crassifolic										
Stigmaphyllon ledifolium										
Thryallis glauca										
Stigmaphyllon ciliatum				+						
Stigmaphyllon tomentosum	+									
TRIGONIACEAE										
VOCHYSIACEAE										
Vochysia sp.										
Salvertia convalloriodora										
TREMANDRACEAE										
Platytheca verticilliata										
Tetratheca ericifolia				+						
Tetratheca pilosa										
Tetratheca setigera				+						
Tetratheca thymifolia				+						
Tetratheca viminoa				+						
POLYGALACEAE										
Polygala capitata										
Polygala dalmaisiana				+						
Polygala myrtifolia			III-IV					III-IV		
Polygala sanguinea										
Polygala senega				+						
Polygala virgata										
Securidaca diversifolia										
Mundtia spinosa		II-III								

Key to symbols:

NR = no red
R = red
PK = pink
C = crystals
Y = yellow
Gy = green-yellow
PY = pale-yellow
BY = brown-yellow
B = brown
OB = orange-brown
YB = yellow-brown
GB = green-brown
PKB = pink-brown
M = magenta
DM = dull magenta
tr = trace

IV Or	Syr.	Rap.	Ehr.	HCN	HCl/M	L.A.	Jug. A	B	C	T.T.	S.T.A.	S.T.B.
	-R	-	-M	-	+4	+	-		+	+++		
	-R	-	-M	-	+	+	-		+	+++		
	-NR	-	-M	-	+3	+	-	-	+	++	-	0
I-IV	-NR	-	-Y	-	-	-	-	-	+	-	-	0
					+2							
				+?	+2		-	-PY	+		-	
			-YG		+3							
	-R	-		+?	+1-2	+	-	-	+	+++		
					+4		-	-	-			
+?	-NR	-		-	-		-		+	tr.		
	-NR	-		+?	-							
	-NR	-	-Y	+?	+4	-	-	+Y	-	-	-	0
	-R	-	-M	-	+4	+	-	-	-	+?	-	1
	-R	-	-M	-	+4	+	-	-	-	+++	-	4
	-R	-	-M	-	-?	+?	-		+	-		
	-R				+1							
	-R	-			+4							
					+4		-	+Y	-			
					+4		-	-	-			
	-R	-	-M	-	+1	+	-	-	-	+++	-	4
	-R	-	-M	-	+4	+	-	-	-	+++	-	3
					+4		-	-	-			
					-		-	-	-			
	-NR	-	-Y	+	+1	-	-	-	+	+?		
	-R	-			+3							
				+	+4							
	-R	-	-M	-	+4							
	-R	-		-	+4					+?		
			-M	-								
	-NR	-			-							
	-NR	-	-Y	-	-		-	+Y	-	-	-	1
II-IV	-NR	-	-B	-	-	-	-		-			
	-NR	-	-Y									
	-NR	-	-Y	-		-						
				-			-		+		-?	0
					-		-	+Y	-			
			-M	-	+2	+	+		tr?	++		

APPENDIX II

Key to a list of phenolic acids and coumarins:

I. Benzoic acids (C_6-C_1)

1. p-Hydroxybenzoic
2. 2,3-Dihydroxybenzoic (6-pyrocatechuic)
3. 3,4-Dihydroxybenzoic (protocatechuic)
4. 2,5-Dihydroxybenzoic (gentisic)
5. 2-Hydroxy-5-methoxy-benzoic
6. 2-Hydroxy-6-methoxy-benzoic
7. 2-Hydroxy-3-methoxy-benzoic
8. 4-Hydroxy-3-methoxy-benzoic (vanillic)
9. 4-Hydroxy-3,5-dimethoxybenzoic (syringic)
10. 3,4,5-Trihydroxy-benzoic (gallic)

II. Phenylacetic acids (C_6-C_2)

1. p-Hydroxyphenylacetic
2. o-Hydroxyphenylacetic
3. 3-methoxy-4-hydroxy-mandelic

III. Cinnamic acids (C_6-C_3)

1. o-Hydroxycinnamic (o-coumaric)
2. p-Hydroxycinnamic (p-coumarin)
3. 3,4-Dihydroxycinnamic (caffeic)
4. 4-Hydroxy-3-methoxycinnamic (ferulic)
5. 4-Hydroxy-3,5-dimethoxycinnamic (sinapic)
6. o-Hydroxydihydrocinnamic (melilotic)
7. p-Hydrodihydrocinnamic (phloretic)
8. 2,3-Dihydroxycinnamic
9. 2-Hydroxy-3-methoxycinnamic
10. 2,3-Dihydroxy-phenyl-proprionic
11. p-Hydroxy-phenyllactic

IV. Coumarins

1. Ellagic
2. Umbelliferone
3. Aesculetin
4. Scopoletin

Appendix II (cont'd.)

	I										II			III								
	1	2	3	4	5	6	7	8	9	10	1	2	3	1	2	3	4	5	6	7	8	9
CNEORACEAE																						
Cneorum tricoccon	-	-	-	+	-	-	-	-	-	-	-	-	-	+	++	++	+	++	-	-	-	-
SIMAROUBACEAE																						
Ailanthus altissima	-	-	-	-	-	-	-	-	-	+	-	-	-	-	+	+++	++	-	Tr	-	-	-
Kirkia acuminata	-	-	-	+?	-	-	-	-	Tr	+++	-	-	-	-	-	Tr	-	-	-	-	-	-
PICRODENDRACEAE																						
BURSERACEAE																						
Commiphora merkeri	-	-	-	-	-	-	-	-	-	+	-	-	-	-	+	++	Tr	-	-	-	-	-
MELIACEAE																						
Ptaeroxylon obliquum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+++	-	+?	-	-	-
Khaya nyasica	-	-	-	+?	-	-	-	-	-	+?	-	-	-	-	+	+	+	-	-	-	-	-
Swietenia macrophylla	+	-	+	+	-	-	-	+	-	+	+	-	-	-	++	++	+	+	-	-	-	-
Carapa guianensis	-	-	-	+	-	-	-	-	-	-	-	-	-	-	+	+	Tr?	-	-	-	-	-
Carapa procera	-	-	-	-	-	-	-	Tr?	Tr?	Tr	-	-	-	-	-	+++	Tr	-	Tr	-	-	-
Cipadessa cinerascens	-	-	-	+?	-	-	-	-	+	-	-	-	-	-	+	+	Tr	-	+?	-	-	-
Melia azedarach	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Tr?	+	+	-	+	-	-	-
AKANIACEAE																						
Akania lucens	+?	-	-	+	-	-	-	Tr?	-	-	-	-	-	-	++	+	+	-	-	-	-	-
MALPIGHIACEAE																						
Gaudichaudia cyananchoides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	Tr?	-	-	-	-	-
Malpighia coccigera	+	-	-	+	-	-	-	-	+	-	-	-	-	-	+	+	+	+	-	-	-	-
Malpighia cubensis	-	-	-	Tr?	-	-	-	-	-	+?	-	-	-	-	-	+	Tr?	-	+	-	-	-
TRIGONIACEAE																						
VOCHYSIACEAE																						
TREMANDRACEAE																						
Platytheca verticilliata	-	-	-	-	-	-	-	+	Tr?	+++	-	-	-	-	+	+?	Tr?	-	+?	-	-	-
Tetratheca thymifolia	-	-	-	-	-	-	-	-	-	+	-	-	-	-	+	-	-	-	-	-	-	-
POLYGALACEAE																						
Polygala myrtifolia	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	+	Tr?	+	-	-	-	-

	I						II			III											IV			
	5	6	7	8	9	10	1	2	3	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4
	-	-	-	-	-	-	-	-	-	+	++	++	+	++	-	-	-	-	-	-	-	-	-	+
	-	-	-	-	-	+	-	-	-	-	+	+++	++	-	Tr	-	-	-	-	-	+++	-	-	-
?	-	-	-	-	Tr	+++	-	-	-	-	-	Tr	-	-	-	-	-	-	-	-	+++	-	-	-
	-	-	-	-	-	+	-	-	-	-	+	++	Tr	-	-	-	-	-	-	-	++	-	-	-
	-	-	-	-	-	-	-	-	-	-	+	+	+++	-	+?	-	-	-	-	-	+	-	+?	-
?	-	-	-	-	-	+?	-	-	-	-	+	+	+	-	-	-	-	-	-	-	++	-	-	-
	-	-	-	+	-	+	+	-	-	-	++	++	+	+	-	-	-	-	-	-	++	-	-	-
	-	-	-	-	-	-	-	-	-	-	+	+	Tr?	-	-	-	-	-	-	-	++	-	-	-
	-	-	-	Tr?	Tr?	Tr	-	-	-	-	-	+++	Tr	-	Tr	-	-	-	-	-	+	-	-	-
?	-	-	-	-	+	-	-	-	-	-	+	+	Tr	-	+?	-	-	-	-	-	Tr	-	-	-
	-	-	-	-	-	-	-	-	-	-	Tr?	+	+	-	+	-	-	-	-	-	Tr	-	-	-
-	-	-	-	Tr?	-	-	-	-	-	-	++	+	+	-	-	-	-	-	-	-	+	-	-	-
-	-	-	-	-	-	-	-	-	-	-	+	-	Tr?	-	-	-	-	-	-	-	-	-	-	-
+	-	-	-	-	+	-	-	-	-	-	+	+	+	+	-	-	-	-	-	-	+	+	-	-
Tr?	-	-	-	-	-	+?	-	-	-	-	-	+	Tr?	-	+	-	-	-	-	-	+	-	-	-
-	-	-	-	+	Tr?	+++	-	-	-	-	+	+?	Tr?	-	+?	-	-	-	-	-	+++	-	-	-
-	-	-	-	-	-	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	+	-	-	-
+	-	-	-	-	-	-	-	-	-	-	-	+	Tr?	+	-	-	-	-	-	-	+	-	-	-

APPENDIX III

Key to a list of coumarins: (cont'd.)

III. 7,8-Furocoumarins

1. Meishoutin (Cyclo-obliquetin)
2. Nieshoutol
3. Thamnosimin

IV. Chromano-coumarins

1. Alloxanthoxyleton
2. Braylin
3. Clausenidin
4. Clausenin
5. Dentatin
6. Luvangetin
7. Nordentatin
8. Obliquin
9. Obliquol
10. Xanthoxyleton (5-Methoxyxanthyletin)
11. Seselin
12. Xanthyletin (2': 2'-dimethyl-pyrano-(5': 6'-6:7) coumarin)

APPENDIX III

Key to a list of Coumarins: (cont'd.)

II. 6-7-Furocoumarins:

1. Alloimperatorin
2. Bergapten (5-Methoxy-psoralen)
3. Bergamottin (5-Geranoyx-psoralen; 5-Geranloxy-6,7-furocoumarin-Bergaptin)
4. Bergaptol (5-Hydroxy-psoralen)
5. Byakangelicin (5-Methoxy-8-dihydroxy-isopentanoxy-psoralen
6. Chalepensin
7. Chalepin
8. 5-(3,6-Dimethyl-6-formy-2-heptenyl) oxy)psoralen
9. 6,7-furocoumarin (Psoralen; Ficusin)
10. 5-Geranoxy-8-methoxypsoralen
11. 8-Geranoxy psoralen
12. Halfordin
13. Heliettin ((+)-3-(1,1-Dimethylallyl)-6,7-dihydro-7-(1-hydroxyl-methylethyl)2H-furo-(2,3-g)-1-benzopyran-2-one)
14. Imperatorin
15. (-)-Imperatorin oxide
16. Isohalfordin
17. Isoimperatorin (5-r,r-Dimethylally-loxypsoralen; 5-Isopenteneoxy-psoralen)
18. Isopimpinellin (5,8-Dimethoxypsora
19. Marmesin ((-)-Marmesin)
20. (+)-Marmesin
21. Marmesine
22. 5-Methoxy-8-geranyloxypsoralen
23. 5-(3'-Methyl-2',3'-dihydroxy-butanyl) 8-methoxy-psoralen
24. Oxypeucedanin hydrate (5-Dihydroxy-isopentanoxy-psoralen)
25. Phellopterin (5-methoxy-8-r,r-dimethylallyloxy-psoralen
26. Kanthotoxin (8-Methoxy-psoralene)

APPENDIX III

Key to a list of Coumarins: (cont'd.)

I. Simple coumarins:

28. Meranzin (Auraptene (2); 7-methoxy-8-epoxy-isopentenyl-coumarin)

29. 7-Methoxy-8(2-formyl-2-methyl-propyl)-coumarin

30. 7-Methoxy coumarin-6-aldehyde

31. 7-Methoxy-5-geranoxy-coumarin

32. 8-Methoxy-4-methylcoumarin

33. Mexoticin (5,7-dimethoxy-8-(2',3'-dihydroxy-isopentyl)-coumarin

34. Micromelin

35. Obliquetin

36. Obliquetol

37. Osthol (7-Methoxy-8-isopentenyl-coumarin)

38. Prenyletin (7-O-(3,3-Dimethylallyl) aesculetin)

39. Prenyletin-6-O-methyl ether

40. Scopoletin (Chrysatropic acid; 6-Methyl-aesculetin)

41. 7-O-(1,1-dimethylallyl) scopoletin

42. 7-O-(3,3-dimethylallyl) Scopoletin

43. Scopolin

44. Skimmin (Umbelliferone-7-glucoside)

45. Suberenol

46. Suberosin

47. Toddaculin (5,7-Dimethoyx-6-(2'-isopentenyl)

48. Toddalo-lactone (Aculeatin-hydrate? 5,7-Dimethoxy-6(2,3-dihydroxy-isopentenyl)-coumarin)

49. 6,7,8-Trimethoxycoumarin (Dimethyl-fraxetin)

50. Umbelliferone (Dichrin-A; Hydrangin; 7-Hydroxy-coumarin; Skimmetin)

APPENDIX III

Key to a list of Coumarins:

I. Simple coumarins:

1. Aculeatin
2. Aurapten
3. Auraptena (7-Geranuloxy-coumarin)
4. Auraptenol (7-Methoxy-8 (2-hydroxy-3-methyl-3-butenyl)-coumarin)
5. Brayleanin
6. Collinin (7-Geranoxy-8-methoxy-coumarin)
7. Coumarins
8. Coumarrayin (5,7-dimethoxy-8 (2-iso-pentenyl)-coumarin)
9. Cyclobisuberoidene
10. Daphnoretin
11. Dehydrogeijerin (6-(B,B-Dimethylacrylyl)-7-methoxycoumarin)
12. 7-Desmethyl-2',3'-dihydroxy dihyrosuberosine
13. 7-Demethylsuberosin
14. 7-(6',7'-Dihydroxy-3',7'-dimethyl-2'-octenyl) oxy) coumarin
15. 5-Isopentenoxy-7-methoxy-coumarin(5-r,r-dimethylallyloxy-7-methoxy coumarin)
16. 5,7-Dimethoxycoumarin
17. 5,7-Dimethoxy-8-(3'-methyl-2'-oxobutyl) coumarin
18. 6,7-Dimethoxycoumarin (Aesculetin-dimethyl ether; Scoparin (2); Scoparone)
19. 8-(Dimethyallyl)-7-hydroxy-6-methoxy-coumarin
20. Geijerin (6-isovaleryl-7-methoxy-coumarin)
21. Geiparvarin (7-(4,7-epoxy-3,7-dimethyl-6-oxoocta-2,4-dienyloxy)coumarin)
22. Gravelliferone (3-(1,1-dimethylallyl)-6-(3,3-dimethylallyl)umberiferone)
23. Gravelliferone methyl ether
24. Herniarin (Ayapanin; 7-Methoxy-coumarin
25. 3-(1,1-Dimethyally) Herniarin
26. Limettin (5,7-Dimethoxycoumarin-Citropten)
27. Marmin (7-Dihydroxygeranoxy-coumarin)

Appendix III Distribution of Coumarins (by genera

(Numbering of Coumarins as in key; numbers

		1	2	3	4	5	6	7	8	9	10	
RUTACEAE												
I. Rutoideae												
Evodia	(120)											
Fagara	(200)											
Geijera	(7)											
												(L
Melicope	(50)											
Zanthoxylum	(15)									1		
Cneoridium	(1)											
Dictamnus	(2)		1									
Ruta	(60)							1			1	
Thamnosma	(6)											
Phebalium	(36)											
III. Flindersioideae												
Flindersia	(20)					1	1 (BK)					
Chloroxylon	(1)											
V. Toddalioideae												
Casimiroa	(6)											
Halfordia	(4)											
Helietta	(8)											
Ptelea	(3)			1								
Skimmia	(10)											
Toddalia	(1)	1 (Rt.Bk)										
VI. Citroideae												
Aegle	(1)			1 (Rt)								
Aeglopsis	(5)											
Citrus	(60)			2	1 (Ft,O)							
Clausena	(30)											
Limonia	(1)											
Luvunga	(12)											
Micromelum	(10)											
Murraya	(9)								1			
Poncirus	(1)											
Severina	(1)											
MELIACEAE												
I. Cedreloideae												
Cedrelopsis	(7)											
Ptaeroxylon	(1)											
Ekebergia	(15)											

Key to symbols:

Bk =	Bark	LV =	Leave
Ft =	Fruit	O =	Oil
HW =	Hardwood	Rt =	Root

genera) in Rutales (Compiled from literature survey)

umbers in table are numbers of species)

10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
		1 (BK)													
								1							
	1 (LV)									1 (BK)	1 (LV)				
								1							
1												1	1	4	1
		1 (HW)													
								1 (Ft)							
				1	1	1									
							1 (LV)								
								1							

Appendix III (cont'd.)

		26	27	28	29	30	31	32	33	34
RUTACEAE										
I. Rutoideae										
Evodia	(120)									
Fagara	(200)									
Geijera	(7)									
Melicope	(50)									
Zanthoxylum	(15)				1					
Cneoridium	(1)									
Dictamnus	(2)									
Ruta	(60)	1								
Thamnosma	(6)									
Phebalium	(36)									
III. Flindersioideae										
Flindersia	(20)									
Chloroxylon	(1)									
V. Toddalioideae										
Casimiroa	(6)									
Halfordia	(4)									
Helietta	(8)									
Ptelea	(3)									
Skimmia	(10)									
Toddalia	(1)									
VI. Citroideae										
Aegle	(1)	1 (Rt,Bk)	1 (Ft)	1 (PLO)						
Aeglopsis	(5)									
Citrus	(60)	3	1			3				
Clausena	(30)									
Limonia	(1)									
Luvunga	(12)					1 (O)				
Micromelum	(10)									1
Murraya	(9)								1 (Bk)	
Poncirus	(1)									
Severina	(1)									
MELIACEAE										
I. Cedrelopsis	(7)									
Cedrelopsis	(7)									
Ptaeroxylon	(1)									
Ekebergia	(15)					1				

3	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
		I															
							1									1	
												1	3 (Bk,Hw)				
				1													
							1										2
				3													
							1 (Bk)										
							1 (Bk)				2 (Bk)					1	
													1	1			
																1	
				2												1	
	1																
L 3k)						2				1 (Ft,Bk)							
		1 (Hw)	1 (Hw)		1 (Hw)	1 (Hw)	1	1	1								

Appendix III (cont'd.)

		1	2	3	4	5	6	7	8	9	10	11
RUTACEAE												
I. Rutoideae												
Evodia	(120)											
Fagara	(200)											
Geijera	(7)											
Melicope	(50)											
Zanthoxylum	(15)								1			
Cneoridium	(1)		1									
Dictamnus	(2)									1		
Ruta	(60)		3			1	2	1		3		
Thamnosma	(6)					1				1		
Phebalium	(36)		1							1		
III. Flindersioideae												
Flindersia	(20)											
Chloroxylon	(1)											
V. Toddalioideae												
Casimiroa			1									
Halfordia	(4)											
Helietta	(8)											
Ptelea	(3)		1			1				2		
Skimmia	(10)											
Toddalia	(1)											
VI. Citroideae												
Aegle	(1)	1 (Ft)										
Aeglopsis	(5)											
Citrus	(60)		2	4	2	2			1 (Pl,O)		2	2
Clausena	(30)											
Limonia	(1)											
Luvunga	(12)											
Micromelum	(10)											
Murraya	(9)											
Poncirus	(1)	1										
Severina	(1)		1 (Ft)									
MELIACEAE												
I. Cedreloideae												
Cedrelopsis	(7)											
Ptaeroxylon	(1)											
Ekebergia	(15)											

		II													
11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
								1 (Bk)		1					
							1								1
							1								
							1								1
			1			1									
															1
			1				1			1					3
							1					1			
															1
							1								
							1				1				1 (Cd)
	2 (Bk)				1										
		1 (Bk)													
			1	1			1	1	1					2	
			1 (Ft)					1							1
			1 (Ft)			1 (Ft)	1 (Ft)								
2			2			2	1						2		
							1								1
			1							1					
			1 (Ft)				1 (Ft)								

Appendix III (cont'd.)

		III						
		1	2	3	1	2	3	4
RUTACEAE								
I. Rutoideae								
Evodia	(120)							
Fagara	(200)							
Geijera	(7)							
Melicope	(50)							
Zanthoxylum	(15)				1 (Bk)			
Cneoridium	(1)							
Dictamnus	(2)							
Ruta	(60)							
Thamnosma	(6)			1				
Phebalium	(36)							
III. Flindersioideae								
Flindersia	(20)					1 (Bk)		
Chloroxylon	(1)							
V. Toddalioideae								
Casimiroa	(6)							
Halfordia	(4)							
Helietta	(8)							
Ptelea	(3)							
Skimmia	(10)							
Toddalia	(1)							
VI. Citroideae								
Aegle	(1)							
Aeglopsis	(5)							
Citrus	(60)							
Clausena	(30)						1	1
Limonia	(1)							
Luvunga	(12)							
Micromelum	(10)							
Murraya	(9)							
Poncirus	(1)							
Severina	(1)							
MELIACEAE								
I. Cedreloideae								
Cedrelopsis	(7)							
Ptaeroxylon	(1)	1 (Hw)	1 (Hw)					
Ekebergia	(15)							

	IV										
	2	3	4	5	6	7	8	9	10	11	12
									1		1
									1		
									1		1
)											
					1						1 (Ft)
	1 (Bk)									1 (Lv,Bk)	
									1		1
									1		
										1 (Lv)	
											4 (Rt)
		1	1	1		1					
					1						
					1 (Ft)						1
										1	1
							1	1			

VI. Flavonols:

1. Auranetin
2. Datiscetin-2'-methyl ether-?-diglucoside
3. Demethoxy-icaritin-7-glucoside (Amurensin)
4. Flindulatin
5. 5-Hydroxy-4',6,7,8-tetramethoxy-flavonol-3-methyl ether
6. Isolimocitrol
7. Limocitrin
8. Limocitrol
9. Melibentin
10. Melisimplexin
11. Melisimplin
12. Meliternatin
13. Meliternin
14. Quercetin-3-rutinoside
15. Quercitrin
16. Tambuletin
17. Tambuletin-4',7-dimethyl ether
18. Ternatin
19. Wharingin

APPENDIX IV

Key to a list of Flavonoids:

I. Anthocyanins
   1. Cyanidin-3-glucoside
   2. Delphinidin-3-glucoside

II. Leucoanthocyanins
   1. Leucopelargonidin

III. Flavanones
   1. Citromitin
   2. Citronetin-7-rhamnoglucoside
   3. Demethylcitromitin
   4. Eriodictyol-7-rhamnoside
   5. Eriocitrin (Eriodictyol-7-rutinoside)
   6. Hesperetin-7B-neohesperidoside (Neohesperidin)
   7. Hesperidin (Hesperetin-7-rutinoside)
   8. Isosakuranetin
   9. Isosakuranetin-7-rutinoside
   10. Isosakuranetin-7-neohesperidoside (Poncirin)
   11. Naringenin
   12. Naringenin-7-neohesperidoside (Naringin)
   13. Naringenin-7-rutinodide
   14. Naringenin-4'-glucoside-7-rutinoside

IV. Flavanonols
   1. Phellamurin

V. Flavones:
   1. Acacetin-7-rutinoside
   2. Apigenin-7-neohesperidoside
   3. Apigenin-7-rutinoside
   4. 3'-Demethoxy-sudachitin
   5. 5,6-Dimethoxyflavone
   6. Diosmetin-7-rutinoside
   7. Diosmetin-6-C-B-D-glucoside
   8. Diosmetin-8-C-B-D-glucoside
   9. 3,3',4',5,5',6,7-heptamethoxyflavone
   10. Luteolin-7-rutinoside
   11. Nobiletin
   12. 5-0-desmethylnobiletin
   13. Orientin
   14. Isoomientin
   15. Ponkanetin
   16. Sinensetin
   17. Sudachitin
   18. Tangeretin
   19. 3',5,5',6-tetramethoxyflavone
   20. 5,6,2'-trimethoxyflavone
   21. 3',5,6-trimethoxyflavone
   22. Vitexin-?-xyloside
   23. O-D-xylosylvitexin
   24. Vitexin
   25. Isovitexin
   26. Zapotin
   27. Zapotinin

Appendix IV Distribution of Flavonoids (

(Compiled from literature survey) (Numbering of

(Numbers in table are numbers of s

		I		II					
		1	2	1	1	2	3	4	5
RUTACEAE									
I. Rutoideae									
1. Zanthoxyleae									
<u>Fagara</u>	(200)								
<u>Melicope</u>	(50)								
<u>Zanthoxylum</u>	(15)								
2. Ruteae									
<u>Boenninghausenia</u>	(1)								
<u>Ruta</u>									
III. Flindersioideae									
<u>Flindersia</u>	(20)								
V. Toddalioideae									
<u>Casmiroa</u>	(6)								
<u>Phellodendron</u>	(10)								
<u>Teclea</u>	(25)								
VI. Citroideae									
<u>Citrus</u>	(60)	1	1		2	1	2	1	1
<u>Fortunella</u>	(6)								
<u>Murraya</u>	(9)								
<u>Poncirus</u>	(1)								
MELIACEAE									
<u>Ptaeroxylon</u>	(I)								
MALPIGHIACEAE									
<u>Malpighia</u>	(30)			1					

Key to symbols: Bk = Bark, Fl = Flower, Ft = Fruit, Lv = Leave, P = Peel, Sd = Seed onoids (by genera) in "Rutales"

ering of Flavenoids as in key)

ers of species)

	III									IV
5	6	7	8	9	10	11	12	13	14	1
		1								
		4								
										1 (Lv)
1	9	18	1	2	3	2	9	2	2	
	1				1	1	1			

Appendix IV (cont'd.)

	1	2	3	4	5	6	7	8	9	10	11	12
RUTACEAE												
I. Rutoideae												
1. Zanthoxyleae												
<u>Fagara</u> (200)						2						
<u>Melicope</u> (50)												
<u>Zanthoxylum</u> (15)												
2. Ruteae												
<u>Boenning-hausenia</u> (1)												
<u>Ruta</u> (60)												
III. Flindersioideae												
<u>Flindersia</u> (20)												
V. Toddalioideae												
<u>Casmiroa</u> (6)					1 (Rt, Br)							
<u>Phellodendron</u> (10												
<u>Teclea</u> (25												
VI. Citroideae												
<u>Citrus</u> (60)		1 (Lv)	2	1			1	1		1 (P)	6 (Bk)	1
<u>Fortunella</u> (6)	3 (Fl)											
<u>Murraya</u> (9)									1			
<u>Poncirus</u> (1)		1										
MELIACEAE												
<u>Ptaeroxylon</u> (1)												
MALPIGHIACEAE												
<u>Malpighia</u> (30)												

		V													
12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
							1	1	1					1	1
	1	1										1	1		
1			1	1 (P)	1	6				1 (Ft)					

Appendix IV (cont'd.)

		1	2	3	4	5	6	7	8	9	10
RUTACEAE											
I. Rutoideae											
1. Zanthoxyleae											
Fagara	(200)										
Melicope	(50)									1	3 (Bk)
Zanthoxylum	(15)										
2. Ruteae											
Boenninghausenia	(1)										
Ruta	(60)										
III. Flindersioideae											
Flindersia	(20)				1 (Lv)						
V. Toddalioideae											
Casmiroa	(6)										
Phellodendron	(10)			1 (Lv, Bk)							
Teclea	(25)										
VI. Citroideae											
Citrus	(60)	1				1 (P)	1 (Ft)	1 (P)	1		
Fortunella	(6)										
Murraya	(9)										
Poncirus	(1)										
MELIACEAE											
Ptaeroxylon	(1)		1 (Bk)								
MALPIGHIACEAE											
Malpighia	(30)										

					VI								
	7	8	9	10	11	12	13	14	15	16	17	18	19
			1	3 (Bk)	3 (Bk)	3 (Bk)	I (Bk)	1 1	1	1 (Sd)	1 (Ft)	2 (Bk)	1 (Bk)
t)	1 (P)	1											

B. Triterpenoids other than saponins and sapogenins (cont'd.)

71. Melianodiol
72. Melianol
73. Melianone
74. Melianotriol
75. Methyl 6-acetoxy-angolensate
76. Methyl angolensate
77. Methyl 6-hydroxyangolensate
78. Mexicanol
79. Mexicanolide
80. Mexicanolide C
81. Neohavanensin
82. Neoquassin
83. Nimbin
84. Nimbinin
85. Nimbolide
86. Nomibin
87. Nyasin
88. Obacunone
89. Picrasmin
90. Pseudo-epitaraxastane-diol
91. Pseudo-taraxasterol
92. Pseudelone-A
93. Pseudocedrelone-B
94. Quassin
95. Rutaevin
96. Salannin
97. Samaderine-A
98. Samaderine-B
99. Samaderine-C
100. Simarolide
101. Swietenin
102. Swietenolide
103. Taraxeral
104. Taraxerone
105. Trichilenone
106. Turraeanthin
107. Utilin
108. Veprisone

V. Tetraterpenoids

1. -Carotene
2. -Carotene
3. B-Carotene
4. Cryptoxanthin
5. Mutatochrome
6. Semi-B-carotene
7. Zeaxanthin

B. Triterpenoids other than saponins and sapogenins (cont'd.)

10. Anthothecol
11. Aphanamixin
12. Arborinol
13. Azadiracione
14. Azadirone
15. Bauerenol
16. α-Boswellic acid
17. Bourjotone
18. Bein
19. Bruceine A
20. Bruceine B
21. Bruceine C
22. Bussein
23. Canaric acid
24. Candollein
25. Carapin
26. Cedrelone
27. Cedronine
28. Cedronyline
29. Chaparrin
30. Chaparrinone
31. β-Citraurin
32. 7-Deacetoxy-3-deacetyl-7-oxo-khivorin
33. 7-Deacetoxy-7-oxo-dihydro--gedunin
34. 7-Deacetoxy-7-oxogedunin
35. 7-Deacetoxy-7-oxokhivorin
36. 7-Deacetylgedunin
37. 3-Deacetyl-khivorin
38. Deacetyl-nomilin
39. 3-Dehydromexicanol
40. Deoxy-limonin
41. 6-Deoxy-swietenolide
42. 6α,11B-Diacetoxy gedunin
43. Dihydrogedunin
44. Entandrophragmin
45. Epi-lupeol
46. Epoxy-malabaricol
47. Eurycoma-lactone
48. Fissinolide
49. Flindissol
50. Gedunin
51. Glaucarubin
52. Glaucarubinone
53. Glaucarubolone
54. Grandifoliolinone
55. Havanensin
56. Heudelottin
57. Hirtin
58. 6-Hydroxy-angolensic acid-methyl ether
59. 6-Hydroxycarapin
60. Ichangin
61. Isoarborinol
62. 11-Keto-α-amyrin
63. Khayanthone
64. Khivorin
65. Lansic acid
66. Limonin
67. Limonin diosphenol
68. Malabaricanedial
69. Malabarical
70. Meldenin

II. Sesquiterpenes (cont'd.)

C. Eremophitone group
1. Nootkatone
2. Valencene

D. Guaianolide group
1. Aromadendrene
2. α-Chigadmarene
3. Cyclocolarenone
4. Ledol

E. Selinene group
1. Canarone
2. β-Caryophyllene-epoxide
3. Elemol
4. (+)-Jujenol
5. (+)-Junenol

III. Diterpenoids

1. Aphanamixol
2. α-Camphorene
3. Crocetin
4. Geranyl-geraniol
5. Incensole
6. Nimbiol
7. Sugiol

IV. Triterpenoids

A. Triterpenoid saponins and sapogenins
1. α-Amyrin
2. β-Amyrin
3. β-Citraurin
4. Ifflaionic acid
5. Lupeol
6. Monninin
7. Polygalic acid
8. Polygala-prosapogenin
9. Polygala-saponin-A
10. Polygala-saponin-B
11. Presenegenin
12. Prosapogenin
13. Sapteroxyloside
14. Senegenin
15. Senegin
16. Xanthophyllum-Saponin

B. Triterpenoids other than saponins and sapogenins
1. 11B-Aceroxygedunin
2. Aglaiol
3. Ailantholide
4. Ailanthone
5. Amarolide
6. Amarolide-12-acetate
7. β-Amyrin acetate
8. Andirobin
9. Angolensic acid

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APPENDIX V

Key to a list of Terpenoids:

I. Monoterpenoids

1. d-Camphene
2. ℓ-Camphene
3. d-Δ^3-Carene
4. ℓ-Δ^3-Carene-5,6-epoxide
5. Carvacrol
6. 1,4-Cineole
7. 1,8-Cineole
8. Citral
9. d-Citronellal
10. d-Citronellic acid
11. Cuminic aldehyde
12. p-Cymene
13. Diosphenol
14. Dipentene
15. Filifilone
16. Geranic acid
17. Geranial
18. d-Limonene
19. d-Linalool
20. ℓ-Linalool
21. Linalool epoxide
22. ℓ-Linalyl acetate
23. d-Menthone
24. Mullilam-diol
25. Myrcene
26. d-myrtenal
27. Nerol
28. Ocimene
29. Perilla alcohol
30. ℓ-Phellandral
31. d-α-Phellandrene
32. d-β-Phellandrene
33. Phellandrinic acid
34. ℓ-α-Pinene
35. ℓ-β-Pinene
36. Sabinene
37. α-Terpinene
38. γ-Terpinene
39. ℓ-Terpinenol-(4)
40. d-α-Terpineol
41. ℓ-α-Terpineol
42. α-Thujene
43. d-Verbenol
44. Verbenone

II. Sesquiterpenes

A. Bisaboiene group
1. Bisabolene
2. Bisabolol

B. Cadinene group
1. Cadinene
2. Cadinol
3. Capaene
4. Epi-khusinol

OK

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
RUTACEAE																			
I. Rutoideae																			
Evodia	(120)																		
Zanthoxylum	(15)						1				1	1							
Medicosma	(1)																		
Dictamnus	(2)																		
Ruta	(60)	5						1				1							
Boronia	(60)																		
Eriostemon	(30)																		
Phebalium	(36)								1										
Zieria	(1)				1											1			
Agathosma	(170)																		
Barosma	(20)										1			1	1				
Calodendron	(2)																		
Empleurum	(1)																		
III. Flindersioideae																			
Flindersia	(20)																		
V. Toddalioideae																			
Acronychia	(40)																		
Amyris	(20)																		
Casimaroa	(2)																		
Phellodendron	(10)																		
Skimmia	(10)																		
Vepris	(20)																		
VI. Citroideae																			
Aegle	(1)									1		1	1						
Atalantia	(30)																		
Citrus	(60)	1	2	1?				2			1		1		1		1	1	1
Clausena	(30)																1		
Fortunella	(1)																		
Glycosmia	(40)																		
Luvunga	(1)							1											
Microcitrus	(5)																		
Murraya	(9)																		
Poncirus	(1)																		
Triphasia	(2)																		
SIMAROUBACEAE																			
Eurycoma	(4)																		
Quassia, *Simaba*, *Simarouba*, *Samadera*	(40)																		
Ailanthus	(10)																		
Brucea	(10-12)																		
Castela	(12)																		
Perriera	(12)																		

Appendix V Distribution of Terpenoids (by genera) in Rutales (compiled from leterature survey)

I. Monoterpenoids

17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
											1														
							1												1	1		1			
								1																	
											1														
									1		1														
											1														
								1																	
						1		1																	
								1																	
								2																	
															1										
														1											
			1		1														1						
1	1	1	2	1				1		1	1	1		1	1		1	2		1	1		2	1	

(by genera) in
survey)

									II. Sesquiterpenes																
									A		B				C		D				E				
36	37	38	39	40	41	42	43	44	1	2	1	2	3	4	1	2	1	2	3	4	1	2	3	4	5
1	1		1																						
																			1						
																				1					
																				1					
1												2													
	1	1		2	1					1						1						1			
									1		1	1													

Appendix V. (cont'd.)

		III. Diterpenoids							A. Triterpenoid saponins and sapogenins															
		1	2	3	4	5	6	7	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
RUTACEAE (cont'd.)																								
I. Rutoideae																								
Evodia	(120)																							
Zanthoxylum	(15)									1			3											
Medicosma	(1)																							
Dictamnus	(2)																							
Ruta	(60)																							
Boronia	(60)																							
Eriostemon	(30)																							
Phebalium	(36)																							
Zieria	(1)																							
Agathosma	(170)																							
Barosma	(20)																							
Calodendron	(2)																							
Empleurum	(1)																							
III. Flindersioideae																								
Flindersia	(20)											1												
V. Toddalioideae																								
Acronychia	(40)																							
Amyris	(20)																							
Casimaroa	(2)																							
Phellodendron	(10)																							
Skimmia	(10)																							
Vepris	(20)																							
VI. Citroideae																								
Aegle	(1)												5											
Atalantia	(30)																							
Citrus	(60)										1		1											
Clausena	(30)																							
Fortunella	(1)																							
Glycosmia	(40)																							
Luvunga	(1)																							
Microcitrus	(5)																							
Murraya	(9)																							
Poncirus	(1)																							
Triphasia	(2)																							
SIMAROUBACEAE																								
Eurycoma	(4)																							
Quassia, Simaba, Simarouba, Samadera	(40)																							
Ailanthus	(4)																							
Brucea	(10-12)																							
Castela	(12)																							
Perriera	(12)																							

						IV. Triterpenoids																									
s and		sapogenins				B. Triterpenoids other than saponins and sapogenins																									
11	12	13	14	15	16	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	2
																						1									
																				1											
																	1														
								1	2	1	6													1	1	1					

	sapogenins																					
	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
										1							11		1			
																	1					
																	1					
						1	1															
									1													
								1														

7	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	5
																						2			
				1							11		1												
											1														
											1														
																				1					
1	1																							1	
			1																1						
		1																							

Appendix V (cont'd.)

IV. Triterpenoids (cont'd.)

		53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	7
RUTACEAE																				
I. Rutoideae																				
Evodia	(120)														3	2				
Zanthoxylum	(15)																			
Medicosma	(1)																			
Dictamnus	(2)														1					
Ruta	(60)																			
Boronia	(60)																			
Eriostemon	(30)																			
Phebalium	(36)																			
Zieria	(1)																			
Agathosma	(170)																			
Barosma	(20)																			
Calodendron	(2)																			
Empleurum	(1)																			
III. Flindersioideae																				
Flindersia	(20)																			
V. Toddalioideae																				
Acronychia	(40)																			
Amyris	(20)																			
Casimaroa	(2)																			
Phellodendron	(10)														1					
Skimmia	(10)																			
Vepris	(20)																			
VI. Citroideae																				
Aegle	(1)																			
Atalantia	(30)																			
Citrus	(60)								1						13					
Clausena	(30)																			
Fortunella	(1)														1					
Glycosmia	(40)									1										
Luvunga	(1)														1					
Microcitrus	(5)														1					
Poncitrus	(1)																			
Triphasia	(2)														1					
SIMAROUBACEAE																				
Eurycoma	(4)																			
Quassia																				
Simaba	(40)																			
Simarouba																				
Samadera																				
Ailanthus	(10)																			
Brucea	(10-12)																1		1	
Castela	(12)																			
Perriera	(12)																			

iterpenoids (cont'd.)

62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
				3	2																							
				1																						1		
																								2		2		
				1																						1		
				13																				3		9		
				1																								
				1																								
				1																								
				1																				1		1		
																				1								
																											1	
						1		1																				

5	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	1
										2												
			1							1												
										1												
	2		2																			
			1																			
																		1	1			
	3		9																			
	1		1																			
									1													
												1	1	1								
				1											1				1			

																	V. Tetrapenoids						
92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	1	2	3	4	5	6	7
			2																				
			1																				
			1																				
											1	1											
																1							
																	1	1		1	1		1
																			1			1	
																			1			1	
		1																					
					1	1	1																
								1				1											

Appendix V (cont'd.)

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
BURSERACEAE																		
Boswellia	(24)														1			
Brusera	(100)																	1
Commiphora	(100)																	
Canarium	(75)														1			
MELIACEAE																		
I. Cedreloideae																		
Cedrela	(7)																	
Ptaeroxylon	(1)																	
II. Swietenioideae																		
Entandrophragma	(20)																	
Khaya	(10)																	
Pseudocedrela	(1)																	
Swietenia	(5)																	
III. Melioideae																		
Carapa	(15)																	
Xylocarpus	(5)																	
Turraeanthus	(6)																	
Melia	(9)																	
Aglaia	(300)						1		1									
Aphanamixis	(23)																	
Dysoxylum	(100)																	
Guarea	(160)																	
Lansium	(7)																	
Trichilia	(230)																	
POLYGALACEAE																		
Xanthophyllum	(40)																	
Monnina	(80)																	
Polygala	(500)																	

I. Monoterpenoids

13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
	1																	1								
				1		1								1			1	1	1	1						
												1														
	1																	1								
																								1		

											II. Sesquiterpenes																
											A		B				C		D				E				
34	35	36	37	38	39	40	41	42	43	44	1	2	1	2	3	4	1	2	1	2	3	4	1	2	3	4	5
									1	1	1																
											1																
																1							1		1	1	1
														1	1												
			1																1								
															1												
											1																
																				1							

Appendix V. (cont'd.)

		III. Diterpenoids							A Triterpenoids saponins and sapogenins															
		1	2	3	4	5	6	7	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
BURSERACEAE																								
Boswellia	(24)					1																		
Brusera	(100)																							
Commiphora	(100)		1																					
Canarium	(75)								1	1														
MELIACEAE																								
I. Cedreloideae																								
Cedrela	(7)			1	1																			
Ptaeroxylon	(1)																				1			
II. Swietenioideae																								
Entandrophragma	(20)																							
Khaya	(10)																							
Pseudocedrela	(1)																							
Swietenia	(5)																							
III. Melioideae																								
Carapa	(15)																							
Xylocarpus	(5)																							
Turraeanthus	(6)																							
Melia	(9)						1	1													1	1		
Aglaia	(300)																							
Aphanamixis	(23)	1																						
Dysoxylum	(100)																							
Guarea	(160)																							
Lansium	(7)																							
Trichilia	(230)																							
POLYGALACEAE																								
Xanthophyllum	(40)																							1
Monnina	(80)												1											
Polygala	(500)													1	2	1	1		2	2		2		1

				IV. Triterpenoids																									
and sapogenins				B. Triterpenoids other than saponins and sapogenins																									
.3	14	15	16	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
																			2										
										1											1					1			
1												1																1	1
												1													1		1		
													1																
				1							1																	1	
1	1																												
					1																								
														1															
												1																	
			1																										
	2		1																										

enins

23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
																						1							
1																													
		1	1								2					1				1					1		2		
	1																				4						2		
									1			1		2				1							1				
											1		1																
		1									1								1										
																											1		
										1										1					1		1		

Appendix V (cont'd.)

		IV. Triterpenoids (cont'd.)															
		53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68
BURSERACEAE																	
Boswellia	(24)																
Brusera	(100)																
Commiphora	(100)																
Canarium	(75)										1						
MELIACEAE																	
I. Cedreloideae								1									
Cedrela	(7)																
Ptaeroxylon	(1)																
II. Swietenioideae																	
Entandrophragma	(20)																
Khaya	(10)		1				2					1	3				
Pseudocedrela	(1)																
Swietenia	(5)																
III. Melioideae																	
Carapa	(15)																
Xylocarpus	(5)																
Turraeanthus	(6)																
Melia	(9)																
Aglaia	(300)																
Aphanamixis	(23)																
Dysoxylum	(100)													1			
Guarea	(160)																
Lansium	(7)			1	1	1							1?				
Trichilia	(230)																
POLYGALACEAE																	
Xanthophyllum	(40)																
Monnina	(80)																
Polygala	(500)																

Appendix V-B,-3

	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	9
																										1	1	
												2		2	3													
												3																
3											1	2	1		1								1					
												1																
																1												
						1	1	1	1	1									1	2	1							
	1																											
												1																
1?																												
																	1											

																			V. Tetrapenoids						
90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	1	2	3	4	5	6	7
1	1																								
																	1								
		1	1																						
											1	1													
																1									
						1																			
															1										

X. Quinoline Group

B. Furoquinolines and Related Alkaloids

1. Acronidine
2. Acronydidine
3. Acrophyllidine
4. Acrophylline [9-(3-methylbut-2-enyl)-7-methoxyfuro(2,3-b) quinal-4-ones]
5. Choisyine
6. Dictaminine
7. Dubinidine
8. Dubinine
9. Evodine
10. Evolatine
11. Evolitrine (7-Methoxy-dictamnine)
12. Evoxine (Haploperine)
13. Evoxoidine
14. r-Fagarine (Haplophine-8-Methoxy-Dictamnine)
15. Flindersiamine (6,7-Methylenedioxy-8-methoxy-dictamine)
16. Flindersine
17. Haplophylidine
18. Haplophylline
19. Haplopine (7-Hydroxy-8-methoxy-dictamnine)
20. Hydroxy-lunacridine
21. (-)-Hydroxy-lunacridine
22. Hydroxy-lunacrine
23. (+)-Hydroxylunacrine (Balfourodine)
24. Hydroxylunidine
25. Hydroxylunine
26. Ifflaiamine
27. 7-Isopentenyloxy-r-fagarine
28. Khaplofoline
29. Kokusagine (7,7-Methylenedioxy-dictamine)
30. Kokusaginine (6,7-Dimethoxy-dictamnine)
31. Kokusaginoline
32. Lunacridine
33. (-) Lunacrine
34. Lunacrinol
35. (+)-Lunacrinol (Isobalfourodine)
36. Lunasine
37. Lunidine
38. Lunine
39. Maculine (6,7-Methylenedioxy-dictamnine)
40. Maculosidine (6,8-Dimethoxy-dictamnine)
41. Maculosine
42. Medicosmine
43. 6-Methoxydictamine (Pteleine)
44. Nor-r-fagarine
45. "Nor-orixine"
46. O-Methyl balfourodinium+
47. O-Methyl-luninium cation
48. Orixine
49. Pilokeanine
50. Platydesmine
51. Platydesmine acetate
52. Ribabinidine (Phenolic tertiary base with-a 2-alkoxy-4-quinoline)
53. Ribalinine
54. Ribalinium
55. Robustine (8-Hydroxy-dictamine)
56. Skimmianine (7,8-Dimethoxydictamnine)

C. Quinolyl-quinoclidine

1. Quinine

App. VI OK 4

IX. Quinazolines

1. Aegelenine (1-Phenyl-7-hydroxytetrahydro-quinazoline-4-one)
2. Arborine (Glycosine; 1-Methyl-2-benzyl-4-1H)-quinazolone)
3. Glycorine (1-Methyl-4-quinazolone)
4. Glycosmicine
5. Glycosminine (2-Benzyl-4-quinazolone; Glycasmine)
6. 7-Hydroxy-1-phenyldihydroquinazol-4-one

X. Quinoline group

A. Simple Quinolines

1. 1-Acetoxymethyl-2-propyl-4-quinolone
2. 2-Amyl-quinoline
3. 2-Amyl-4-methoxy-quinoline
4. 2-[4'-(3",4"-Methylene-dioxyphenyl)]-n-Butyl-quinolone
5. Casimiroine (1-Methyl-4-methoxy-7,8-methylene-dioxy-2-quinolone)
6. Casimiroitine (1-Methyl-4-O-ethyl-7,8-methylene-dioxy-2-quinolone)
7. Cuspareine
8. Cusparidine
9. Cusparine
10. 1,2-Dimethyl-4-quinolone
11. 3-Dimethylally-4-methoxy-2-quinolone
12. 3-Dimethylallyl-4-dimethylallyloxy-2-quinolone
13. Dubamine
14. Eduleine (N-methyl-2-phenyl-7-methoxy-4-quinolone)
15. Eduline (N-Methyl-2-phenyl-6-methoxy-4-quinolone)
16. Edulinine
17. Edulirine (4,8-Dimethoxy-2-quinolone
18. Evocarpine
19. Fagaramide
20. Foliosidine
21. Galipine
22. Galipoidine
23. Galipoline
24. Graveoline [(N-Methyl-2-(3',4'-methylene-dioxyphenyl)4-quinolone]
25. Graveolinine (2-(3',4'-Methylene-dioxyphenyl)-4-methoxy-quinoline)
26. 3-Isopentenyl-4-methoxy-7,8-methylenedioxy-2-quinolone
27. Lunamarine (N-Methyl-2(3',4'-methylenedioxyphenyl-7-methoxy-4-quinolone)
28. 1-Methyl-2-quinolone
29. N-Methyl-2-quinolone
30. 2-Pentylquinoline
31. 4-Methoxy-2-pentyquinoline
32. 2-Phenyl-4-methoxy-quinoline
33. Quinaldine
34. Quinoline
35. Rutamine (Dimethyl-graveoline)

D. Canthin-6-ones
1. Canthinone (Canthin-6-one)
2. 4,5-Dimethoxycanthin-6-one
3. Nigakinone (4-Methoxy-5-hydroxycanthin-6-one)
4. 5-Methoxycanthionone (5-Methoxy-canthin-6-one)
5. 4-Methylthio-cantin-6-one)

E. The carbazole group
1. Girinimbine
2. Glycozolidine (5,7-Dimethyl-carbazole)
3. Glycozoline (3-Methyl-6-methoxy-carbazole
4. Heptaphylline
5. Murrayanine (1-Methoxy-3-formycarbazole)

V. Isoquinoline group

A, 1,1'-Benzylisoquinolines
1. Tembetarine(N-Methyl-1-(+)-reticuline)

B. The aporphine group
1. 6-Hydroxy-2,3,5-trimethoxy-NN-dimethyl-aporphine
2. Isocorydine (Artabotrine; Lauteanine)
3. Isocorydine methiodide
4. Laurifoline
5. Magnoflorine
6. Magnoflorine iodide
7. (+)N-Methylcorydine
8. N-Methyl-corydinium cation
9. N-Methylisocorydine
10. N-Methyl-isocorydinium cation
11. Quaternary aporphine
12. Xanthoplanine

C. Protoberberine
1. Berberine
2. Jatrorrhizine (Jaterorhizine)
3. α-l-Canadine methochloride [(-)-N-Methyl-tetrahydroberberine chloride)]
4. (-)-α-Canadine methoidide
5. N-Methyl-α-Canadine+
6. Palmatine (Calystegine;Gindarinine)
7. Phellodendrine

D. Protopine group
1. Allocryptopine
2. α-Allocrytopine (B-homochelidonine; r-Fagarine)
3. β-Allocryptopine (r-Homochelidonine)
4. Fagarine II

E. Phthalide-isoquinalines
1. (-)-α-Narcotine

F. The α-Naphthaphenanthridines
1. Avicine
2. Chelerythrine (Toddaline)
3. Chelerythrine chloride
4. Chelerytrine
5. Dihydrochelerythrine
6. 7,8-Dimethoxy-2',3'-methylenedioxy-1,2-benzophenanthridine
7. Nitidine
8. Oxynitidine

VI. The oxizole group
1. Halfordine
2. Halfordinol
3. Halfordinone
4. N-Methyl-halfordinium chloride

VII. Pyridines
1. Trigonelline (Coffeorin)

VIII. Pyridines
1. Stachydrine

APPENDIX VI

Distribution of Alkaloids (by genera) in "Rutales"
(Compiled from literature survey)

Key to a list of Alkaloids:

I. Acridine group
1. 1,3-Dimethoxy-10-methylacridone
2. 1,2,3-Trimethoxy-10-methyl-acridone
3. N-methylacridone
4. Acronycine
5. Arborinine
6. Evoprenine
7. Evoxanthidine
8. Evoxanthine (1-Methoxy-2,3-methyenedioxy-N-methyl-acridone)
9. Melicopicine
10. Melicopidine
11. Melicopine
12. Xanthevodine
13. Xanthoxoline

II. Alkaloid amines (Including the β-Phenyl-ethylamine)
1. Aegeline
2. Candicine (β-p-Hydroxy-phenylethyl-trimethyl-ammonium hydroxide)
3. Coryneine (3-Hydroxy-candicine)
4. Feruloputrescine
5. Jaborandine
6. Noradrenaline
7. N-Benzaytyramine
8. (±)-N-benzoyl(2-hydroxy-2-(4'-methoxyphenyl) ethylamine
9. N-Methyl-anthranilic acid
10. N-Methyl-anthranlic acid methyl ether
11. N,N-Dimethyl-4-methoxy-phenethylamine
12. Nor-adreneline (Arterenol; Nor-epinephrine
13. ℓ-Octopamine (1-Nor-synephrine)
14. O-Methyl-tyramine-N-methylcinnamide (Herclavin)
15. ℓ-synephrine
16. Tyramine

III. Imidazole group
1. Casimiroedine
2. Isopilocarpine
3 N,N-Dimethylhistamine
4. Pilocarpidine (De-N-methyl-pilocarpine)
5. Pilocarpine
6. Pilosine
7. Zapotidine

IV. Indole group

A. Simple indole bases
1. Indole
2. 6-Methoxy-Nb-dimethyl-tryptamine
3. 5-Methoxy-Nb,Nb-dimethyl-tryptamine
4. Nb,Nb-Dimethyl-tryptamine (Nigerine)
5. Tryptamine

B. Carboline alkaloids
1. Hermaline (3,4-Dihydro-harmine; Harmidine)
2. Harmine (?Banisterine; Passiflorine; Telepathine; ?Yageine)
3. Tetrahydro-harmine (Leptoflorine)

C. The quinazoline carboline
1. Evodiamine
2. Hortiacine
3. Hortiamine
4. Hydroxy-evodiamine
5. Rhetsine (dl-Evodiamine)
6. Rhetsinine
7. Rutaecarpine

		I. Acridine Group												
		1	2	3	4	5	6	7	8	9	10	11	12	13
RUTACEAE														
I. Rutoideae														
Choisya	(7)													
Evodia	(120)		1			2	1	2	2		2	2	1	1
Fagara	(200)													
Geijera	(7)													
Medicosma	(1)													
Melicope	(50)				1					1	1	1		
Orixa	(1)													
Platydesma	(3)													
Pentaceras	(1)													
Balfourodendron	(1)								1					
Lunasia	(10)													
Zanthoxylum	(15)													1
Boenninghausenia	(1)													
Dictamnus	(2)													
Ruta	(60)													
Thamnosma	(6)			1										
Haplophyllum	(70)													
Boronia	(60)													
Eriostemon	(30)													
Phebalium	(36)													
Geleznowia	(3)													
Cusparia	(25)													
Galipea	(8)													
Pilocarpus	(20)													
Ravenia	(18)					1								
II.Dictyolomatoideae														
Dictyoloma	(2)													
III.Flindersoideae														
Chloroxylen	(1)													
Flindersia	(20)													
V.Toddalioideae														
Acronychia	(40)	1			1	1				1	1	2	1	
Casimiroa	(6)													
Phellodendron	(3)													
Ptelea	(3)													
Skimmia	(10)													
Teclea	(25)							1	2					
Toddalia	(1)													
Vepris	(20)													
Halfordia	(1)													
Hortia	(10)													
VI. Citroideae														
Aegle	(1)													
Citrus	(60)													
Clausena	(30)													
Glycosmis	(40)					1								
Murraya	(9)													
Poncirus	(1)													
SIMAROUBACEAE														
II. Simarouboideae														
Picrasma	(17)													
Picrolemma	(3)													
MALPIGHIACEAE														
Banisteria	(75)													
Cabi	(1)													
Banisteriopsis	(1)													

I. Acridine Group							II. Alkaloid amines (Including the B-Phenyl-Ethylamine)																II
7	8	9	10	11	12	13	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	1
2	2		2	2	1	1																	
								6	1														
		1	1	1																			
	1																						
						1														1			
											1												
		1	1	2	1																		
													1										1
1	2																1						
							1																
										1		1			1	1		1	1		1	1	
														1									

APPENDIX VI Distributic

amines [-Ethylamine) 12	13	14	15	16	III. Imidazole Group 1	2	3	4	5	6	7	IV. Ind A. Simple indole bases 1	2	3	4	5	B. Carboline alkaloids 1	2	3	C. T 1	2
																				1	
		1																			
						2		1	5	1											
														1							
					1		1				1										
																				1	2
1	1		1	1								1				1					
																	1	1	1		
																		1			
													1		1			1			

APPENDIX VI Distribution of Alkaloids (b

		III. Imidazole Group							IV. Indole Group															
									A. Simple indole bases					B. Carboline alkaloids			C. The quinazdine carboline							
15	16	1	2	3	4	5	6	7	1	2	3	4	5	1	2	3	1	2	3	4	5	6	7	1
																	1			1		1	1	
																								1
																					1	2		2
			2		1	5	1																	
											1													
		1		1				1																
																	1	2	2				1	
1	1								1				1											
																								2
														1	1	1								
															1									
										1		1			1									

APPENDIX VI Distribution of Alkaloids (by genera) in "Rutales" (Comp…

IV. Indole Group

…ole …bases 3	4	5	B. Carboline alkaloids 1	2	3	C. The quinazdine carboline 1	2	3	4	5	6	7	D. Canthin-6-ones 1	2	3	4	5	E. The Carbazole group 1	2	3	4	5	A.I… lisoq… [illegible]
						1			1		1	1											
																							6
													1			1	1						
										1	2		2										1
1																							
						1	2	2				1											
		1																					
																					1		
																			1	1			
																		1				1	
													2	1	1								
			1	1	1																		
				1																			
	1			1																			

APPENDIX VI Distribution of Alkaloids (by genera) in "Rutales"

le Group			IV. Indole Group																								
			A. Simple indole bases					B. Carboline alkaloids			C. The quinazdine carboline							D. Canthin-6-ones					E. The Carbazole group				
5	6	7	1	2	3	4	5	1	2	3	1	2	3	4	5	6	7	1	2	3	4	5	1	2	3	4	5
											1			1		1	1										
																		1			1	1					
															1	2		2									
5	1																										
					1																						
		1																									
											1	2	2				1										
			1				1																				
																										1	
																								1	1		
																							1				1
																		2	1	1							
								1	1	1																	
									1																		
				1		1			1																		

"

(Compiled from literature survey)

Carba- group 4	Carba- group 5	V. Isoquinoline Group: A. 1,1'-Benzylisoquindines I	B. The Aporphine Group 1	B. 2	B. 3	B. 4	B. 5	B. 6	B. 7	B. 8	B. 9	B. 10	B. 11	B. 12	C. Protoberberine 1	C. 2	C. 3	C. 4	C. 5	C. 6	C. 7	D. Protophine Group 1	D. 2	D. 3	D. 4
															1										
		6	1			3	5		1	1	4	2	2	2	1					1		1	1		1
		1		2	2	2	3	1			1				1		3	3	1			1	2	1	
							1								3	1				1	1				
															1										
1																									
	1																								

to- Group		E. Phthalide- isoquinalines	F. The α-Naphthaphen- anthridines								VI. The Oxa- zole Group				VII. Pyri- dines	VIII. Pyro- lidines	
3	4	1	1	2	3	4	5	6	7	8	1	2	3	4	1	1	1
	1			6		6	1		5								
1			1	4	1	4			2	1							
															1		
			1		1	1	1										
											1	1	1	1			
		2														1	

thalide- quinalines	F. The α-Naphthaphen- anthridines								VI. The Oxa- zole Group				VII. Pyri- dines	VIII. Pyro- lidines	IX. Quina- zolines					
1	1	2	3	4	5	6	7	8	1	2	3	4	1	1	1	2	3	4	5	6
		6		6	1		5													
	1	4	1	4			2	1												
													1							
	1		1	1	1															
									1	1	1	1								
															1					1
2														1						
																1	1	1	1	

APPENDIX VI (cont'd.)

		A. Simple																	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
RUTACEAE																			
I. Rutoideae																			
Choisya	(7)																		
Evodia	(120)																		1
Fagara	(200)											1							
Geijera	(7)																		
Medicosma	(1)																		
Melicope	(50)																		
Orixa	(1)																		
Platydesma	(3)										1								
Pentaceras	(1)																		
Balfourdendron	(1)																		
Lunasia	(10)														2				
Zanthoxylum	(15)																		
Boenninghausenia	(1)																		
Dictamnus	(2)																		
Ruta	(60)				1														
Thamnosma	(6)												1	1					
Haplophyllum	(70)																		
Boronia	(60)	1																	
Eriostemon	(30)																		
Phebalium	(36)																		
Geleznowia	(3)																		
Cusparia	(25)									1									
Galipea	(8)		1	1				1	1	3									
Pilocarpus	(20)																		
Ravenia	(18)																		
II. Dictyolomatoideae																			
Dictyoloma	(2)																		
III. Flindersoideae																			
Chloroxylen	(1)																		
Flindersia	(20)																		
V. Toddalioideae																			
Acronychia	(40)										1								
Casimiroa	(6)					1	1								1	1	1	1	
Phellodendron	(3)																		
Ptelea	(3)																		
Skimmia	(10)																		
Teclea	(25)																		
Toddalia	(1)																		
Vepris	(20)																		
Halfordia	(1)																		
Hortia	(10)																		
VI. Citroideae																			
Aegle	(1)																		
Citrus	(60)																		
Clausena	(30)																		
Glycosmis	(40)																		
Murraya	(9)																		
Poncirus	(1)																		
SIMAROUBACEAE																			
II. Simarouboideae																			
Picrasma	(17)																		
Picrolemma	(3)																		
MALPIGHIACEAE																			
Banisteria	(75)																		
Cabi	(1)																		
Banisteriopsis	(100)																		

I (cont'd.)

															A. Simple				Quinolines		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
AE																					
toideae																					
hoisya (7)																					
vodia (120)																		1			
agara (200)											1								2		
eijera (7)																					
edicosma (1)																					
elicope (50)																					
rixa (1)																					
latydesma (3)										1											
entaceras (1)																					
alfourdendron (1)																					
unasia (10)														2							
anthoxylum (15)																					
oenninghausenia (1)																					
ictamnus (2)																					
uta (60)				1																	
hamnosma (6)												1	1								
aplophyllum (70)																					
oronia (60)	1																				
riostemon (30)																					
hebalium (36)																					
eleznowia (3)																					
usparia (25)									1												
alipea (8)		1	1				1	1	3												1
ilocarpus (20)																					
avenia (18)																					
ctyolomatoideae																					
ictyoloma (2)																					
lindersoideae																					
hloroxylen (1)																					
lindersia (20)																					
ddalioideae																					
cronychia (40)										1											
asimiroa (6)					1	1								1	1	1	1				
hellodendron (3)																					
telea (3)																					
kimmia (10)																					
eclea (25)																					
oddalia (1)																					
epris (20)																					
alfordia (1)																					
ortia (10)																				1	
troideae																					
egle (1)																					
itrus (60)																					
lausena (30)																					
lycosmis (40)																					
urraya (9)																					
oncirus (1)																					
UBACEAE																					
maroubοideae																					
icrasma (17)																					
icrolemma (3)																					
HIACEAE																					
anisteria (75)																					
abi (1)																					
anisteriopsis (100)																					

A.	Simple				Quinolines																						
14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	1	2	3	4	5	6
																						1				1	
				1																							2
					2																						
																							1				
																											1
														1													1
2											1		1				1	1									
																											3
																											1
																											1
										1	1										1						1
																											1
																											1
							1	1	1						1	1	1		1	1							
																											5
																						1	1	1	1		
1	1	1	1																								1
												1															1
																											2
						1																					1
																											1
																					1						

X. Quinoline Group

B. Furoquinolines and Related Alkaloids

2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
			1							1																				
				2			1	1	2	1	1																1	4		
												1																		
												1																		
1																														
				1					1																		1	1	1	
									1																			1		
				1									1						1		1									
																		1		1		1	1				1	1		1
				3								1																		
				1																										
				1								1																		
				1								1																1		
												1																		
				1	2	1				1		2		1	2	1	1									1				
				1					1			1																1		
									1																					
												1																		
				5									7	1										1				4		
1	1	1																										1		
				1								1																		
				1																					1			2		
				2																										
													1																	
													1															1		
				1								1																		
				1								1																		
												1																1		

e Group

Furoquinolines and Related Alkaloids

18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
											1	4										
											1	1	1									
												1										
			1		1												1					1
		1		1		1	1				1	1		1	2	1		3	1	2		
												1										
1	1									1												
																						5
												1										
																					1	2
								1				4										
												1										
									1			2									1	
												1									1	
												1										

Simple			Quinolines																									
16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	1	2	3	4	5	6	7	8	9
																				1				1				
		1																							2			1
			2																									
																					1							
																									1			
												1													1			
									1		1				1	1												
																									3			
																									1			
																									1			
								1	1										1						1			
																									1	2	1	
																									1			
					1	1	1						1	1	1		1	1										
																									5			
																				1	1	1	1					
1	1																								1			
										1															1			
																									2			
				1																					1			
																									1			
																		1										

ines

0	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	1	2	3	4	5	6	7	8	9	10	11	12
																1				1							1
																					2			1	1	2	1
																	1										
																					1					1	
																										1	
								1													1						
					1		1				1	1															
																					3						
																					1						
																					1						
				1	1										1						1						
																					1	2	1				1
																					1					1	
																										1	
	1	1	1						1	1	1		1	1													
																					5						
																1	1	1	1								
																					1						
						1															1						
																					2						
1																					1						
																					1						
														1													

X. Quinoline Group

B. Furoquinolines and Related Alkaloids

2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
			1							1																			
				2			1	1	2	1	1																1	4	
												1																	
												1																	
1																													
				1					1																		1	1	1
									1																			1	
				1									1						1		1								
																		1		1		1	1				1	1	
				3								1																	
				1																									
				1								1																	
				1								1																1	
												1																	
				1	2	1				1		2		1	2	1	1									1			
				1					1			1																1	
									1																				
												1																	
				5									7	1										1				4	
1	1	1																										1	
				1								1																	
				1																					1			2	
				2																									
													1																
													1															1	
				1								1																	
				1								1																	
												1																1	

ːelated Alkaloids

25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
				1	4																				
																									1
																	1								
				1	1	1														1			1		
					1													1						1	1
										1					1	1					1				
1				1	1		1	2	1		3	1	2									1			
																									1
					1																				
			1																						
															5										
					1																				
														1	2	1									
	1				4																				
					1																				
		1			2									1				1							
					1									1											
																			1						
					1																				

39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	C 1
																	1	
																	7	
											1	1					1	
			1															
																	1	
						1			1								1	
				1						1	1							
	1	1					1						1	1	1		1	
								1									1	
											1						4	
																	2	
																	1	
																	1	
																1	5	
																	1	
	5																4	
																	1	
																	1	
1	2	1															1	
																	5	
																	1	
																	1	
1				1													3	
																	3	
																	1	
1																	1	
					1												1	
																	1	
																	2	
																	1	
																	1	
																	1	
																		1

138

APPENDIX VII

The Distribution of Saponins in the Rutales
(from Amarasingham *et al*, 1964)

Genus	saponins Present	Absent
Rutaceae		
Xanthoxylum		-2
Glycosmis	+1	
Micromelum		-1
Luvunga	+1	
Atalantia		-1
Cneoraceae		
Simaroubaceae		
Eurycoma		-1
Picrodendraceae		
Burseraceae		
Triomma		-1
Canarium		-2
Dacryodes		-2
Santiria		-1
Meliaceae		
Walsura		-1
Aphanamixis		-2
Amoora?		-1
Aglaia?		-6
Chisocheton	+2	-2
Dysoxylum	+I	-4
Akaniaceae		
Malpighiaceae		
Hiptage		-1
Trigoniaceae		
Vochysiaceae		
Tremandraceae		
Polygalaceae		
Xanthophyllum	+1	-1

139

APPENDIX VIII

The Occurrence of Alkaloids in Rutales

(from Li and Willaman, 1968)

	% of alkaloid plants in those tested	Approx. no. of species in family	Species tested for Alkaloids	
			Positive	Negative
Rutaceae	60%	1,300	181	103
Cneoraceae				
Simaroubaceae	50%	200	14	13
Picrodendroaceae				
Burseraceae	20%	600	2	7
Meliaceae	40%	800	20	29
Akaniaceae	100%	1	1	-
Malpighiaceae	30%	850	7	14
Trigoniaceae				
Vochysiaceae				
Tremandraceae	50%	30	1	1
Polygalaceae	50%	700	3	3

APPENDIX IX

Distribution of Phenolic Constituents (by genera) in I

(From Bate-Smith, 1957; 1962)*

		Anatomical data		Leucoant	
		Tannin	L-A Reaction	D	(
RUTACEAE		-5/5 +7/8	-8/8 +7/8	-10/12 +5/5	-1(+4,
I. Choisya	(7)	-1	-1	-1	-1
Evodia	(120)	+1	+1	+1	+1
Zanthoxylum	(15)	+2	+2,-1	-2	+2
Boronia	(60)		+1	+1	-1
Correa	(11)	+1	+1	+1	+1
Crowea	(4)	+1	+1	+1	+1
Eriostemon	(30)	+1	+1	-1	-1
Coleonema	(6)	+1	+1	+1	?
V. Phellodendron	(10)			-1	-1
Ptelea	(3)	+1	-1	-2	-2
Skimmia	(10)	-1	-1	-1	-1
VI. Citrus	(60)	-1	-1	-1	-1
Glycosmis	(40)			-1	-1
Murraya	(9)	-1	-1	-1	-1
Poncirus	(1)	-1	-1	-1	-1
CNEORACEAE		-1/1	-1/1	-1/1	-1,
Cneorum	(2)	-1	-1	-1	-1
SIMAROUBACEAE		+1/1	+1/1	-2/4	-2,
Quassia	(40)			-1	-1
Ailanthus	(10)	+1	+1		1?
BURSERACEAE					+1,
Protium	(2)				+2
MELIACEAE		+2/2	+1/1,-1/1	-3/4	-2/2,-
Cedrea	(7)			-2	+2
Swietenia	(5)	+1	+1		
Melia	(9)	+1	-1	-1	-1
Aitonia	(1)			-1	-1
MALPIGHIACEAE		-1/1,+2/2	-1/1,+2/2	-4/4	-2/2,-
Heteropteris	(90)	-1	-1	-1	-1
Hiptage	(25)	+1	+1	-1	+1
Malpighia	(30)	+1	+1(L.P)	-1	-1
Tristellateia	(22)			-1	+1
TREMENORACEAE			-1/1	-2/2	-2,
Platytheca	(1)		-1	-1	-1
Tetratheca	(25)			-1	-1
POLYGALACEAE		-1/1	-1/1	-1/1	-1,
Polygala	(500)	-1	-1	-1	-1

*Fractions represent numbers of compounds/species

Key to symbols: D = Leuco-delphinidin K = kaempfe
Cy = Leuco-cyanidin E = ellagic
M = myricetin Caff.= caffeic
Q = Quercetin

y genera) in Rutales

962)*

	Chemical data						
	Leucoanthocyanins			Flavonols		Phenolic acids	
on	D	Cy	M	Q	K	E	Caff.
	-10/12	-10/11	- /	-4/4	-4/4	-12/13	-7/7
	+5/5	+4/10	+5/5	+9/10	+8/8		+5/6
	-1	-1	-1	+1	+1	-1	+1
	+1	+1	+1	+1	+1	-1	-1
	-2	+2	-2	+2	+1,-1	-2	+2
	+1	-1	+1	+1	+1	-1	-1
	+1	+1	+1	+1	+1	-1	-1
	+1	+1	+1	+1	+1	-1	-1
	-1	-1	-1	-1	-1	-1	-1
	+1	?	+1	+1	+1		
	-1	-1	-	+1	?	-1	+1
	-2	-2	-1	+1	+1	-1	+1
	-1	-1					
	-1	-1	-1	-1	?	-1	-1
	-1	-1	-1	-1	-1	-1	-1
	-1	-1		-1	-1	-1	+1
	-1	-1					
	-1/1	-1/1	-1/1	+1/1	+1/1	-1/1	-1/1
	-1	-1	-1	+1	+1	-1	-1
	-2/4	-2/3	-2/4	-1/1,+1/3	+1/3, -1/1	+2/3	+1/2,-2/2
	-1	-1	-1	-1	-1	+1	-1
		1?		+3	+3	+2	-1,+2
		+1/2		+1/2	+1/2	-1/2	+1/1,-1/1
		+2		+2	+2	-2	-1,+1
1	-3/4	-2/2,+1/2	-3/4	+3/4	+2/3,-1/1	-3/4	+2/2,-1/1
	-2	+2	-2	+2	+2	-2	+1
	-1	-1	-1	+1	+1	-1	+1
	-1	-1	-1	+1	-1	-1	-1
/2	-4/4	-2/2,+2/2	-4/4	-3/3,+1/1	-2/2,+2/2	-4/4	-2/2
	-1	-1	-1	+1	+1	-1	+1
	-1	+1	-1	-1	-1	-1	
P)	-1	-1	-1	-1	-1	-1	-1
	-1	+1	-1	-1	+1	-1	-1
	-2/2	-2/2	+2/2	+1/1	-2/2	1/1,+1/1	-1/1
	-1	-1	+1	+1	-1	-1	-1
	-1	-1	+1	?	-1	+1	
	-1/1	-1/1	-1/4	-1/1,+1/3	-1/2,+1/2	-1/4	+2/2,-2/2
	-1	-1	-4	+3,-1	+2,-2	-4	-2,+2

s/species

K = kaempferol
E = ellagic
Caff.= caffeic acid

APPENDIX X

Cyanogenesis in Rutales (from Gibbs (MSS))

Family	Others +	Others ?	Others -	Gibbs +	Gibbs ?	Gibbs -
Rutaceae	4/12		18/25	2/3		11/15
Cneoraceae			1/1			1/1
Simaroubaceae						2/3
Picrodendraceae						1/1
Burseraceae	1/2		1/1			
Meliaceae	5/5		2/3		1/1	2/2
Akaniaceae			1/1		1/1	
Malpighiaceae					2/3	2/3
Trigoniaceae						
Vochysiaceae						
Tremandraceae			1/1		2/2	1/3
Polygalaceae			2/4			2/4

* Fraction represent numbers of Genera/Species

#2

APPENDIX XI

The Occurrence of Calcium Oxalate
(from Metcalfe and Chalk, 1950)

	Solitary crystals	Cluster crystals	Styloids	Raphides	Crystal sand
Rutaceae	xx	xx	(x)	(x)	(x)
Cneoraceae	(x)				
Simaroubaceae	x	x	(x)		
Picrodendraceae					
Burseraceae	x	x			
Meliaceae	x	x			
Akaniaceae	(x)	x			
Malpighiaceae	x	x	x		
Trigoniaceae	x	x			
Vochysiaceae	x	x			
Tremandraceae	x	x			
Polygalaceae	x	x			

Key to symbol: ( )= limited in distribution

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58

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Appendix II Paper chromatographic results of phenolic acids and coumarins in "Rutales" (by writer and Galang) (Numbering as in Key)

	I										II			III											IV			
	1	2	3	4	5	6	7	8	9	10	1	2	3	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4
RUTACEAE																												
I. Melicope ternata	-	+	-	+	-	-	-	-	-	-	-	-	-	+	+	+	++	+	-	-	-	-	-	-	-	-	-	+
Evodia Danielli	+	-	-	-	-	-	-	-	-	Tr	-	-	-	-	+	++	+	+	-	-	-	-	-	-	+	-	-	-
Evodia Henryi	-	-	-	+	-	-	-	-	-	-	-	-	-	-	+	++	+	-	-	-	-	-	-	-	+	-?	-	+
Orixa japonica	-	-	-	+	-	-	-	-	+	-	-	-	-	-	+	++	+	-	-	-	-	-	-	-	-	-	-	-
Zanthoxylum americanum	+	-	-	+	+	-	-	-	-	-	-	-	-	+	+	++	++	++	+	+	-	+	-	+	+	+	-	+
Dictamnus albus	-	-	-	Tr	-	-	-	-	-	-	-	-	-	-	+	Tr	Tr	+	-	-	-	-	-	-	-	-	-	-
Ruta graveolens	-	-	+?	-	-	-	-	-	-	-	-	-	-	-	+	-	+?	+?	-	-	-	-	-	-	Tr	-	-	-
Ruta bracteosa	-	+	+	+	-	-	-	-	-	-	-	-	-	+	+	+	++	+	-	-	-	-	-	-	-	-	-	-
Boronia denticulata	-	-	-	Tr	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	+	-	-	-
Boronia lanagmusa	+?	-	-	+	-	-	-	+	-	-	-	-	-	-	+	+	+	+	-	-	-	-	-	-	+++	-	-	-
Boronia purdiana	+?	-	-	+	-	-	-	+	-	-	-	-	-	-	++	+	+	+	-	-	-	-	-	-	+++	-	-	-
Boronia viminea	-	-	-	+?	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	+	-	-	-
Eriostemon spicatum	-	-	-	+	-	-	-	Tr	Tr	-	-	-	-	-	Tr	-	+	+	-	-	-	-	-	-	++	-	-	-
Nematolepis phebalioides	-	-	-	-	-	-	-	Tr	-	-	-	-	-	-	+++	Tr?	+++	-	-	-	-	-	-	-	+++	-	-	+
Diplolaena angustifolia	-	-	-	-	-	-	-	+	-	Tr	-	-	-	-	-	Tr?	+	+?	-	-	-	-	-	-	+	-	-	Tr
Calodendrum capense	-	-	-	-	-	-	-	-	-	-	-	-	-	-	++	+	+	-	-	-	-	-	-	-	-	-	-	-
Barosma scoparia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	-	-	-	-	-	-	++	-	-	-
Coleonma album	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	Tr?	Tr	+	-	-	-	-	-	-	+	-	-	+++
Coleonema pulchrum	-	-	-	+?	-	-	-	Tr	-	Tr		-	-	-	+	+	+	+	-	-	-	-	-	-	+++	-	-	+
Diosma ericoides	-	-	-	+?	-	-	-	-	-	-	-	-	-	-	Tr	Tr	+	+	-	-	-	-	-	-	+	-	-	+
Pilocarpus pennatifolius	-	-	-	-	-	-	-	Tr	+?	-	-	-	-	-	+	+	+	+	-	-	-	-	-	-	+	-	-	+?
Erythrochiton brasiliensis	-	-	-	+?	-	-	-	++	++	-	-	-	-	-	-	++	+++	+++	-	-	-	-	-	-	+	+	-	-
V Phellodendron japonicum	+	+	-	Tr	-	-	-	-	-	-	-	-	-	-	++	++	++	-	-	-	-	-	-	-	+	+?	-	+
Phellodendron lavallei	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	Tr?	-	-	-	-	-	-	-	-	-	-	-
Ptelea trifoliata	+	+	+	+	+	-	-	+	++	-	-	-	-	+	++	++	++	+	-	-	+	-	-	+	+	+	-	-
Casimiroa edulis	-	-	-	Tr?	-	-	-	-	-	+	-	-	-	-	+	+	++	+	-	-	-	-	-	-	+	-	-	-
Skimmia reevesiana	-	-	-	Tr	-	-	-	-	+++	-	-	-	-	-	+	Tr	+	+	-	-	-	-	-	-	-	-	-	+
Teclea simplicifolia	-	-	-	+	-	-	-	-	+	-	-	-	-	-	+	+	+	++	-	-	-	-	-	-	-	+++	-	-
VI Glycosmis pentaphylla	+	-	-	+	-	-	+	+	+	-	-	-	-	-	++	+	++	++	-	-	-	-	-	+	+	-	-	-
Murraya exotica	-	-	-	+	-	-	-	+	-	-	-	-	-	-	+	+	+++	+?	+?	-	-	-	-	-	+	-	-	+?
Triphasia trifolia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Tr	Tr	+	+	-	-	-	-	-	-	+	-	-	+
Atalantia ceylanica	-	-	-	+?	+	-	-	+	-	+	-	-	+	+	++	++	++	++	-	-	-	-	-	-	+	-	-	+

Melicope ternata	-	+	-	+	-	-	-	-	-	-	-	-	-	+	+	+	++	+	-	-	-	-	-	-	-	-	-	+
Evodia Danielli	+	-	-	-	-	-	-	-	-	Tr	-	-	-	-	+	++	+	+	-	-	-	-	-	-	+	-	-	-
Evodia Henryi	-	-	-	+	-	-	-	-	-	-	-	-	-	-	+	++	+	-	-	-	-	-	-	-	+	-?	-	+
Orixa japonica	-	-	-	+	-	-	-	-	+	-	-	-	-	-	+	++	+	-	-	-	-	-	-	-	-	-	-	-
Zanthoxylum americanum	+	-	-	+	+	-	-	-	-	-	-	-	-	+	+	++	++	++	+	+	-	+	-	+	+	+	-	+
Dictamnus albus	-	-	-	Tr	-	-	-	-	-	-	-	-	-	-	+	Tr	Tr	+	-	-	-	-	-	-	-	-	-	-
Ruta graveolens	-	-	+?	-	-	-	-	-	-	-	-	-	-	-	+	-	+?	+?	-	-	-	-	-	-	Tr	-	-	-
Ruta bracteosa	-	+	+	+	-	-	-	-	-	-	-	-	-	+	+	+	++	+	-	-	-	-	-	-	-	-	-	-
Boronia denticulata	-	-	-	Tr	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	+	-	-	-
Boronia lanagmusa	+?	-	-	+	-	-	-	+	-	-	-	-	-	-	+	+	+	+	-	-	-	-	-	-	+++	-	-	-
Boronia purdiana	+?	-	-	+	-	-	-	+	-	-	-	-	-	-	++	+	+	+	-	-	-	-	-	-	+++	-	-	-
Boronia viminea	-	-	-	+?	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	+	-	-	-
Eriostemon spicatum	-	-	-	+	-	-	-	Tr	Tr	-	-	-	-	-	Tr	-	+	+	-	-	-	-	-	-	++	-	-	-
Nematolepis phebalioides	-	-	-	-	-	-	-	Tr	-	-	-	-	-	-	+++	Tr?	+++	-	-	-	-	-	-	-	+++	-	-	+
Diplolaena angustifolia	-	-	-	-	-	-	-	+	-	Tr	-	-	-	-	-	Tr?	+	+?	-	-	-	-	-	-	+	-	-	T
Calodendrum capense	-	-	-	-	-	-	-	-	-	-	-	-	-	-	++	+	+	-	-	-	-	-	-	-	-	-	-	-
Barosma scoparia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	-	-	-	-	-	-	++	-	-	-
Coleonma album	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	Tr?	Tr	+	-	-	-	-	-	-	+	-	-	++
Coleonema pulchrum	-	-	-	+?	-	-	-	Tr	-	Tr	-	-	-	-	+	+	+	+	-	-	-	-	-	-	+++	-	-	+
Diosma ericoides	-	-	-	+?	-	-	-	-	-	-	-	-	-	-	Tr	Tr	+	+	-	-	-	-	-	-	+	-	-	+
Pilocarpus pennatifolius	-	-	-	-	-	-	-	Tr	+?	-	-	-	-	-	+	+	+	+	-	-	-	-	-	-	+	-	-	+
Erythrochiton brasiliensis	-	-	-	+?	-	-	-	++	++	-	-	-	-	-	-	++	+++	+++	-	-	-	-	-	-	+	+	-	-
Phellodendron japonicum	+	+	-	Tr	-	-	-	-	-	-	-	-	-	-	++	++	++	-	-	-	-	-	-	-	+	+?	-	+
Phellodendron lavallei	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	Tr?	-	-	-	-	-	-	-	-	-	-	-
Ptelea trifoliata	+	+	+	+	+	-	-	+	++	-	-	-	-	+	++	++	++	+	-	-	+	-	-	+	+	+	-	-
Casimiroa edulis	-	-	-	Tr?	-	-	-	-	-	+	-	-	-	-	+	+	++	+	-	-	-	-	-	-	+	-	-	-
Skimmia reevesiana	-	-	-	Tr	-	-	-	-	+++	-	-	-	-	-	+	Tr	+	+	-	-	-	-	-	-	-	-	-	+
Teclea simplicifolia	-	-	-	+	-	-	-	-	+	-	-	-	-	-	+	+	+	++	-	-	-	-	-	-	-	+++	-	-
VI Glycosmis pentaphylla	+	-	-	+	-	-	+	+	+	-	-	-	-	-	++	+	++	++	-	-	-	-	-	+	+	-	-	-
Murraya exotica	-	-	-	+	-	-	-	+	-	-	-	-	-	-	+	+	+++	+?	+?	-	-	-	-	-	+	-	-	+
Triphasia trifolia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Tr	Tr	+	+	-	-	-	-	-	-	+	-	-	+
Atalantia ceylanica	-	-	-	+?	+	-	-	+	-	+	-	-	+	+	++	++	++	++	-	-	-	-	-	-	+	-	-	+
Citrus limetta	-	-	-	+?	-	-	-	+	-	-	-	-	-	-	+++	+	+++	+	-	-	-	-	-	-	+	-	-	+
Citrus limonia	-	-	-	-	-	-	-	+	-	-	-	-	-	-	+++	+	++	Tr	-	-	-	-	-	-	+	-	-	-
Limonia trifolia	-	-	-	Tr?	-	-	-	-	-	-	-	-	-	-	+	-	++	++	-	-	-	-	-	-	Tr	+	-	-
Feronia limonia	-	-	-	+?	-	-	-	+	-	+?	-	-	-	-	+	+	+	+	-	-	-	-	-	-	+	-	-	-
Fortunella margarita	+	-	-	+	-	-	-	+	-	-	-	-	+	+	++	+	++	++	+	-	+	-	+	+	-	-	-	-