COMPARATIVE CHEMISTRY AND TAXONOMY

OF THE

"HAMAMELIDALES"

by

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INTRODUCTION

Present day systematists have at least 150,000 species of angiospermous plants to deal with. Obviously, this large number must be divided into smaller groups, and several methods have been devised to separate them. The earliest workers used rather simple characters, resulting in very arbitrary divisions. For example, Theophrastus recognized trees, shrubs, under-shrubs and herbs. However, one modern taxonomist also uses this sort of division. Hutchinson (1926, 1948, 1959) divides the dicotyledons and monocotyledons into two main lines of development; i.e., the "Lignosae", or woody line, and the "Herbaceae" or herbaceous line.

In more recent times, morphological characters such as leaf shape and flower color have been used to delimit groups of plants, but the use of such characters results in arrangements which are largely artificial. Keys using such characters enable one to determine the identity of a plant, but give few clues as to its affinities.

The aim of systematists has been to develop a truly phylogenetic system, that is, one which takes into account the evolutionary histories of the taxa considered, dealing with their origins and probable courses of development. It is unlikely that a completely phylogenetic system will ever appear, but if it should, it will probably be too unwieldy for practical classification.

The greatest stumbling block in creating a phylogenetic system is that our knowledge of palaeobotany is incomplete and

will remain so. To compensate for this deficiency, hypotheticla ancestral groups, such as Engler's "Protangiospermae" and the "Hemiangiospermae" of Arber and Parkin have been proposed, but they are too much founded on conjecture to permit one to use them as a basis of comparison.

The most important problem in creating a phylogenetic system is that of determining how closely particular groups of plants are related. There is, however, a secondary problem which logically arises from the first. That is, at which level should closely related plants be placed? Should two plants be regarded as species of a single genus, or as separate genera, placed next each other in a system of classification?

As manifested at higher levels, the problem is more difficult to solve. Should two groups of plants be treated as families in one order, or as separate orders, near both spacially and temporally? Solution of such problems is largely a matter of judgment, and is of rather minor importance, as long as the relationships between groups of plants can be recognized.

In general, those characters most used by systematists have been morphological, anatomical and embryological. "Embryological" is here used in a broad sense, referring not only to characters of the embryo itself, but also to those of the surrounding tissues, and to those characters appearing during the course of embryogenesis.

For specific problems, other disciplines, such as palaeontology, palynology and cytology have been called into use, but they have not been used in considering large groups of plants.

In spite of the use of all these, no truly natural scheme has yet appeared. Two systems, both purporting to be phylogenetic, may be compared in regard to treatment of the <u>Tubiflorae</u>. Pulle(1950) places in the Sympetalae an order <u>Tubiflorae</u> in which he includes twenty-five families. Hutchinson (1959) recognizes twenty-four of these families, as well as four segregates, but distributes them among nine orders, five of which he considers to be evolutionary ends. Furthermore, these nine orders are divided between Hutchinson's two main lines of development, the "Lignosae" and the "Herbaceae".

In an effort to establish a natural classification, syssematists have curned to other types of characters. One possible tool, which has been ignored by the majority of taxonomists, is comparative chemistry. Most of the work relating chemistry and taxonomy has been done by those interested in pharmacognosy and similar fields.

Chemical characters can be considered to be an expression of genetic constitution. In light of what is known of genetic control of certain chemical characters, such as anthocyanins, it does not seem illogical to assume that those plants most closely related, that is, most recently split off from a common ancestor, would show the closest correspondences in chemical characters.

A corollary of this hypothesis is that chemical differ-

ences between taxa are strong grounds for separating them, especially if this separation is supported by other types of evidence. The validity of this assumption has been proved in several cases, some of which will be discussed later.

Of course, comparative chemistry should not be used as the sole basis for a system of classification. However, it is certainly just as good a criterion as any of those previously mentioned, and used in addition to them, may help in solving some taxonomic problems.

There are a number of approaches to comparative chemistry. One compound , characteristic of a genus or group of genera, may be selected and its distribution traced throughout those plants which have been thought to be allies of the original plant or plants. To a limited extent, this has been done in the work described in this thesis.

An intensive study of a smaller taxon may be made; for example, a single genus may be investigated. In this case, the most profitable line of approach is to deal with as many biochemical characters as possible, establishing a type biochemical pattern for the genus. All species investigated are compared with the pattern; the number and the types of departures from the pattern may be of significance.

A third method is to pick certain characters and to follow their distribution throughout as many families and orders as possible. An investigation of this nature requires that the number of characters be limited, in order that a comparatively large number of plants may be tested. It is also essential

that the tests be simple, not time-consuming, and readily reproducible. This approach was used in the present study.

The widely used system of Adolf Engler, embodied in the two editions of "Die naturlichen Pflanzenfamilien, considers the most primitive dicotyledons to be the "Amentiferae", plants generally having simple anemophilous flowers borne in aments or catkins. Engler did not feel that the amentifers compose a natural group, but maintained that each of the families had arisen separately from a hypothetical ancestral group, the "Protangiospermae".

However, these views of the amentifers have been attacked by taxonomists such as Hutchinson, Tippo and Takhtajan, who believe that many of the amentiferous families, rather than being primitive, are highly reduced derivatives of hamamelidalian ancestors. The <u>Hamamelidaceae</u> themselves, have been thought to be reduced derivatives of rosalian or magnolialian ancestors.

In this discussion, Harms' (1930) arrangement of the Hamamelidaceae has been followed.

The family <u>Hamamelidaceae</u> is a rather small group of relic genera. The main centre of distribution is south-eastern Asia, including Japan and the Philippine Islands, while a secondary centre is the south-eastern United States, where species of <u>Fothergilla</u>, <u>Liquidambar</u> and <u>Hamamelis</u> occur. Scattered representatives are found in South Africa (<u>Trichocladus</u>), Madagascar and the Comora Islands (<u>Dicoryphe</u>), Asia Minor and the Caucasus (<u>Parrotia</u>) and <u>Queensland</u> (<u>Ostrearia</u>). Fossil evidence shows that the family had a wide distribution during

the Miocene. The present scattered distribution appeared after the last glaciation.

The members of the <u>Hamamelidaceae</u> are trees, such as <u>Liquidambar</u>, or shrubs, such as <u>Hamamelis</u>. There is great diversity in floral morphology. Flowers may be bisexual or unisexual; in the latter case, the plants are usually monoecious. Within the sub-family <u>Hamamelidoideae</u>, <u>Distylium</u> is hypogynous, <u>Trichocladus</u> is perigynous, and <u>Loropetalum</u> is epigynous. Moreover, transitional stages may be seen. The number of fertile stamens per flower ranges from two (<u>Distylium</u>) to twenty-five (Fothergilla).

Engler treated the <u>Hamamelidaceae</u> as a family of the <u>Rosales</u>, but several writers have considered the family to be the type of an order <u>Hamamelidales</u>. Because the <u>Hamamelidaceae</u> have often given a central position in schemes of classification, it was thought that it would be of interest to determine the chemical characters of the family, and to try to find which concept of the order is best supported by the chemical evidence.

In addition to those families which have at one time or another been placed in the <u>Hamamelidales</u>, other groups, such as the <u>Rosaceae</u> and several of the amentiferous families have been dealt with, for they have often been placed near the <u>Ha-</u> <u>mamelidaceae</u>.

REVIEW OF LITERATURE

(i) The order Hamamelidales

An order <u>Hamamelidales</u> was established in the first edition of his "Handbuch der systematischen Botanik" by Richard von Wettstein, who considered the order to form a transitional group between the Monochlamydeae and the Dialypetalae. He included in the order only two families, the <u>Hamamelidaceae</u> [as recognized by Niedenzu (1891)] and the <u>Platanaceae</u>, but said that the families <u>Cercidiphyllaceae</u>, <u>Eucommiaceae</u> and <u>Eupteleaceae</u> are quite closely related to the <u>Hamamelidaceae</u>.

von Wettstein said that the <u>Hamamelidales</u> show many primitive characters, a fact which militates against placing these families in the <u>Rosales</u>, in spite of the similarities in structure of the gynoecium. According to von Wettstein, the presence of so many primitive characters indicates a close relationship between the <u>Hamamelidales</u> and the <u>Urticales</u>. He suggested that the members of the <u>Hamamelidaceae</u> are so sharply distinguished that a further splitting into families might be warranted.

In later editions of his "Handbuch", Wettstein modified his ideas somewhat. In the third edition (1924), he included the <u>Cercidiphyllaceae</u>, <u>Eucommiaceae</u> and <u>Eupteleaceae</u> within the <u>Hamamelidales</u>. In the fourth edition (1935), he removed the <u>Eucommiaceae</u> to the <u>Urticales</u>, and added the <u>Myrothamnaceae</u> to the <u>Hamamelidales</u>.

From the first edition of the "Handbuch" one may conclude

that Wettstein considered the amentiferous families to be the most primitive dicotyledons; he suggests that the <u>Rosales</u> and <u>Polycarpicae</u> $\begin{bmatrix} Ranales \\ Ranales \\ (s.l.) \end{bmatrix}$ have been derived from hamamelidalian ancestors.

In 1912 Hallier described an order <u>Hamamelinae</u> in which he placed two families, the <u>Hamamelidaceae</u> [including such diverse plants as <u>Eucommia</u>, <u>Euptelea</u>, <u>Cercidiphyllum</u>, <u>Trochodendron</u>, <u>Tetracentron</u>, <u>Daphniphyllum</u>, <u>Balanops</u>, <u>Platanus</u>, <u>Myrothamnus</u>, <u>Croton curtiflorus</u> Elmer, <u>Mallotus campanulatus</u> Koorders, the <u>Buxaceae</u>, and <u>Geissoloma</u>], and the <u>Coriariaceae</u> which he derived from the <u>Hamamelidaceae</u> in the vicinity of the <u>Buxaceae</u>. <u>Didymeles</u> Thou. and <u>Batis</u> L. he doubtfully placed in the <u>Hamamelidaceae</u>.

Hallier believed this order to be derived from the <u>Magno-</u><u>liaceae</u> near the <u>Illicineae</u>, and thought that it gave rise to the <u>Umbelliflorae</u> (<u>Cornaceae</u> and <u>Umbelliferae</u>).

The British botanist Hutchinson, in the first edition of his "Families of Flowering Plants" (1926), places an order <u>Hamamelidales</u>, including the <u>Hamamelidaceae</u>, <u>Bruniaceae</u>, <u>Eucommiaceae</u>, <u>Stachyuraceae</u>, <u>Myrothamnaceae</u>, <u>Buxaceae</u> and <u>Platanaceae</u>, as a link between the <u>Rosales</u> and "Amentiferae".

These families can be grouped together, he says, because of similarities in having such characters as actinomorphic flowers, often collected into heads or catkins, and generally bicarpellate ovaries.

In "British Flowering Plants" (1948), Hutchinson still

considers the <u>Hamamelidales</u> to stand between <u>Rosales</u> and "Amentiferae", as shown in the following diagram:



It should be noted that in this work Hutchinson is dealing only with British plants, so one cannot exactly determine his concept of the <u>Hamamelidales</u>.

The order <u>Hamamelidales</u> as defined in the second edition of "Families of Flowering Plants" (1959), differs from that of 1926 in that the <u>Tetracentraceae</u> and <u>Daphniphyllaceae</u> are added to the order, while the <u>Eucommiaceae</u> are removed to the <u>Urticales</u>.

Hutchinson's ideas concerning the <u>Hamamelidales</u> have not changed much. He has a rather broad concept of the order and considers it to form a link between the <u>Rosales</u> and "Amentiferae". The increasing reduction and specialization of the inflorescence in the hamamelidalian families, which chiefly distinguishes them from the <u>Rosales</u>, culminates in the much reduced amentiferous orders <u>Leitneriales</u>, <u>Myricales</u>, <u>Balanopsidales</u>, <u>Fagales</u>, <u>Juglandales</u>, and <u>Casuarinales</u>, the last named order being the climax of this series.

An order <u>Hamamelidales</u> was described by Tippo (1938), who included in it the <u>Hamamelidaceae</u>, <u>Platanaceae</u> and <u>Myrothamna-</u> ceae. He adds that the <u>Stachyuraceae</u> and <u>Buxaceae</u> might well be included in this order. In this paper, Tippo was investigating anatomical characters, and on the strength of these characters, he considered the <u>Platanaceae</u> to be the most advanced family of the order.

Tippo's views on the relationships of the <u>Hamamelidales</u> may best be shown diagrammatically:



Pulle (1952) recognizes an order <u>Hamamelidales</u> in which he places the <u>Hamamelidaceae</u> and <u>Platanaceae</u>. He considers the order to be derived from the <u>Ranunculales</u>, as shown in the diagram below:



Gundersen (1950) places an order <u>Hamamelidales</u>, including the <u>Hamamelidaceae</u>, <u>Myrothamnaceae</u>, <u>Stachyuraceae</u>, <u>Bruniaceae</u>, <u>Cunoniaceae</u>, <u>Pittosporaceae</u>, <u>Byblidaceae</u>, <u>Hydrangeaceae</u>, <u>Saxifragaceae</u>, <u>Podostemaceae</u> and <u>Hydrostachyaceae</u>, in a super-order Rosiflorae, in which are also put the <u>Rosales</u>, <u>Thymelaeales</u> and <u>Myrtales</u>. Gundersen derived the Rosiflorae from a super-order Magnoliflorae.

He separates the <u>Rosales</u> from the <u>Hamamelidales</u> on the grounds that the families in the latter order have fused carpels and seeds containing a small embryo in abundant endosperm. He admits, however, that the separation is not clear.

Gundersen's concept of the <u>Hamamelidales</u> is rather wider than those discussed before, particularly in including the highly specialized families <u>Hydrostachyaceae</u> and <u>Podostema-</u> <u>ceae</u>. His views on the systematic position of the order are essentially the same as those of Hutchinson, Tippo and Pulle.

> "Ulmus group" Rosiflorae

Magnoliflorae

In the "Ulmus group" Gundersen includes several amentiferous families.

Takhtajan (1954) also considers the <u>Hamamelidales</u>, including <u>Hamamelidaceae</u>, <u>Cercidiphyllaceae</u>, <u>Eupteleaceae</u>, <u>Al-</u> <u>tingiaceae</u>, <u>Platanaceae</u>, <u>Myrothamnaceae</u>, <u>Daphniphyllaceae</u>, <u>Bux-</u> <u>aceae</u> and <u>Simmondsiaceae</u>, to be transitional between the Magnoliales and amentifers. He considers the flowers of plants in this group to be highly specialized, showing reduction in number of parts, and says that:

"At present it may be considered as proved that they [Amentiferae] represent the subsequent developement of wind-pollinated Hamamelidales, in which flowers have achieved a still greater simplification whereas the inflorescences have become even more specialised for wind pollination."

Of the amentiferous plants, Takhtajan feels that the <u>Urticales</u>, in particular the <u>Ulmaceae</u>, are closest to the <u>Hamamelidales</u>. He considers <u>Eucommia</u> to form a link between these two orders, but emphasizes that <u>Eucommia</u> does not belong in the <u>Hamamelidales</u>, chiefly because of differences in fruit structure.

Takhtajan's views on the position of the <u>Hamamelidales</u> may be graphically shown in the following manner:



Soo (1953) and Boivin (1956) have both recognized an order <u>Hamamelidales</u>, in each case including six families. They agree in including the <u>Hamamelidaceae</u>, <u>Platanaceae</u>, <u>Myrothamnaceae</u>, <u>Stachyuraceae</u> and <u>Bruniaceae</u>; Soo's sixth family is the Eucommiaceae, while Boivin's is the Buxaceae. Skottsberg (1940, 1956) recognizes an order <u>Hamameli-</u> <u>dales</u> which includes two <u>families</u>, the <u>Hamamelidaceae</u> and <u>Platanaceae</u>. He says that the <u>Rosales</u> and <u>Hamamelidales</u> stand closely together. In Skottsberg's scheme the ten orders following the <u>Hamamelidales</u> are all amentiferous.

Thorne (private communication, 1959) includes in his order <u>Hamamelidales</u> six families; i.e., the T<u>rochodendraceae</u>, <u>Eupteleaceae</u>, <u>Cercidiphyllaceae</u>, <u>Eucommiaceae</u>, <u>Platanaceae</u>, and <u>Hamamelidaceae</u>. He feels that these families have in common too many features to explain other than by descent from a common ancestor. Their flowers are mostly radially symmetrical and bisexual, and the pollen, Thorne says, is remarkably similar for such diverse plants.

Thorne believes that the <u>Hamamelidales</u> are one of the most primitive dicotyledonous: orders and that they are not closely related to the <u>Magnoliales</u>. He says:

"Its [Hamamelidales] phyletic significance lies in its possession of a combination of primitive features and evolutionary tendencies that appear in many modified forms in several larger, more successful orders, such as the Fagales, Rosales, Umbellales, Caprifoliales, and Asterales. The resemblances of the Hamamelidales to the Casuarinaceae, Betulaceae, Fagaceae, Cunoniaceae, Saxifragaceae, Cornaceae, Nyssaceae and Caprifoliaceae are striking and probably significant."

One may thus conclude that those authors who recognize an order <u>Hamamelidales</u> have generally considered it to have arisen from rosalian or magnolialian ancestors, and to have itself given rise to various amentiferous families.

Of course authors who have not recognized an order <u>Hamam</u>-<u>elidales</u> have dealt with the families mentioned in the preceeding pages, and some discussion of the positions in which these families have been placed should be presented.

The first to treat <u>Hamamelis</u> as the type of a family was Robert Brown (1818) who described a group <u>Hamamelidae</u>. He included in this group <u>Hamamelis</u> L., <u>Dicoryphe</u> Thou., and <u>Dahlia</u> Thunb. [<u>Trichocladus</u> Pers.], but added that <u>Fothergilla</u> L. might belong in it, placed in a separate section.

Lindley (1846), who was the first to use the form "<u>Hamam-elidaceae</u>", placed the family, including thirteen genera, following the <u>Cornaceae</u> in his order <u>Umbellales</u>. Oliver (1860) agreed with this positioning, saying that the <u>Hamamelidaceae</u>?

"--- have much in common with Corhaceae (including Alangieae and Nyssa)--- of this order family it may not improbably be regarded as a section---"

In the "Genera Plantarum" (1862-1883), Bentham and Hooker placed a family <u>Hamamelideae</u>, along with the <u>Bruniaceae</u> and <u>Halorageae</u>, in a section of the <u>Rosales</u>, chiefly distinguished from the rest of the order by having pendulous ovules. They said that the <u>Hamamelideae</u> constitute a very natural, although polymorphic group, which can only with difficulty be distinguished from the Saxifragaceae.

In the English edition (1873) of LeMaout and Decaisne's work, it is said that the <u>Hamamelideae</u> approach the <u>Cornaceae</u>,

⁽ii) Families which have been included in the "Hamamelidales"

Araliaceae, <u>Cunoniaceae</u>, <u>Grubbiaceae</u> and <u>Plataneceae</u>, but stand closest to <u>Liquidambar</u>.

Niedenzu (1891), writing in the first edition of "Die naturlichen Pflanzenfamilien", said that the <u>Hamamelidaceae</u>, which ih this work are placed in the <u>Rosales</u>, are closely related to the <u>Saxifragaceae</u>, <u>Cunoniaceae</u> and <u>Bruniaceae</u>. In the second edition, Harms (1930) says that the family appears to be as closely related to the <u>Rosales</u> as to any other order.

Harms' treatment of the family is the most recent with any degree of completeness, and his arrangement of the included genera will be followed in further discussion (see next page).

Harms places <u>Ostrearia</u> Baill. and <u>Mytilaria</u> Lecomte at the end of the family, but assigns them to no sub-family, saying that they are too incompletely known. He considers the sub-families, in the sequence shown, to show progressive reduction in floral characters. Indeed, he says that the sub-family <u>Liquidambaroideae</u> is so much reduced that it might well be treated as a family in its own right.

SUB-FAMILIES	TRIBES	GENERA
I <u>Disanthoideae</u>		Disanthus Maxim.
	Hamamelideae	Hamamelis L. Loropetalum R. Br. Tetrathyrium Benth. Trichocladus Pers. Maingaya Oliv. Embolanthera Merr. Dicoryphe Thou.
	Eustigmateae	<u>Eustigma</u> Gardn. et Champ.
II <u>Hamameli</u> - <u>doideae</u>	Corylopsideae	<u>Corylopsis</u> Sieb.& Zucc. Fortunearia Rehder et Wilson
	Fothergilleae	Parrotia C.A. Mey Parrotiopsis Schneid . Fothergilla L.
	Distylieae	<u>Distylium</u> Sieb. et Zucc. <u>Sycopsis</u> Oliv. <u>Sinowilsonia</u> Hemsl.
III <u>Rhodoleioidea</u>	<u>ae</u>	Rhodoleia Champ. ex Hook.
IV <u>Bucklandioideae</u>		Bucklandia R. Br.
V <u>Liquidambaroideae</u>		Liquidambar L. Altingia Nor.

Division of the family Hamamelidaceae according to Harms (1930)

Dumortier (1829) was the first to treat <u>Platanus</u> L. as the type of a family, <u>Plataneae</u>, which he placed together with the <u>Salicaceae</u>, <u>Myricaceae</u> and <u>Betulaceae</u>. Lindley (1836) was the first to use the more familiar form "<u>Platanaceae</u>"; in the third edition of his "Vegetable Kingdom" (1853), he put a family <u>Platanaceae</u> in the <u>Urticales</u>, and mentioned that the family is related to the <u>Artocarpaceae</u>. Bentham and Hooker (1.c.) placed the family in a series [order] <u>Unisexuales</u>, and said that it stands close to the <u>Urticaceae</u>.

LeMaout and Decaisne (l.c.) have as order [family] 198, the <u>Plataneae</u>, which, they say, stand near the <u>Balsamifluae</u> [<u>Liquidambar</u>]. They say that the <u>Plataneae</u> approach the <u>Hamamelidaceae</u> and also have affinities with the <u>Garryaceae</u>. However, the editor, Hooker, adds a note saying that <u>Platanus</u> is related to the amentiferous families rather than to those just mentioned.

Griggs (1909) who investigated the floral morphology of <u>Platanus</u>, considered it to be apetalous, and suggested that it probably belongs next the <u>Urticales</u>. The floral headw of <u>Platanus</u> he thought similar to those of <u>Artocarpus</u> and <u>Toxylon</u> Raf. [<u>Maclura Nutt.</u>]. Hallier (1912) included <u>Platanus</u> in his family <u>Hamamelidaceae</u>.

Rendle (1938) placed the <u>Platanaceae</u> in the <u>Rosales</u>, next the <u>Hamamelidaceae</u>, but said that <u>Platanus</u> has a perigynous flower with free carpels, which indicates that it is closest

to the sub-family <u>Spiraeoideae</u> of the <u>Rosaceae</u>; Bessey (1915)) and Gundersen (1950) have also placed the <u>Platanaceae</u> in the Rosales.

Thus it seems that the <u>Platanaceae</u> have most often been put into one of three positions; i.e., near the <u>Urtica-</u> <u>ceae</u>, among the amentiferous families, or in the <u>Rosales</u>, that is, near the <u>Hamamelidaceae</u>, according to many systems of classification.

The little genus <u>Myrothamnus</u> Welw. was first placed in a distinct family by Niedenzu (1891b), who put the <u>Myrothamnaceae</u> in the <u>Rosales</u>. Bentham and Hooker (l.c.) in the addenda to the first volume of the "Genera Plantarum", added <u>Myrothamnus</u> at the end of their family <u>Hamamelideae</u>, and apparently intended that it should belong in this family. Baillon (1871-1888) put <u>Myrothamnus</u>, along with <u>Myosurandra</u>, a[°] genus sometimes joined to <u>Myrothamnus</u>, in a tribe <u>Myosurandreae</u> in the <u>Saxifragaceae</u>.

Hallier (l.c.) placed the genus in his <u>Hamamelidaceae</u>, saying that it approaches the tribe <u>Parrotieae</u> [<u>Parrotia</u>, <u>Distylium</u>, <u>Fothergilla</u> and <u>Corylopsis</u>, according to Niedenzu (1891)]. van Tieghem and Constantin (1918) included the family, recognizing two genera, <u>Myrothamnus</u> and <u>Myosur-</u> <u>andra</u>, in an order <u>Piperales</u>.

Bessey (1915) put the family in the <u>Rosales</u> as did Engler and Diels (1936), Pulle (1952), Cronquist (1957) and others. Copeland (1957) has it in an order <u>Juliflorae</u>, along with

the families <u>Hamamelidaceae</u>, <u>Platanaceae</u>, <u>Stacyuraceae</u>, <u>Be-</u> <u>tulaceae</u>, <u>Fagaceae</u> and <u>Casuarinaceae</u>.

Wettstein (1935), as mentioned before, put the family in his order <u>Hamamelidales</u>, but was rather uncertain as to its correct position, saying that it might belong near the <u>Rosales</u>. In fact, he mentions the family both among the <u>Rosales</u> and the <u>Hamamelidales</u>.

Thus, one may conclude that most taxonomists have agreed in placing the <u>Myrothamnaceae</u> among the <u>Rosales</u>.

The <u>Platanaceae</u> and the <u>Myrothamnaceae</u> are the families which have most often been associated with the <u>Hamamelidaceae</u> by those authors who recognize an order <u>Hamamelidales</u>. Of thirteen such authors, eleven have included the <u>Platanaceae</u>, while eight have included the <u>Myrothamnaceae</u>.

The family <u>Stachyuraceae</u> of Gilg (1893) is a small one, including only one genus,<u>Stachyurus</u> Sieb. et Zucc.. Lindley, in the third edition of his "Vegetable Kingdom" (l.c.), included <u>Stachyurus</u> in his family <u>Pittosporaceae</u>, a position in which Siebold and Zuccarini themselves put it.

Bentham and Hooker (l.c.) placed <u>Stachyurus</u>, along with <u>Saurauja</u> Willd. and <u>Actinidia</u> Lindl., in a tribe <u>Sauraujeae</u> in their <u>Ternstroemiaceae</u>, saying that it has particular affinities with <u>Saurauja</u>. They mention that <u>Stachyurus</u> differs from the <u>Pittosporaceae</u> in several important characters of ovary, seed and stamens. In the English edition of LeMaout and Decaisne (l.c.), it is also placed in a tribe <u>Sauraujeae</u> in the <u>Camelliaceae</u>, which family is more or less equivalent to the <u>Ternstroemiaceae</u> of Bentham and Hooker.

Several authors have seen connections between <u>Stachyurus</u> and the <u>Parietales</u>. Baillon (l.c.) found affinities between <u>Stachyurus</u> and his <u>Bixaceae</u>, which latter group includes some of the tribes of the <u>Flacourtiaceae</u> of Gilg (1925).

Gilg, writing in the second edition of "Die naturlichen Pflanzenfamilien", said that the <u>Stachyuraceae</u> show connections with the <u>Actinidiaceae</u> in characters of aril, fruit and seed, but are distinguished by floral characters and anatomical features; e.g., the presence of raphides in the <u>Actinidiaceae</u>. Metcalfe and Chalk (1950) state that cluster crystals are present in <u>Stachyurus</u>, but make no mention of raphides. They say that on anatomical grounds alone it is difficult to decide if the affinities of <u>Stachyurus</u> are with the <u>Flacourtiaceae</u> or the <u>Hamamelidaceae</u>.

Benson (1957) has recently put the <u>Stachyuraceae</u> in an order <u>Violales</u>, along with the <u>Flacourtiaceae</u>, <u>Violaceae</u>, <u>Tur-</u> <u>neraceae</u>, <u>Malesherbaceae</u>, <u>Passifloraceae</u>, <u>Achariaceae</u> and <u>Canellaceae</u>.

Thus it is seen that <u>Stachyurus</u> has been thought related to the <u>Pittosporaceae</u>, <u>Camelliaceae</u>, <u>Flacourtiaceae</u> and <u>Hamam-</u> <u>elidaceae</u>.

The family <u>Bruniaceae</u> was established by Robert **Brown** (1818) who thought it to be related to the <u>Hamamelidaceae</u>. Lindley (1853) put the <u>Bruniaceae</u> in his <u>Umbellales</u>, near the

Hamamelidaceae. Bentham and Hooker (l.c.) placed the family in a similar position.

Baillon (1.c.) had the group as a section <u>Brunieae</u> in the <u>Saxifragaceae</u>. van Tieghem (1898) returned to the earlier views, suggesting that the <u>Bruniaceae</u> belong near the <u>Cornaceae</u> rather than near the <u>Saxifragaceae</u>.

Hallier (1912) doubtfully placed the <u>Bruniaceae</u> in the <u>Rosales</u>, and mentioned that they are related to the <u>Cunonia</u>-<u>ceae</u> and <u>Saxifragaceae</u>. As mentioned before, Hutchinson (1926, 1959), Gundersen (1950), **S**oo (1953) and Boivin (1956) have put the family in an order <u>Hamamelidales</u>.

The family has been placed in the <u>Rosales</u> by several authors, among them Wettstein (1935), who considered it to be of uncertain position. Niedenzu and Harms also included it in the <u>Rosales</u>, but emphasized that the family is very isolated in this position, being set aside by its ericoid habit.

The <u>Buxaceae</u>, first described as a family (<u>Buxineae</u>) by Loiseleur (1819) were placed in the <u>Euphorbiaceae</u> by most of the earlier authors. In Hooker's edition of LeMaout and Decaisne (l.c.), a family <u>Buxineae</u> follows the <u>Euphorbiaceae</u>, but it is mentioned that in some respects, it approaches the <u>Hamamelidaceae</u>.

In 1853 Plee separated a family "Buxinées" from the <u>Euphorbiaceae</u> on the grounds that the former lack latex and have parietal placentation. van Tieghem (1897) pointed out

that Plee's observations on this latter point were in error; placentation in the <u>Buxaceae</u> is, in fact, axile.

Bentham and Hooker considered the "Buxineae" to be a tribe of the <u>Euphorbiaceae</u>. van Tieghem (l.c.) who monographed the family, placed the <u>Buxaceae</u>, excluding <u>Simmondsia</u>, in his order <u>Geraniales</u>. The <u>Simmondsiaceae</u> (<u>Simmondsia</u> only), he placed in the <u>Chenopodiales</u>. Hallier, as mentioned before, lumped all the buxaceous genera in the <u>Hamamelidaceae</u>.

Takhtajan (1954) places the <u>Buxaceae</u> and <u>Simmondsiaceae</u> in his order <u>Hamamelidales</u>. Several authors, such as Pulle (1952) and Bessey (1915) have placed the <u>Buxaceae</u> in the <u>Celas-</u> <u>trales</u>. One may only conclude that the positioning of the <u>Buxaceae</u> is a problem which has not yet been settled.

We may now turn to discussion of five very interesting genera; i.e., <u>Cercidiphyllum</u>, <u>Eucommia</u>, <u>Euptelea</u>, <u>Trochoden</u>-<u>dron</u> and <u>Tetracentron</u>. The opinions concerning the phylogeny of these genera are many and often conflicting. They range from those of Oliver (1895) who placed all five genera in the <u>Trochodendraceae</u>, to Hallier's idea that they should all be put in the <u>Hamamelidaceae</u>, to Smith's belief that each genus is best placed in a separate family.

<u>Cercidiphyllum</u> Sieb.&Zucc. is a monotypic Japanese genus, the only species being <u>C</u>. japonicum Sieb..& Zucc.. Baillon (l.c.) suggested that <u>Cercidiphyllum</u> might be included in the <u>Hamamelidaceae</u>, although he mentioned that it shows similarities to Spiraeanthemum A. Gray of the Cunoniaceae.

Maximowicz (1872) placed <u>Cercidiphyllum</u>, <u>Trochodendron</u> and <u>Euptelea</u> in a tribe of the <u>Magnoliaceae</u>, stressing the presence of stipules as a feature common to all three. Similarly, Prantl (1891), writing in the first edition of "Die naturlichen Pflanzenfamilien", considered these three genera to form a family <u>Trochodendraceae</u>.

van Tieghem (1900) in his work on the vesselless dicotyledons, was the first to place <u>Cercidiphyllum</u> in a distinct family, but made no suggestions concerning the positiom of the family. Harms (1916) placed the family in the <u>Ranales</u>, and said that it stands there as an isolated type.

Swamy and Bailey (1949), who made one of the most recent studies of <u>Cercidiphyllum</u>, concluded that there is no evidence for placing it in the <u>Hamamelidaceae</u> or in any other family, and decided that it is best made the type of its own family.

The position of <u>Cercidiphyllum</u> is much in doubt. There are three main lines of thought, one placing it near the <u>Hamamel-idaceae</u>, the second putting it close to <u>Trochodendron</u>, and the third making it an isolated family in the <u>Ranales</u>. It seems rather unlikely that <u>Cercidiphyllum</u> and <u>Trochodendron</u> are closely related, for there is one great gap between them in regard to anatomical characters; <u>Cercidiphyllum</u> has vessels, while <u>Trochodendron</u> does not.

The family <u>Eucommiaceae</u> van Tieghem (1900) is composed of one monotypic genus. Oliver (1890) described <u>Eucommia</u> <u>ulmoides</u> Oliv., but was unable to assign it to a definite position as he had not seen flowering specimens. The fruits and general aspect of the plant, Oliver said, suggested the <u>Ulmaceae</u>, although he mentioned the tribe <u>Phyllantheae</u> of the <u>Euphorbiaceae</u> as being of possible affinity. After studying flowering material, he placed <u>Eucommia</u> with <u>Trochodendron</u> on the grounds that they both lack a perianth.

Solereder (1899) placed <u>Eucommia</u> as a separate tribe in the <u>Hamamelidaceae</u>, setting it apart because of the fruit (a samara). As mentioned before, Hutchinson (1926), Soo (1953) and Thorne (1.c.) have all included the <u>Eucommiaceae</u> in an order <u>Hamamelidales</u>, although in the second edition of "The Families of Flowering Plants" (1959), Hutchinson removes the family to the <u>Urticales</u>. Wettstein (1935), Cronquist (1957), Benson (1957) and Takhtajan (1954) have all placed the Eucommiaceae in the Urticales.

Tippo (1940), who made a careful study of the wood anatomy of <u>Eucommia</u>, concluded that it is closer to the <u>Urticales</u>, especially the <u>Ulmaceae</u>; than to the <u>Hamamelidales</u>. He was of the opinion that the <u>Eucommiaceae</u> form a link between the <u>Hamamelidaceae</u> and the <u>Urticales</u>. Varossieau (1942) who investigated <u>Eucommia ulmoides</u> without knowing of Tippo's earlier work, said that it shows affinities with the <u>Ulmaceae</u>;

Moraceae, Cannabaceae, Urticaceae, Euphorbiaceae, Hamamelidaceae and Trochodendraceae. Its nearest relative, he felt, is <u>Ulmus</u>.

Thus most modern taxonomists have placed the <u>Eucommia-</u> <u>ceae</u> in either an order <u>Hamamelidales</u> or in the <u>Urticales</u>. Oliver's idea that <u>Eucommia</u> is related to <u>Trochodendron</u> does not seem supported by the available evidence. Firstly, <u>Trochodendron</u> is vesselless, while <u>Eucommia</u> has vessels; secondly, as Smith (1946) has suggested, <u>Trochodendron</u> may not be entirely devoid of a perianth.

The little family <u>Eupteleaceae</u> with the single genus <u>Euptelea</u> Sieb. & Zucc., has been included in an order <u>Hamameli-dales</u> by Wettstein (1935), Thorne (l.c.) and by Takhtajan (1954). Most of the earlier workers considered it to be related to <u>Trochodendron</u>, although Lindley (1853) placed it in a tribe <u>Ulmeae</u> of his family <u>Ulmaceae</u>.

Bentham and Hooker (l.c.) mention <u>Euptelea</u> in the addendate to the first volume of the "Genera Plantarum" and erect a tribe <u>Trochodendreae</u> (<u>Trochodendron</u> and <u>Euptelea</u>), which they place at the beginning of the <u>Magnoliaceae</u>. Hooker and Thomson (1864) placed <u>Euptelea</u> in a tribe <u>Wintereae</u> of the <u>Magnoliaceae</u>; in the "Genera Plantarum" this tribe includes <u>Illicium</u> and <u>Drimys</u>.

van Tieghem (1900) was the first to place <u>Euptelea</u> in a distinct family "Eupteleacees". van Tieghem and Constantin (1918) place this femily, including Euptelea with five species, as family nine of their order <u>Piperales</u>. Hutchinson (1926) placed <u>Euptelea</u> and <u>Trochodendron</u> in his family <u>Trochodendraceae</u> and said that this family may have given rise to part of the <u>Hamamelidales</u>. Gundersen (1950) and Soo (1953) both treated the <u>Eupteleaceae</u> as a family of the <u>Magnoliales</u>, although Gundersen said that the position is doubtful. Benson (1957) places the family in an order <u>Ranales</u> between the <u>Tetracentraceae</u> and <u>Myristicaceae</u>, but says that it is not closely related to any other in the Ranales.

Smith (1946) suggests that the lack of a perianth, so often mentioned as a feature common to <u>Euptelea</u> and <u>Trocho-</u> <u>dendron</u>, may be unreliable, saying that the toral bracteoles of <u>Trochodendron</u> may be interpreted as the remains of a perianth.

Nast and Bailey (1946) who investigated the relations between Euptelea and Trochodendron say that:

"The evolutionary gap between the vesselless xylem of <u>Trochodendron</u> and <u>Tetracentron</u> and the vessel containing wood of <u>Euptelea</u> is so wide that it alone serves as a serious, if not insuperable obstacle to the inclusion of <u>Euptelea</u> in the Trochodendraceae---."

Metcalfe and Chalk (1950) support this view, saying that the woods of Euptelea and Trochodendron are completely unlike. Smith (l.c.) who made a taxonomic review of the genus, expresses the consensus of modern taxonomic opinion, saying:

"That it <u>Euptelea</u>] is a member of the Ranales, in the broad sense, appears to be reasonable certain, but it is anticipated that an eventual revision of the order will result in the proposal of a separate suborder to include only the family Eupteleaceae."

The family <u>Trochodendraceae</u>, based on <u>Trochodendron</u> S.& Z., was established (as "<u>Trochodendreae</u>") by Seemann (1864). Most of the earlier workers put <u>Trochodendron</u> in the <u>Magnoliaceae</u>, and ignored <u>Tetracentron</u> Oliv. which is sometimes included in the <u>Trochodendraceae</u>. Bentham and Hooker, in the first volume of the "Genera Plantarum", excluded <u>Trochodendron</u> from the <u>Magnoliaceae</u> and said that it is an anomalous member of the <u>Araliaceae</u>. For this, they were taken to task by Seemann in his revision of the <u>Hederaceae</u> (1864). In the supplement(1867) to the first volume of the "Genera Plantarum", a tribe <u>Trochodendreae</u>, including <u>Euptelea</u> and <u>Trochodendron</u>, was added to the Magnoliaceae.

In 1945 Smith, reviewing the taxonomy of <u>Trochodendron</u> and <u>Tetracentron</u>, summarized the **evidence** available, and concluded that these genera do not belong in the <u>Magnoliaceae</u>, but should each be placed in a separate family. He emphasized that they are not closely related to <u>Euptelea</u> or to <u>Cercidiphyllum</u>.

Nast and Bailey (1946) investigated the morphology of <u>Trochodendron</u> and <u>Tetracentron</u> and decided that:

"---there are no cogent evidences of close relationship between either <u>Erochodendron</u> or <u>Tetracentron</u> and the Magnoliaceae (sensu lato), Degeneriaceae, Himantandraceae, Winteraceae, Schisandraceae, Cercidiphyllaceae, or Eucommiaceae."

On the other hand, Thorne (l.c.) geels that <u>Trocho-</u> <u>dendron</u> and <u>Tetracentron</u> do not belong with the <u>Magnoliales</u> or <u>Ranales</u> (s.l.), although they have retained vesselless wood, apocarpy and other primitive features. Their true affinities are, he feels, with <u>Euptelea</u>, <u>Cercidiphyllum</u>, <u>Eucommia</u>,

<u>Platanus</u> and the <u>Hamamelidaceae</u>. Croizat (1947) takes a somewhat broader view of their affinities, saying:

"In short, <u>Trochodendron</u> and <u>Tetracentron</u> are isolated offshoots of a truly colossal phylogenetic plexus which is responsible for the evolution of the Hamamelidaceae, Cornaceae and Saxifragaceae as the main families."

These genera just discussed, <u>Euptelea</u>, <u>Cercidiphyllum</u>, <u>Trochodendron</u> and <u>Tetracentron</u>, have generally been placed among the <u>Ranales</u> (s.l.), but there is no agreement concerning the exact position they should be given. <u>Trochodendron</u> and <u>Tetracentron</u> differ very much from the <u>Hamamelidaceae</u> in that they are vesselless; this seems an insurmountable obstacle to placing them near this latter family. Probably, further research will suggest that each genus should be in a separate family, but all put among the primitive dicotyledons, that is, in the <u>Ranales</u> (s.l.).

The next group of families to be discussed are those which have been included in an order <u>Hamamelidales</u> by only one or two authors.

<u>Daphniphyllum</u> Blume is the type of the family <u>Daphni-</u> <u>phyllaceae</u> Muel.- Arg. (1869). Rosenthal (1916) who monographed the genus, found no resemblances between <u>Daphniphyl-</u> <u>lum</u> and the <u>Hamamelidaceae</u>. Writing in the second edition of "Die naturlichen Pflanzenfamilien" (1931), she placed the family after the Euphrbiaceae.

Metcalfe and Chalk (1950) place the family after the <u>Bux-aceae</u>, stating that the wood of <u>Daphniphyllum</u> is quite different from that of the Euphorbiaceae. Only two authors, Hallier (1912) and Takhtajan (1954) have associated <u>Daph-</u> <u>niphyllum</u> with the <u>Hamamelidaceae</u>.

A family <u>Altingiaceae</u> (Hayne, 1830) has sometimes been split off from the <u>Hamamelidaceae</u>. Lindley (1853) placed a family <u>Altingiaceae</u>, including <u>Altingia</u> Nor. and <u>Liquidambar</u> L., in his order <u>Amentales</u>, that is, among the amentiferous plants. Takhtajan (1954) has a family <u>Altingiaceae</u> in his order <u>Hamamelidales</u>; he obviously includes <u>Altingia</u> in the family, but makes no mention of <u>Liquidambar</u>. As mentioned in the discussion of the <u>Hamamelidaceae</u>, Harms felt that these genera might well be removed from the family.

The family <u>Coriariaceae</u> (de Candolle, 1824) is unigeneric, including only some twelve species of <u>Coriaria</u> L. Bentham and Hooker (l.c.) placed the family between the <u>Anacardiaceae</u> and <u>Moringaceae</u> at the end of the <u>Sapindales</u>, describing <u>Coriaria</u> as an anomalous genus, and saying that it has no close affinity with any other family.

Engler (1890), writing in "Die naturlichen Pflanzenfamilien", placed the <u>Coriariaceae</u> after the <u>Empetraceae</u>, and said that <u>Coriaria</u> has no affinities with any family with the possible exception of the <u>Empetraceae</u>.

The majority of the more recent authors have placed <u>Coriaria</u> in either the <u>Rutales</u> or the <u>Sapindales</u>, although Cronquist (1957) puts it in the <u>Berberidales</u>. Boivin (1956) treats the family as the type of an order <u>Coriariales</u>, as Hutchinson (1926, 1959) has also done.

Thus one can conclude that <u>Coriaria</u> is an isolated genus, not closely related to any other.

Gundersen (1950) included in his order <u>Hamamelidales</u> seven families which no other authors have placed in such a position. As families seven and eight respectively, he has families <u>Hydrangeaceae</u> and <u>Saxifragaceae</u>.

His <u>Hydrangeaceae</u> are composed of predominantly woody sub-families segregated from the <u>Saxifragaceae</u> (s.l.). He includes in the family six sub-families, <u>Baueroideae</u>, <u>Ptero-</u> <u>stemonoideae</u>, <u>Hydrangeoideae</u>, <u>Iteoideae</u>, <u>Escallonioideae</u> and <u>Ribesioideae</u>; the last three might, he says, be raised to familial rank. His <u>Saxifragaceae</u> includes mainly herbaceous genera.

The majority of authors have placed the <u>Saxifragaceae</u> (s.l.) in the rosalian complex. Lindley (1853) treated the family as the first member of his order <u>Saxifragales</u>, a group which also included the families <u>Hydrangeaceae</u>, <u>Cunoniaceae</u>, <u>Brexiaceae</u> and <u>Lythraceae</u>. In an order which he called <u>Grossales</u>, Lindley placed the <u>Grossulariaceae</u>: <u>Ribesiaceae</u>, Escalloniaceae, Philadelphaceae and Barringtoniaceae.

Bentham and Hooker (l.c.) placed a family <u>Saxifrageae</u>, of six tribes including <u>Cunonieae</u>, in their order <u>Rosales</u>. They said that the affinities of the family are with the <u>Rosaceae</u>, most particularly with <u>Spiraea</u>, <u>Astilbe</u> and <u>Neillia</u>, but mentioned that it also shows evidence of relationship with the Lythraceae, <u>Rhizophoraceae</u>, <u>Droseraceae</u>, Ficoida-

ceae and Stylidiaceae.

Engler (1928) writing in the second edition of "Die naturlichen Pflanzenfamilien", places the <u>Saxifragaceae</u>, including fifteen sub-families, in the <u>Rosales</u>. The family, he says, stands nearest the <u>Crassulaceae</u> and <u>Cunoniaceae</u>, but also shows connections to the <u>Hamamelidaceae</u> and <u>Rosaceae</u>, in particular with the tribes <u>Astilbineae</u> and Spiraeae of the Rosaceae.

Hutchinson (1926), who divides the angiosperms into woody and herbaceous stocks, considered the true <u>Saxifra-</u> <u>gaceae</u> to be entirely herbaceous. His order <u>Cunoniales</u>, including the <u>Cunoniaceae</u>, <u>Escalloniaceae</u>, <u>Grossulariaceae</u>, <u>Hydrangeaceae</u>, <u>Brunelliaceae</u> and <u>Greyiaceae</u>, is woody and shows "--- considerable affinity with the <u>Dilleniaceae</u>, and might--- conceivably have been derived from the same basal stock as that family."

In the second edition of "The Families of Flowering Plants", Hutchinson includes those families listed above, as well as five others, in the <u>Cunoniales</u>. He says, however, that this group is much in need of revision and probable reassessment into families.

Gundersen also included the families <u>Cunoniaceae</u>, <u>Pittosporaceae</u>, <u>Byblidaceae</u>, <u>Podostemonaceae</u> and <u>Hydro</u>stachyaceae in his Hamamelidales.

The family <u>Cunoniaceae</u> was established by Robert Brown (1814) who considered it to show affinity with the

Saxifragaceae, saying that the <u>Cunoniaceae</u> are most distinguished from the <u>Saxifragaceae</u> by habit.

Bentham and Hooker (l.c.) reduced the family to a tribe of the <u>Saxifragaceae</u>. Hallier (1912) placed the <u>Cunoniaceae</u>, including <u>Bauera</u> Banks, in his order <u>Rosales</u>, suggesting that the family is descended from the <u>Rosaceae</u>.

On the basis of anatomical studies, Metcalfe and Chalk (l.c.) suggest a close connection between the <u>Eucryphiaceae</u> and the <u>Cunoniaceae</u>. Benson (1957) places the family in the <u>Rosales</u> and suggests that it is perhaps not distinct from the <u>Brunelliaceae</u>. Croizat (1952) also feels that the <u>Brunelliaceae</u> and <u>Cunoniaceae</u> are related, while Soo (1953) actually includes the <u>Brunelliaceae</u> in the <u>Cunoniaceae</u>.

Thus it is apparent that the <u>Cunoniaceae</u> have most often been placed in the neighbourhood of the <u>Rosaceae</u>.

Robert Brown (1814) described a family <u>Pittosporaceae</u>, including <u>Pittospotum</u> Banks, <u>Bursaria</u> Cav. and <u>Billardiera</u> Sm.. These genera, he said, "---appear to me to constitute, along with some unpublished Australian genera, a very distinct natural family.".

Bentham and Hooker (l.c.) included the family, along with the <u>Tremandraceae</u>, <u>Polygalaceae</u> and <u>Vochysiaceae</u>, in their order <u>Polygalinae</u>. LeMaout and Decaisne (l.c.) placed the <u>Pittosporaceae</u> preceeding the <u>Polygalaceae</u> and Tremandraceae, and suggested that the family shows affinity
with the <u>Celastraceae</u> and <u>Ericaceae</u>, in particular with <u>Ledum</u>.

Hallier (1912) placed the <u>Pittosporaceae</u>, including <u>Cheiranthera</u> Brongn. and <u>Elaeodendron</u> Zipp., in the <u>Tubi-</u> <u>florae</u>. Its relationships are, he said, with the <u>Olaca-</u> <u>ceae</u>, <u>Polemoniaceae</u>, <u>Convolvulaceae</u>, <u>Apocynaceae</u> and <u>Lina-</u> <u>ceae</u>.

Rendle (1938) and Gundersen (1.c.) agree in suggesting a close relation between the <u>Pittosporaceae</u> and the sub-family <u>Escallonioideae</u> of the <u>Saxifragaceae</u>, but both point out anatomical differences; i.e., the presence of resin canals in the <u>Pittosporaceae</u>. Metcalfe and Chalk (1.c.) place the family between the <u>Flacourtiaceae</u> and the <u>Tremandraceae</u>, but suggest that it shows connections to the <u>Araliaceae</u>. The anatomical characters, they feel, preclude any relation to the <u>Escallonioideae</u>.

Thus the family has most often been placed near the <u>Tre-</u> <u>mandraceae</u> and related families; that is, rather far removed from the <u>Hamamelidaceae</u>.

The genus <u>Byblis</u> Salisb. was made the type of a family <u>Byblidaceae</u> by Domin (1922). Some authors also place <u>Rori</u>dula L. in this family.

Hutchinson (1948), in discussing the <u>Droseraceae</u>, said that <u>Roridula</u> and <u>Byblis</u> belong in **a** separate family (<u>By-</u> <u>blidaceae</u>) which shows affinity with the <u>Tremandraceae</u> and Pittosporaceae. Gundersen (l.c.) says that only Byblis

should be included in the family; directly afterwards, he mentions <u>Roridula</u>, but does not say what he feels its proper position to be.

The family <u>Podostem(on)aceae</u> is a highly specialized group of aquatic plants. Lindley (1853) placed it, including a tribe <u>Hydrostachyeae</u>, in the <u>Rutales</u>, and Hallier (1912), also including <u>Hydrostachys</u> Thou., put the family in his order <u>Ranales</u>, but most authors have placed the <u>Podostemaceae</u> in the <u>Rosales</u>.

Engler (1928b), writing in the second edition of "Die natürlichen Pflanzenfamilien", suggested that the <u>Podostema-</u> <u>ceae</u> and the <u>Rosales</u> might be derived from the same protangiospermous stock, but placed the <u>Podostemaceae</u> (as an order <u>Podostemales</u>) after the <u>Urticales</u>. The consensus of taxonomic opinion was expressed by Croizat (1952) who said that the family is "---beyond doubt one of the most primitive in existence, and its affinities are poorly understood."

<u>Hydrostachys</u> Thou. has been included in the <u>Podostema</u>ceae by some, but Engler (1894) considered it to be the type of a family <u>Hydrostachydaceae</u>. In the first edition of "Die naturlichen Pflanzenfamilien", the family was included in the <u>Rosales</u>, but in the llth "Syllabus" of Engler and ' Diels (1936) it is placed, as an order <u>Hydrostachydales</u>, following the <u>Piperales</u>, in the Monochlamydeae.

(iii) The "Amentiferae"

In this discussion the term "<u>Amentiferae</u>" is interpreted to include eleven of the first thirteen orders of dicotyledons according to the llth "Syllabus"; that is, the <u>Verticillatae</u> <u>Casuarinales</u>, <u>Salicales</u>, <u>Garryales</u>, <u>Myri-</u> <u>cales</u>, <u>Balanopsidales</u>, <u>Leitneriales</u>, <u>Juglandales</u>, <u>Juliani-</u> <u>ales</u>, <u>Batidales</u>, <u>Fagales</u> and <u>Urticales</u>, but to exclude the <u>Piperales</u> and the <u>Hydrostachydales</u>.

These orders form a group of plants, generally woody, which have naked or haplochlamydeous flowers, usually gathered into catkins or aments. Some taxonomists, notably Engler, have felt that these plants have primitively simple flowers, and have therefore placed them at the beginning of the dicotyledons. Others feel that the apparently primitive characters are the result of reduction, many believing that a number of the amentiferous orders have been derived from hamamelidalian ancestors.

Of the "<u>Amentiferae</u>", special mention should be made of the order <u>Verticillatae</u>, which includes only the family <u>Casuarinaceae</u>. The only genus in the family is <u>Casuarina</u> Labill. with some sixty species. Mirbel (1810), who was the first to place <u>Casuarina</u> in a distinct family, felt that it is related to the conifers, and said:

"Les casuarina, ces conifères des regions australes, peuvent constituer une famille à part, sous le nom de Casuarinees."

Dumortier (1829) placed the families <u>Casuarineae</u> and <u>Ephedraceae</u> in his order <u>Ephedrarieae</u>. Perhaps the first

to include <u>Casuarina</u> among the angiosperms was Endlicher (183661840), who placed it in the <u>Juliflorae</u>, a class in which he included several amentiferous families, as well as the <u>Antidesmeae</u>, <u>Plataneae</u>, <u>Balsamifluae</u> and <u>Lacistemmeae</u>.

<u>Casuarina</u> displays some unusual embryological features, the most sriking of which is chalazogamy; that is, the pollen tube enters the ovule through the chalazal end rather than by the micropylar end. Other differences from the usual are the formation of tracheids in sporogenous tissue and the ability of any or all of the four megaspores to become functional.

Treub (1891) felt that these differences from the rest of the angiosperms are so note-worthy that <u>Casuarina</u> should be separated from them. He divided the angiosperms into "Porogames" (monocotyledons and dicotyledons) and "Chalazogames", the last group including only <u>Casuarina</u>. He considered these embryological features to be primitive, and wrote:

"---on aurait tort, je crois, de considerer les Casuarinees comme famille transitoire entre les Gymnospermes d'aujourdhui et les Angiospermes vivant actuellement."

However, chalazogamy is now known to occur in several other genera, including <u>Rhus</u>, <u>Circaeaster</u>, <u>Ostrya</u> and <u>Ju-</u> <u>glans</u> (Maheshwari, 1950). It seems likely that chalazogamy is a sporadic feature which has arisen many times in widely separated genera.

Bessey (1915) placed the Casuarinaceae in the Rosales,

considering them to be reduced derivatives of the <u>Hamameli-</u> daceae. Hutchinson (1926, 1959) also considers the family to be reduced from the <u>Hamamelidaceae</u>: in the second edition of "The Families of Flowering Plants" (1959), he derives <u>Ca-</u> suarina from rosalian stock via the <u>Hamamelidales</u>, and places it as the climax order of a series, <u>Leitneriales</u>, <u>Myricales</u>, Balanopsidales, Fagales, Juglandales and Casuarinales.

Moseley (1948) investigated the anatomical features of Casuarina and concluded that they are advanced and derived, rather than primitive. He says:

"---the anatomical evidence presented supports, or at least is not inconsistent with, the derivation of the Casuarinaceae from hamamelidaceous ancestors, as suggested by floral morphology."

Moseley also suggested that cytological evidence supports a relationship between <u>Casuarina</u> and the <u>Hamamelida-</u> <u>ceae</u>. He based this on the grounds that the basic chromosome number in <u>Casuarina</u> is twelve, while that of the <u>Hamam-</u> <u>elidaceae</u> is usually twelve or fifteen. However, Barlow (1959) has recently shown that the basic chromosome number in <u>Casuarina</u> is probably nine; according to Barlow, twelve is actually a secondary number occurring only in the most advanced species.

The trend of modern opinion is that <u>Casuarina</u> is a much reduced genus, which has been derived from the rosalian complex, some authors specifying that the path of evolution has been through hamamelidalian ancestors. The order <u>Salicales</u> is generally considered to include only the family <u>Salicaceae</u> which includes two genera, <u>Populus</u> L. with about twenty species, and <u>Salix</u> (Tourn.) L. with some one hundred and sixty species. Nakai (1920) based the genus <u>Chosenia</u> Nakai on <u>Salix splendida</u>, but it is doubtful if this is a valid segregation.

The <u>Salicales</u> have generally been placed among the amentiferous orders, although Hallier (1912) placed the <u>Sali-</u> <u>caceae</u> in his order <u>Passionales</u>, and suggested that the family is descended from the <u>Flacourtiaceae</u>. Hjelmqvist (1948) feels that the <u>Salicaceae</u> are the most advanced family of the "<u>Amentiferae</u>" and so stand somewhat apart from the rest.

The <u>Garryales</u> are an order of only one family, the <u>Gar-ryaceae</u>, which includes <u>Garrya</u> L. of about thirteen species. The family was established by Lindley (1834) who suggested that it is allied to the <u>Cupuliferae</u>. In the third edition of his "Vegetable Kingdom" (1853), Lindley placed the family, along with the <u>Helwingiaceae</u>, in an order <u>Garryales</u>. <u>Hel-</u> <u>wingia</u> Willd. is now generally placed in the <u>Cornaceae</u>.

LeMaout and Decaisne (1.c.) placed the <u>Garryaceae</u>, including <u>Simmondsia</u> Nutt., following the <u>Cornaceae</u>, although Hooker, the editor, added a note saying that he disagreed with this treatment of <u>Simmondsia</u>. Numerous authors have concurred in placing <u>Garrya</u> near the <u>Umbelliflorae</u>. Baillon (1.c.), Bessey (1915) and Hallier (1912) all included <u>Garrya</u> in the Cornaceae, while Hallock (1930) placed the Garryaceae

next to the Cornaceae.

The family has also been placed among the amentiferous taxa. Lindley (1853) was unsure of its proper position, and related it to amentiferous groups, as well as to the <u>Euphorbiaceae</u> and <u>Chloranthaceae</u>. Endlicher (l.c.) inserted it after the <u>Antidesmeae</u> in a group of families headed "<u>Antidesmeae affines</u>", but said that its affinities are with the <u>Cupuliferae</u> and the <u>Chloranthaceae</u>. Rendle (1938), Wettstein (1935) and Pulle (1950) have considered <u>Garrya</u> to be amentiferous.

Hutchinson (1926) placed the <u>Garryaceae</u> in his group "Archichlamydeae" and considered the family to have arisen by reductions from the <u>Rosales</u> through the <u>Hamamelidales</u>. In the second edition of "The Families of Flowering Plants" (1959), Hutchinson has moved <u>Garrya</u> to the <u>Araliales</u>, placing it with the <u>Cornaceae</u>, <u>Alangiaceae</u>, <u>Nyssaceae</u>, <u>Caprifolia</u>-<u>ceae</u> and <u>Araliaceae</u>. Of this order <u>[Araliales]</u>, he says "Probably derived from <u>Rosales</u> via the <u>Cunoniales</u>. <u>Cornaceae</u> being connected with <u>Philadelphaceae</u> through the genus <u>Broussaisia</u> in the latter family.

through the genus <u>Broussaisia</u> in the latter family. Nyssaceae approach <u>Hamamelidales</u>.

The <u>Garryaceae</u> have also been placed in yet a third position. Pulle (1952) has changed his earlier ideas, and suggests relationship with the <u>Celastrales</u>, placing the <u>Garryales</u> between the <u>Apiales</u> and the <u>Rubiales</u>. Gundersen (1950) indirectly suggests a connection with the <u>Rubiales</u> by placing the <u>Umbellales</u>, including the <u>Garryaceae</u>, in a super-order "Rubiflorae".

The order <u>Myricales</u> is made up of the <u>Myricaceae</u>, a family of about forty-five species. Some authors include all species in the genus <u>Myrica</u> L., while others divide them among several genera; for example, <u>Comptonia</u> L'Her., <u>Angeia</u> Tides., <u>Cerothamnus</u> Tides., and several others.

Nearly all authors are agreed in placing the family among the amentiferous taxa, although Bessey (1915) included it in his order <u>Sapindales</u>. Most authors isolate the family in an order <u>Myricales</u>, although Rendle (1938) and Gundersen (1950) include the <u>Myricaceae</u> in the <u>Juglan</u>-<u>dales</u>.

Boivin (1956), Benson (1957) and Hutchinson (1959) have all suggested that the family is related to the <u>Hamamelidales</u>, having a common ancestry in rosalian stock.

The order <u>Balanopsidales</u> is composed of the <u>Balanopsida</u>-<u>ceae</u>, a small family of two genera and about ten species. In addition to having been placed among the "<u>Amentiferae</u>" by some authors, the family has also been placed near the <u>Centrospermae</u> [<u>Chenopodiales</u>, <u>Caryophyllales</u>], a position to which Wettstein (1935), Hutchinson (1926, 1959) and Gundersen (1950) have assigned it.

The little order <u>Leitneriales</u> includes only the monotypic family <u>Leitneriaceae</u>, the type of which is <u>Leitneria</u> <u>floridana</u> Chapman. This is a family whose affinities are only imperfectly understood. Chapman (1884) first placed Leitneria in the Myricaceae. He later (1897) inserted the

family <u>Leitneriaceae</u> between the <u>Myricaceae</u> and the <u>Betula-</u> <u>ceae</u>, but described it as "---intermediate between the Wax-Myrtle <u>Myricaceae</u> and Willow <u>Salicaceae</u> families---."

Soo (1953) has a family <u>Leitneriaceae</u> in his order <u>My-</u> <u>ricales</u>, while Cronquist (1957) places it in the <u>Urticales</u>. Gundersen (1950) suggests a similar position, placing the <u>Leitneriales</u> in his "Ulmus group".

Abbe and Earle (1940) investigated the floral anatomy and morphology of <u>Leitneria</u> and tentatively placed it in either the <u>Rosales</u> or <u>Geraniales</u>, but stressed the need for more information, particularly that of a cytological and embryological nature.

Some authors have placed <u>Didymeles</u> Thou., a monotypic genus from Madagascar, in the <u>Leitneriaceae</u>, but little is known of it.

The order <u>Juglandales</u> of the llth "Syllabus" includes only the family <u>Juglandaceae</u>. The order has often been placed among the amentiferous taxa, although several authors have suggested that it is related to the <u>Sapindales</u>. Kunth (1824), who first published the family, considered <u>Juglans</u>, <u>Carya</u> and <u>Pterocarya</u> to be related to the <u>Terebinthaceae</u>, a group of genera usually included in the <u>Sapindales</u>.

Gundersen (1950) places the order, including the families <u>Rhoipteleaceae</u>, <u>Myricaceae</u> and <u>Juglandaceae</u>, between the <u>Rutales</u> and <u>Sapindales</u> in his supra-ordinal "Geranium group".

The order <u>Julianiales</u> includes only the family <u>Juliani</u>-<u>ceae</u> (Hemsley, 1907), in which are placed <u>Juliania</u> Schlect. and <u>Orthopterygium</u> Hemsley. The family has often been placed in the <u>Juglandales</u>, although Gundersen (1950) includes it in the <u>Rutales</u> between the <u>Anacardiaceae</u> and <u>Coriariaceae</u>. Rendle (1938) places the order <u>Julianiales</u> between the <u>Jugland</u>-<u>ales</u> and <u>Fagales</u>, but mentions that it shows resemblances to the <u>Anacardiaceae</u>.

The only family of the order <u>Batidales</u> is the <u>Batida</u>-<u>ceae</u>, a family which includes only <u>Batis</u> L. with one species. Although included in the "Amentiferae" by some, the latest study of the family (McLaughlin, 1959) indicates that it is best placed, as a separate order <u>Batidales</u>, near the <u>Centro</u>-<u>spermae</u>.

The order <u>Fagales</u> includes the families <u>Betulaceae</u> and <u>Fagaceae</u>. The <u>Betulaceae</u> have generally been placed among the amentiferous families, although Bessey (1915) included the family in his order <u>Sapindales</u>.

The anatomy of the family was investigated by Hoar (1916), who concluded that:

"---the general internal anatomy of the Betulaceae and especially the ray structures supply no proof for and much against their being placed anywhere but near the base of the Dicotyledons."

The family was restudied by Hall (1952) who says that:

"---the woods of the Betulaceae possess s series of specialized anatomical characters which indicate the family does not occupy a primitive position." Several authors have split the family into the <u>Betula-</u> <u>ceae</u> (s.s.) [<u>Alnus</u> and <u>Betula</u>] and <u>Corylaceae</u> [<u>Carpinus</u>, <u>Os-</u> <u>trya</u>, <u>Corylus</u> and <u>Ostryopsis</u>]. Hall (l.c.) who investigated the secondary wood of all six genera, concluded that:

"The Betulaceae are an anatomically natural and closely .knit family, composed of two tribes, also homogeneous, at two levels of specialization."

He considers <u>Alnus</u> and <u>Betula</u> to constitute one line of development within the family, while <u>Ostrya</u> and <u>Carpinus</u> form a branch of the line leading to <u>Corylus</u> and <u>Ostryopsis</u>.

Anderson and Abbe (1934), who made an investigation of the family based on quantitative comparison of six characters which they felt to be phylogenetically important, cohcluded that <u>Alnus</u> and <u>Betula</u> belong at one end of the family, while <u>Ostrya</u>, <u>Carpinus</u> and <u>Ostryopsis</u> form a group at the other end. They placed <u>Corylus</u> to one side.

The family <u>Fagaceae</u> has generally been placed near the <u>Betulaceae</u>. Most authors include the <u>Fagaceae</u> and the <u>Betu-laceae</u> in the same order, although Hjelmqvist (1957) has suggested that on embryological grounds, the <u>Fagales</u> [Faga-ceae only] and the <u>Betulales</u> [Betulaceae only] should be regarded as separate orders.

The order <u>Urticales</u> of the llth "Syllabus" is made up of three families, the <u>Ulmaceae</u>, <u>Moraceae</u> and <u>Urticaceae</u>. A number of other families, in particular the <u>Eucommiaceae</u>, have also been placed in this order by various authors. There seems to be general agreement in including the

<u>Ulmaceae</u> in the <u>Urticales</u>, although Bessey (1915) placed the family in his order Malvales. Metcalfe and Chalk (1950) say:

"The anatomical structure of the Ulmaceae has points in common with that of the Cannabinaceae, Urticaceae, and Moraceae, which are generally accepted as closely related to the Ulmaceae."

Most authors divide the <u>Ulmaceae</u> into two sub-families, the <u>Ulmoideae</u> and <u>Celtidoideae</u>, the former including <u>Ulmus</u> (Tourn.) L., <u>Planera</u> Gmel., <u>Phyllostylon</u> Capan. ex B.et H.f., and <u>Holoptelea</u> Planch., the latter including <u>Celtis</u> (Tourn.) L., <u>Zelkova</u> Spach., <u>Trema</u> Lour., and about ten other genera. The monotypic genus <u>Barbeya</u> Schweinf. has been separated as a family <u>Barbeyaceae</u> by Hutchinson (1926, 1959).

The family <u>Moraceae</u> is a rather large group (about fiftyfive genera and eight hundred species) which has by various authors been split into smaller families; e.g., <u>Artocarpaceae</u>, <u>Ficaceae</u>, <u>Cannabinaceae</u>, and others.

Tippo (1938) made a detailed study of the anatomy of the <u>Moraceae</u> and their supposed allies and concluded that the <u>Moraceae</u>, <u>Ulmaceae</u> and <u>Urticaceae</u> form a natural group which had its origins in the <u>Hamamelidales</u>. He considered the <u>Ulmaceae</u> to be the most primitive family of the order, and the <u>Urticaceae</u> to be the most advanced.

Perhaps the broadest view of the <u>Urticales</u> has been taken by Cronquist (1957) who, in addition to the <u>Moraceae</u>, <u>Ulma-</u> <u>ceae</u>, and <u>Barbeyaceae</u>, includes the <u>Leitneriaceae</u> (doubtfully

placing <u>Didymeles</u> Thou. here), <u>Platanaceae</u>, <u>Myricaceae</u>, <u>Betulaceae</u>, <u>Fagaceae</u>, <u>Eucommiaceae</u> and <u>Balanopsidaceae</u>.

COMPARATIVE CHEMISTRY

(i) General discussion of comparative chemistry

For purposes of comparative chemistry, it is necessary, in nearly all cases, to consider secondary metabolic products, for those compounds generally needed for maintainance of life, that is, primary building blocks and intermediates of metabolism, are present in all plants. This is a fact which suggests that the higher plants have had a monophyletic origin.

The enormous variety of complex substances found in plants is built up from a not unlimited number of simpler, metabolically active compounds. The chemical differences between plants lie in the differing pathways of further syntheses which these compounds follow. Although exceptions are known known, the most straight-forward way of regarding synthesis ôf highly complex molecules is to consider each step in the synthesis as mediated by a specific enzyme, in turn produced as the result of action by a particular gene or group of genes.

In using comparative chemistry as a taxonomic tool, there are three facts which should be borne in mind. These facts can, to a large extent, serve as refutation of many of the arguments which are advanced against comparative chemistry. It is quite true that comparative chemistry alone cannot serve as the basis of a system of classification, no more than can any other one character. But used judiciously in combination

with the traditional taxonomic tools, it is of great value.

The first point is that since the building blocks of the more complex molecules are present in all plants, it is not impossible that the same metabolic pathways should appear in plants not closely related, resulting in sporadic distribution of certain compounds.

It may be mentioned here that sporadic distribution of some chemical characters and inconsistencies within a group, such as presence of a compound in some species of a genus and absence in other species of the same genus, cannot be used as strong arguments against the validity of use of chemical characters in taxonomy. If the other types of characters generally used in taxonomy be considered, it is seen that similar situations occur.

Members of the genus <u>Cornus</u> usually have opposite leaves, but in the case of some species, such as <u>C. alterni-</u> <u>folia</u> Linn.f., the leaves are alternate. Yet it is not doubted that these species do belong to <u>Cornus</u>.

Another example is given by <u>Kalanchoe</u> of the <u>Crassula</u>-<u>ceae</u>. In general, the members of this family are polypetalous, but <u>Kalanchoe</u>, which no one doubts is a member of the <u>Crassu-</u> <u>laceae</u>, is sympetalous. Chemically, <u>Kalanchoe</u> resembles other members of the <u>Crassulaceae</u> in that large quantities of sedoheptulose have been found in two species.

A second point to consider is that a few additional occurrences among diverse genera of a compound generally restricted to a particular group of species, genera or families, do not detract from the value of the compound as a taxonomic tool. Distribution of the alkaloid nicotine affords an example.

Nicotine is a rather simple alkaloid which was first found in the genus <u>Nicotiana</u> of the <u>Solanaceae</u>. It has now been found in all members of the <u>Solanaceae</u> analysed, as well as in some members of the <u>Asclepiadaceae</u>, <u>Crassulaceae</u>, <u>Lycopodiaceae</u> and <u>Equisetaceae</u>.

Occurrence of nicotine in <u>Equisetum</u> does not mean that general distribution of the compound throughout the <u>Solana</u>-<u>ceae</u> is not taxonomically useful, nor does it mean that <u>Equisetum</u> belongs in the <u>Solanaceae</u>. It merely indicates that a metabolic pathway common to many members of the <u>Solan</u>-<u>aceae</u> has also evolved independently a number of times in genera not closely related.

However, if a particular genus had been placed in the **<u>Bolànaceae</u>** by some authors, and in another family in which nicotine had never been found, by others, then occurrence of nicotine in this hypothetical genus would constitute a strong argument for placing it in the <u>Solanaceae</u>. Absence of nicotine would be just as strong an, if not a stronger, argument for excluding it.

A good example of a third point to be considered in

regard to comparative chemistry is given by consideration of the distribution of sedoheptulose. There are certain compounds, metabolically active in all plants, which in some plants, accumulate in comparatively large amounts.

Sedoheptulose is wide-spread throughout the plant kingdom as it is an intermediate in photosynthesis. Calvin (1953) says:

"Both ribulose and sedoheptulose seem to be present in all plants and their active pools are generally quite small---."

However, in many succulent families, such as the <u>Crassulaceae</u>, and in others such as the <u>Saxifragaceae</u>, it has been found that sedoheptulose accumulates in large quantities.

As the ability to accumulate large amounts of these ubiquitous compounds seems to be restricted to certain families, consideration of their distribution is useful in taxonomy. (ii) Some examples of the use of comparative chemistry

The idea that chemical characters are of taxonomic value is not new. As long ago as 1699, James Petiver, an apothecary, suggested that plants "of the same figure or likeness, have for the generallity much the same vertues and use". In referring to plants "of the same figure", he was thinking of related plants, for he discussed members of the <u>Umbelliferae</u>, <u>Labiatae</u> and <u>Cruciferae</u>, showing that within each family, the plants have similar properties.

Although Petiver did not apply his idea to taxonomic problems, this was one of the earliest suggestions that related plants have similar constituents, assuming similar properties to be generally an index of similar compounds.

An early use of raphides, a visible chemical character, was made by Gulliver (1866). Raphides, which are calcium oxalate crystals, are arranged in parallel bundles in special cells (raphide sacs).

In a paper entitled "On raphides as a natural character in the British flora", Gulliver recorded distribution of raphides in some detail, and said:

"---I believe that a fair examination will prove that raphides may give a diagnosis at once as fundamental and universal, and as simple and truly natural, between plants of some different and proximate orders, as any one of the secondary characters heretofore used for this purpose in systematic botany."

He raised raphide-containing plants under differing conditions in an effort to prevent development of these crystals,

but found that their presence is a constant character. He concluded by saying:

> "In short, I know of no means by which a raphidean plant can be grown in health, if at all, so as to extinguish this character, nor by which a plant, regularly devoid of raphides can be made to produce them."

Several years later, Greshoff, who had spent some years at Buitenzorg investigating plant chemistry, suggested that to every description of a new species or genus a chemical description should be appended. Greshoff paid particular attention to the occurrence of cyanogenetic compounds, and felt that study of the distribution of such compounds would be of special interest in taxonomy (Greshoff, 1906, 1909).

That which is perhaps the best-known technique, so far used in studies of comparative chemistry, is serology, extensively used in Germany by the Königsberg and Berlin schools. The method is essentially the following.

A plant extract is injected into an animal, several injections being given over a period of days. This extract contains substances, usually proteins, which are known as "antigens". In response to introduction of plant antigens, there are antibodies produced in the animal's blood serum. These antibodies affect the antigens in various ways, which may be demonstrated by serological reactions.

The reactions most used by the Königsberg workers were precipitation and agglutination. After an animal has been sensitized by injection of antigens from plant "a", a quantity of its blood serum is added to an extract of plant "b".

The degree of precipitation or agglutination caused by reaction between "b" antigens and the antibodies produced in the blood serum as a result of sensitization with "a" antigens, is taken as a measure of the similarity between "a" and "b" antigens. Thus, if they are very nearly the same, the precipitation or agglutination is rapid and complete.

Proponents of serology feel that structure of plant proteins is a basic manifestation of the genotype of the plant. They claim that the structural complexity of proteins is such, and the number of possible combinations of the component amino acids is so great, that parallel evolution of identical or similar proteins is very unlikely. Therefore, plants which show similarities in protein structure, as evidenced by serological reactions, must be closely related.

Mez and Ziegenspeck (1926) published (and patented) the "Königsberger Stammbaum", a system, based on results of serological tests, which even dealt with plants known only from fossil remains.

Although serology is undoubtedly of great value and significance, it has not been used in this work, and will not be discussed further. A review, with many references, on the subject of plant serology, has been published by Chester (1937).

An attempt to apply chemical characters to the classi-

fication of the entire plant kingdom was made by McNair who was not entirely successful. His results are described in a series of papers which appeared from 1928 to 1945.

Certain of his basic hypotheses are much in doubt. For example, in 1934 he suggested that the evolutionary progression of an alkaloid-containing plant could be measured by the molecular weight, apparently considered equivalent to complexity, of the alkaloids; that is, plants which contain high moleular weight alkaloids are further along developmentally than plants with those of low molecular weight.

After considering several types of compounds, he concluded that, in the tropics at least, the more advanced a plant is, the more highly organized its chemical constituents will be.

There are certainly many obvious exceptions to this rule. The lower plants form some of the most complex compounds known; for example, the ergot alkaloids, produced by the fungus <u>Claviceps</u>, are among the most highly organized of the alkaloids.

McNair's work gives an example of the improperly based use of comparative chemistry.

We might now consider a piece of work in which consideration of the distribution of alkaloids has been of real value, that is, the work of Manske and his associates on the alkaloids of the <u>Papaveraceae</u>.

This is a case in which consideration of two sorts of compounds, alkaloids and certain soluble nitrogenous compounds, supports two distinct taxonomic views.

According to Fedde (1936) the <u>Papaveraceae</u> (s.l.) are divided into three sub-families; i.e., the <u>Hypecoideae</u>, including only two genera, <u>Pteridophyllum</u> and <u>Hypecoum</u>, the <u>Papaveroideae</u> with about twenty-five genera, and the <u>Fumarioideae</u> with some fifteen genera. The <u>Hypecoideae</u> have sometimes been thought to be transitional between the <u>Papaveroideae</u> and the <u>Fumarioideae</u>.

Hutchinson (1921, 1926, 1959) feels that the <u>Fumarioideae</u> and <u>Papaveroideae</u> are sufficiently distinct to be made separate families (<u>Fumariaceae</u> and <u>Papaveraceae</u> s.s.), both of which he places in the <u>Rhoeadales</u>. <u>Hypecoum</u> and <u>Pteridophyllum</u> he includes in the <u>Fumariaceae</u>. He says (1921) that the <u>Fumariaceae</u> are quite distinct from the <u>Papaveraceae</u> (s.s.) and are just as closely related to certain berberidaceous genera as to the <u>Papaveraceae</u>. The relation between the <u>Fumariaceae</u> and the <u>Papaveraceae</u> is "more apparent than real" according to Hutchinson.

However, Manske says that no papaveraceous (used in the wider sense) plant has ever been found to be completely devoid of alkaloids, and that one alkaloid, protopine, has been found in every papaveraceous plant investigated. This indicates that in regard to this characters, the <u>Papavera</u>- ceae (s.l.) are a quite homogeneous group.

There is, however, one recent bit of chemical evidence which tends to support Hutchinson. Reuter (1957) has determined the main form of soluble nitrogen in the storage organs (roots, bulbs and corms) of a large number of plants and finds that the <u>Papaveroideae</u> and the <u>Fumarioideae</u> differ sharply in this respect.

Of twenty-one species in fifteen genera of the Papaveroideae, seventeen species in eleven genera contain glutamine in largest amount, three species in three genera have arginine in largest quantity, while one species, <u>Hunnemannia fumarii-</u> <u>folia</u>, has glutamic acid in largest amount.

However, nineteen species in four genera of the <u>Fumari</u>-<u>oideae</u> were found to contain δ -acetylornithine as the main form of soluble nitrogen in the storage organs.

<u>Hypecoum procumbens</u> was found to contain glutamic acid in greatest amount, a fact which sets it apart from the <u>Fumarioideae</u> and most of the <u>Papaveroideae</u>.

Obviously, this is a case in which proponents of the views of either Hutchinson or Fedde may support their arguments by reference to the facts of comparative chemistry. However, there are many comparable situations is the usual taxonomic criteria be considered.

The most extensive use of comparative chemistry in taxonomy has been made by Gibbs (1945, 1954, 1958) who uses a series of standardized tests (described in the next sec-

tion), applying them to as many plants as possible. One test which he has used on an especially large number of plants is the "HCl/methanol" test.

Gibbs has found that use of this test shows the existence of two series of families, one series being positive to the test, and the other, negative. An example of the use of this test can be seen in its application to clarification of the relationships among the <u>Aquifoliaceae</u>, <u>Salvadoraceae</u> and <u>Oleaceae</u> (Gibbs, 1954).

The first two of these families have often been placed in the <u>Celastrales</u>. Some authors feel that the <u>Salvadora-</u> <u>ceae</u> are allied to the <u>Oleaceae</u>, Gundersen saying that it [family <u>Salvadoraceae</u>] is "apparently a link between <u>Aqui-</u> <u>foliaceae</u> and <u>Oleaceae</u>". The <u>Salvadoraceae</u> have also been connected to the <u>Loganiaceae</u>.

Gibbs has found that all those representatives of these four families which were tested are negative to the HCl/methanol test, supporting the view that they do have features in common. Results from other chemical tests also support this conclusion.

The pieces of work which have been mentioned in the preceeding pages by no means include all the uses which have been made of comparative chemistry..Numerous other examples may be found in Gibbs' papers of 1954 and 1958.

(iii) Methods of comparative chemistry used in this work

When sufficient parts of a given plant were available, a series of seven tests (the first seven discussed below) was carried out. In the later stages of the investigation, two additional tests ("cigarette" and "hot-water" tests) were done on fresh leaves. About one-fifth of the plants obtained were also examined chromatographically for the presence of sedoheptulose and D-glucitol.

(a) <u>Leuco-anthocyanin test L.-A. (Test A)</u>

The leuco-anthocyanin test is done according to the method of Bate-Smith and Lerner (1954). About one-half gram of fresh leaves is finely cut up and placed in a 10x25mm test tube which is marked at the five and ten milliliter levels. 2N hydrochloric acid is added to the five milliliter mark. The tube is heated in a boiling water-bath for twenty minutes (with occassional stirring of the contents) and cooled. During heating there is, in some cases, development of a red colour; in other cases, a greenish or yellow colour may appear, or there may be no visible change.

When the tube and contents are cool, <u>iso</u>-amyl alcohol is added to the ten milliliter mark, and the tube is vigorously shaken. On standing, the mixture separates into two layers, the upper being <u>iso</u>-amyl alcohol. In most cases in which a coloured substance is produced during heating, it is extracted into the <u>iso</u>-amyl alcohol. The colour in this

layer is determined by the use of Ridgway's "Color Standards and Color Nomenclature" (1912). A pink or red colour indicates a positive test, while shades of yellow, buff, or green indicate negative tests.

Bate-Smith (1954) says that in this process colourless, water-soluble leuco-anthocyanins are hydrolysed and oxidized to the corresponding coloured anthocyanidins which are soluble in <u>iso</u>-amyl alcohol.

The chemical nature of leuco-anthocyanins is not definitely known, but their properties are not inconsistent with a "flavantriol" structure as proposed by the Robinsons (1933) or an oxidized "flavandiol" structure suggested by Bate-Smith (1953):



Bate-Smith suggests that reactions of the following sort might take place, assuming that the leuco-anthocyanins are present in the "flavantriol" form:



cyanidin chloride

In general, the results of this test are sharply distinguished as positive or negative; those results which are questionable may be explained, in many cases, by the presence of interfering substances, which are often glycosides of the "aucubin group". In other cases, questionable results (showing only a trace of pink) are caused by the presence of only small amounts of leuco-anthocyanins in the tissues.

The "aucubin group" of glycosides was proposed by Trim and Hill (1952) who include in this group aucubin, asperuloside, monotropitoside and certain unidentified compounds found in members of the <u>Labiatae</u> and the <u>Scrophulariaceae</u>. When such compounds are present, the leuco-anthocyanin test is usually obscured by the development of a blue or black colour.

Bate-Smith also mentions that catechins may obscure the

test. When catechins are heated with dilute hydrochloric acid, they are changed to "phlobaphenes" which are soluble in iso-amyl alcohol. Catechins proper become deep golden in colour, while gallocatechins produce a brown substance (see discussion under "HCl/methanol" test).

Bate-Smith (1954) points out that usually leuco-cyanidin and leuco-delphinidin are present in plant tissues, leuco-paeonidin having been found only in some members of the Rosaceae and in a few legumes.

There are two main factors determining the presence or absence of leuco-anthocyanins in a species; these are (1) the character and systematic position of the family in which the species belongs, and (11) the evolutionary stage of the species within the family, especially in regard to habit.

Bate-Smith has found that leuco-anthocyanins are much more common in woody than in herbaceous families. He feels that the ability to produce these compounds is a primitive character which herbaceous groups have lost, correlating it with an evolutionary trend from the woody to the herbaceous habit.

(b) <u>HCl/methanol test</u>

The HCl/methanol test was first used by Isenberg and Buchanan (1945) who found that if wood shavings are soaked in a mixture of concentrated hydrochloric acid and methanol (5:200 parts by volume), a purple colour sometimes develops.

Gibbs has applied the test to many woody plants, and has found results to be remarkably consistent. Members of some families always give positive (purple) reactions, while other families are consistently negative. A few families are mixed, some genera giving weakly positive reactions, while others are negative (see Gibbs, 1954).

The test is done in the following manner. Shavings of sapwood are placed in a test tube (18mm diameter), covered with a mixture of concentrated hydrochloric acid and methanol (5:200 by volume) and left to stand overnight. The liquid is then poured off. The colours of the liquid and the wood are determined by use of Ridgway (1912).

The development of a pink to magenta colour in the wood is regarded as constituting a positive test. The intensity of the colour is recorded as "purple 1-4", "purple 1" being a very pale purple, "purple 3" being "magenta" (plate 26 in Ridgway), and "purple 4" being darker than magenta. In negative tests, the wood may be yellow, buff, green or white.

It is not definitely known what compound or compounds are responsible for the development of the purple colours, but Adler (1951) suggests that catechol tannins may be the cause. These are condensed tannins which yield polyphenols on hydrolysis, and may be considered to be condensation products of compounds such as catechin or gallocatechin. As such, they are closely related to the leuco-anthocyanins.



catechin

gallocatechin

Indeed, a positive reaction to the HCl/methanol test is very closely correlated with a positive reaction to the leuco-anthocyanin test. Cases in which a plant is positive to one test and negative to the other may be caused by limited distribution of these flavanols; that is, they may be present in the wood of a given plant and absent from the leaves or <u>vice versa</u>.

(c) Syringin (1:1 H₂SO₁) test

Syringin, so called because it was first found in <u>Syringa</u>, is the glucoside of 5-methoxyconiferyl alcohol.



According to Tunmann (1931), if sections of plant tissue which contain syringin are placed in a mixture of concentrated sulphuric acid and water (1:1 by volume), a blue colour develops in the section.

The "syringin test" is done on cross sections of twigs in the case of woody plants and on stems or leaf petioles in the case of herbaceous plants. In each test two sections are cut with a sharp razor; one section is mounted in water, while the other is mounted in aqueous sulphuric acid. The section mounted in water is used as a control.

The sections mounted in acid are left to stand for about thirty minutes and are then checked for colour changes. The appearance of a deep blue in xylem and/or bast fires is regarded as a positive "syringin test". In some cases the blue colour may be caused by reaction with the sulphuric acid of compounds other than syringin.

There are a number of other reactions which have been noted. In some cases, the xylem and bast fibres become deep yellow in colour. A very common reaction is the development of a pink to red colour in fibres and xylem. When this reaction is weak, colour is often seen only at xylem/pith and xylem/cambium boundaries.

This development of red is so very often correlated with a positive reaction to the HCl/methanol test that if herbaceous material is tested with the aqueous sulphuric acid, development of a red colour can be considered equivalent to a positive HCl/methanol test done on woody material.

Following a suggestion made by Dr. Deirdre Edward, a chromatographic method for the detection of syringin was devised.

An aqueous extract of plant material was made by boiling about one gram of it in a few milliliters of warer. The extract was then spotted at one or at both ends of a narrow strip $(l_{\overline{z}}^{+}x8^{+})$ of filter paper (Whatman #1). An extract of <u>Syringa</u> bark (assumed to contain syringin) was spotted as a reference.

A glass rod was placed across the top of a beaker (400ml.) and the strip of paper hung over the rod so that the ends of the paper reached the bottom of the beaker where the solvent was placed. The solvent used was the organic phase of n-butanol-acetic acid-water (4:1:5). The three compounds were shaken together and the mixture allowed to come to equilibrium. The upper layer was used as solvent.

The solvent ascended the paper and in about one hour reached the cross rod. The paper was then removed and dried. When dry, it was sprayed with 2N sulphuric acid and dried in a current of warm air (or in front of an oven at 100° C). Reaction of syringin with the sulphuric acid caused appearance of a blue-green spot with an Rf value of 0.50. This agrees well with the results of Janot et al (1953) who reported syringin to have an Rf value of 0.51 in this solvent system.

Extract of bark of a lilac (<u>Syringa sp.</u>) which almost certainly contains syringin, and which gives a deep blue colour with aqueous sulphuric acid, gave a bright bluegreen spot. An extract of bark of <u>Staphylea trifolia</u>, which is strongly positive to the "syringin test", gave a seemingly identical spot. Checks were made using extracts of bark of <u>Ailanthus altissima</u> and <u>Paulownia tomentosa</u>, neither of which is positive to the "syringin test". In neither case was a blue-green spot seen on the chromatogram.

Thus, use of chromatography gives an easy and rapid method of checking the results of the 1:1 H_2SO_4 tests.

(d) Raphides

In this discussion, the term "raphides" is interpreted to mean sheaf-like bundles of needle-shaped calcium oxalate crystals which are contained in special large cells. Raphides are of particular interest because they are one of the few chemicals which are visible within the cell.

An early use of the occurrence of raphides was made by Robert Brown (1845) in an investigation of <u>Rafflesia</u>. <u>Raf-</u>. <u>flesia Arnoldi</u> R. Br. is parasitic on the roots of <u>Cissus</u> <u>spp</u>. The vegetative parts are reduced to mycelium-like filaments; the flower buds develop within the host tissues and break through only when ready to open.

Brown was unsure of the origin of the veil of tissue over the bud, that is, whether it was tissue of <u>Rafflesia</u> or of Cissus, but he solved his problem by recourse to

comparative chemistry. He said:

"That the whole of this covering belongs to the stock, is proved by its containing those raphides or acicular crystals which are so abundant in the root of the <u>Vitis</u> or <u>Cissus</u>, and which are altogether wanting in the parasite."

Mention has already been made of the studies on raphides carried out by Gulliver (see page 50).

In this work, the sections used as controls in the "syringin test" were examined for the presence of raphides. When sections are made of tissues which have raphide-containing cells, the cells are usually ruptured, and the raphides escape into the surrounding water where they are easily seen.

In addition, much use has been made of "Anatomy of the Dicotyledons" by Metdalfe and Chalk (1950). In this work, a list of genera described is placed at the end of the discussion of each family. If no mention has been made of raphides in a particular genus, we have tentatively assumed that the genus lacks them. Of course, the observations of Metcalfe and Chalk are not based on all the species of each genus, so it is quite possible that some species not examined by them might contain raphides. In the tables of genera which follow this section, these tentative assumptions that raphides are absent are recorded as negative followed by a question mark.

(e) Ehrlich test

The "Ehrlich test" is done on fresh leaves. About one-

half gram of material is chopped and dropped into a few milliliters of boiling 50 per cent aqueous alcohol (ethanol) heated on a water-bath. The alcohol is allowed to boil for about twenty minutes. The alcoholic extract is spotted onto a piece of filter paper (Whatman #1). Three separate spots are made, each one being built up by repeated applications of the extract.

When thoroughly dry, on one of the spots is placed a drop of acid Ehrlich's reagent (1 gram p-dimethylaminobenzaldehyde, 200 ml. 95% ethanol, 5 ml. concentrated hydrochloric acid). On the second spot is placed a drop of "Ehrlich's control" (5 ml. concentrated hydrochloric acid, 500 ml. 95% ethanol). The third spot is left untreated. When dry, the colours of the spots are recorded. The paper is then heated in an oven at 100°C. for thirty seconds, examined, and then heated for a further thirty seconds. Colours of the spots after the final heating are also recorded.

Development of a deep blue colour on the spot treated with Ehrlich's reagent is considered to be positive and to indicate the presence of aucubin or asperuloside. This reaction was rarely seen in the plants examined in this study.

In many cases, however, a colour within the range from pink to magenta was recorded. In a comparatively few cases, a brick-red or orange colour resulted. Those which show

none of the above-mentioned colours usually show the yellowy or greenish colour of the original extract. It should be noted that in almost all cases, there is a slight darkening of the spots when heated.

Although Trim and Hill (1952) speak of an "aucubin group" of glycosides (see in discussion of leuco-anthocyanin test), aucubin, asperuloside and monotropitoside show little structural similarity. The structure of aucubin has not been definitely established, although Nakamura (1950) has proposed two possibilities:



 $H_{3}C - C = 0$ $H_{3}C - C = 0$ $H_{3}C - C = 0$ G = 0 G

monotropitoside

asperuloside





aucubin

OR

*glucose in x position
Development of a pink to magenta colour (a quantitative difference?) is quite well correlated with positive reactions to the HCl/methanol and leuco-anthocyanin tests and development of a red colour in the "syringin test". Thus if one is unable to do an HCl/methanol test on wood of a particular plant, a positive leuco-anthocyanin test and a magenta Ehrlich test on leaves can safely be considered equivalent to a positive HCl/methanol test.

(f) <u>HCN test</u>

The occurrence of hydrogen cyanide or prussic acid in plants was first reported by Bohm (1803) who found it in water in which bitter almonds had been steeped.

In probably all cases, the hydrogen cyanide is present in the combined form, mostly or entirely as a glycoside. About fourteen of these cyanogenetic glycosides, as they are called, have been identified. The first to be found was amygdalin which was identified in 1830 by Robiquet and Boutron-Charlard.

Probably the earliest use of the occurrence of HCN as a taxonomic character was made by Endlicher (1840) who noted that the easiest way to distinguish the families "Chrysobalaneae" and "Amygdaleae" is that the former lack HCN:

"Chrysobalaneae----ab Amygdaleis, quibus proxime affinis, calyce saepissime basi obadnatum ovarii stipitem inaequalie---necnon acidi hydrocyanici defectu facillime distinguuntur."

In the present work, a few grams of fresh leaves,

preferably the youngest available, are chopped and then ground in a mortar. Buring the grinding a few drops of water, a few drops of chloroform, and a few grains of emulsin are added. The mixture is poured into a test tube which is provided with a ground-in glass stopper.

On the bottom of the stopper is attached with paraffin a triangular piece of picric acid paper (prepared by soaking Whatman's #1 filter paper in a saturated aqueous solution of picric acid and allowing it to dry). Just before inserting the stopper into the tube, the picric acid paper is dipped into a 10 percent aqueous solution of sodium carbonate and then blotted.

A change from the original yellow of the paper to shades of red-brown or orange indicates the emission of free HCN, produced by the hydrolysis of any cyanogenetic glysosides which might be present. In very weak tests, there is only a slight darkening.

The time required for the appearance of the positive colouration ranges from a few minutes ("strong") to four or five days ("weak"). In any case, the tubes are allowed to stand for at least a week. If no colour change has appeared in that time, the test is assumed to be negative, although in exceptional cases some colour has developed only after a longer time.

If a HCN test done on leaves of a particular plant is negative, one cannot be certain that the plant as a

whole lacks cyanogenetic compounds, for these substances may be present only in certain organs, or only at certain stages of development of these organs. A notable example is <u>Eriobotrya japonica</u>; the leaves lack HCN while the seeds contain a great deal. In some cases, seeds may be as good a test material as leaves or even better.

It also seems that HCN content may vary with age of a particular organ; for example, Treub (1907) found fifteen times as much HCN in young leaves as in older leaves of the same plant. For this reason, it is wise to use the youngest leaves available in doing this test.

To be certain that HCN is absent from a plant, all organs should be tested at all stages of development. This is quite impractical in work such as is described here. Therefore negative tests done on leaves or seeds have been assumed to indicate absence of cyanogenetic compounds from a plant.

(g) "Juglone" tests

Juglone is a naphthoquinone which probably occurs in the plant as the glucoside of hydrojuglone (1,4,5-trihydroxynaphthalene). There are many colour reactions for quinones, the majority of them based on reactions of the quinones with sulphuric acid, ferric chloride or dilute alkali. This last reaction is the one used in this work.

The "juglone" tests are done on bark, fresh leaves and often roots of plants. About one gram of material (preferably fresh) is chopped and left overnight in a few milli-

liters of chloroform (enough to cover the material). The chloroform is then filtered off and evaporated on a waterbath. The film left on the inside of the test tube is taken up in about 3 milliliters of ether; an equal volume of dilute aqueous ammonia is added and the tube shaken. On standing, the mixture separates into two layers, the upper being ether.

Appearance of a purple colour in the aqueous (lower) layer as soon as the ammonia is added indicates the probable presence of juglone or of similar quinones. Thomson (priv. com., 1959) suggests that under the test conditions, mono-<u>peri</u>hydroxynaphthoquinones such as juglone, should give a purple colour. Compounds such as droserone (3,5-dihydroxy-2-methyl-1,4-naphthaquinone) and lawsone (2-hydroxy-1,4-naphthaquinone) should give a red colour, while 2,3dihydroxynaphthaquinones and some dihydroxybenzoquinones should give blue alkaline solutions.

In the beginning of the investigation, the colour was recorded as soon as the phases had separated after shaking. This is recorded as "Juglone (Test A)". It was later found that if the tubes are observed in ultraviolet light, fluorescence can, in some cases, be seen in one or both layers. This checking in ultraviolet light has been made a regular part of the procedure; these tests are recorded as "Juglone (Tests A-B)".

Still later it was discovered that in some cases,

a substance which becomes green in contact with ammonia diffuses down from the ethereal phase into the ammonia layer. A third step was then added to the test; that is to allow the tubes to stand for three or four days (with occasional shaking) and to record any colour changes. These tests are recorded as "Juglone (Tests A-C)".

This test is not specific for juglone, for as can be seen by reference to Thomson's work on quinones (1957), there are a few other compounds which fulfill the requirement of being mono-<u>peri</u>hydroxynaphthaquinones. However, in this work, it seems certain that juglone (or a very similar derivative) is responsible for the development of the purple colours recorded.

(h) Chromatographic tests for D-glucitol and sedoheptulose

D-glucitol (sorbitol) is a sugar alcohol which is rather widely distributed among members of the <u>Rosaceae</u>. Appearance of this compound in the <u>Hamamelidaceae</u>, or in any other family presumed to be close to the <u>Rosaceae</u>, would greatly strengthen arguments for relating such families.

Sedoheptulose is a heptose which is probably present in all plants as it is an intermediate in photosynthesis. However, presence of sedoheptulose in <u>large</u> amounts seems to be a character of taxonomic value (see page 49).

In this work, alcoholic extracts of leaves were prepared by boiling about one gram of finely chopped fresh leaf material in 10 milliliters of 75% ethanol for ten minutes. The extracts were refrigerated until used.

When the extracts were to be examined, the liquid was decanted off the leaves which were then washed with a few milliliters of 75% ethanol; this washing was added to the original extract. The alcoholic extract was washed with petrol ether to remove as much as possible of the chlorophylls and carotenoids. The extract was then blown to dryness under an air jet.

The residue was taken up in a few milliliters of water, and then spotted on strips (7"x21") of filter paper (Whatman #1). In each case a pair of chromatograms were prepared, one to be examined for glucitol, the other, for sedoheptulose.

The chromatograms were run in water-saturated phenol until the solvent front was about one inch from the end of the paper. The chromatograms were air-dried, and in most cases, autoclaved at fifteen pounds pressure for ten minutes to remove the last traces of phenol.

Those chromatograms to be examined for the presence of sedoheptulose were sprayed with Bial's orcinol reagent (0.5 g. orcinol, 15.0 g. trichloroacetic acid, 100 ml. water-saturated butanol; this reagent must be kept under refrigeration and be freshly prepared each week.). The chromatograms were allowed to dry and were then heated in an oven at 100°C. until the position of sedoheptulose was shown by the appearance of a blue spot. Comparison of the

position of this spot with that of a standard spot of sedoheptulose which was run on all chromatograms, was taken as proof of identity.

Chromatograms to be examined for the presence of D-glucitol were sprayed with bromcresol purple buffered with borate (Bradfield and Flood, 1950). D-glucitol appeared as a yellow spot on a blue background. Bromcresol purple is a pH indicator and is not specific for glucitol, so it was necessary to run a reference spot of glucitol on all chromatograms.

(i) "Cigarette" and "Hot-Water" tests

During the course of the investigation, it was found that Dagmar Dykyj-Sajfertova had published a paper on the relation between the respiratory pigments of plants and their phylogenetic position. In this paper (1958) she based her work on that of A. V. Blagoveschenskii (1950) who suggested that those plants more advanced, either ontogenetically or phylogenetically, show a specialized sort of metabolism, resulting in the accumulation of compounds such as rubber, alkaloids, terpenes and similar complex molecules.

This sort of metabolism, he claims, is correlated with the presence of terminal respiratory enzymes of the polyphenolase type; those plants which are more primitive have respiratory enzymes of the peroxidase type. Polyphenolases may be located by the darkening, when injured, of tissues containing them.

Dykyj-Sajfertova found that if a lighted gigarette is applied to the underside of a green leaf (three seconds for the average leaf), a dark ring appears around the heated area if polyphenolases are present. This ring ranges in colour from dark brown to inky black. Dykyj-Sajfertova classified her results in the following manner:

I..... a strong rapid reaction; dark ring in 5-10 sec. II.... slower, but strong reaction; ring after 1-3 min. III... slow and weak reaction; ring after 10-15 min. IV.... negative; no ring after 30 min. *.... ocher yellow (referred to by Dykyj-Sajfertova as the "<u>Oxalis</u> reaction", as it appeared in all species of <u>Oxalis</u> tested)

The "<u>Oxalis</u> reaction" seems to be correlated with an acid cell sap.

She found that the intensity of the reaction (darkness of the ring) was a constant, characteristic of a species, and did not vary with differing ecological conditions. In some cases, however, old leaves may react more quickly than young ones.

Another test based on the same principles was also used. In this test, the leaf-blades were dipped part-way into water at $90^{\circ}95^{\circ}$ C. and held there for four or five seconds. A darkening reaction, either as a band across the top of the dipped part, or as a darkening of the entire dipped portion, corresponding to the ring obtained in the "cigarette" test, could be seen in many cases. Results obtained by this method were often a bit slower than those obtained by use of a cigarette. (j) Other sources of information

It is, of course, true that a great deal of work has been done on plant chemistry, but only rarely as a means to a taxonomic end. Those plants which contain compounds of medicinal or commercial value, such as alkaloids or edible oils, have been quite thoroughly investigated, and much information on distribution and composition of such compounds is scattered throughout the literature. Compilation of such data often gives taxonomically useful results. This is especially true of the fats and of the fatty oils (fats liquid at room temperature).

At this point, a brief discussion of fats may be presented. The fatty acids present in plants may be divided into several group; i.e., saturated, mono-unsaturated, diunsaturated, etc. Most of the fatty acids which occur in vegetable fats are unsaturated, that is, one or more pairs of carbon atoms are linked by double bonds (by triple bonds in at least one case). Whether saturated or unsaturated, they are generally straight-chain molecules with an even number of carbon atoms, ranging from C_6 to C_{26} . These fatty acids are esterified with the trihydric alcohol glycerol.

One of the most interesting aspects of fatty acid distribution is that certain fatty acids are found only in rather limited groups. For @xample, acids of the chaul-

moogric acid series have so far been found only in some members of the <u>Flacourtiaceae</u>.

In this investigation, distribution of fatty acids was used in discussing the <u>Ulmaceae</u>, <u>Rosaceae</u> and <u>Jugland</u>-<u>aceae</u>.

RESULTS

The results of the experimental work demcribed in the preceding section are presented in tabular form under four sub-headings; i.e., (i) <u>Hamamelidaceae</u>, (ii) families which have been associated with the <u>Hamamelida</u>-<u>ceae</u> in an order <u>Hamamelidales</u>, (iii) <u>Rosaceae</u>, (iv) "<u>Amentiferae</u>". The appropriate tables immediately preceed the discussion of each sub-division.

The fractions in the tables and text represent numbers of genera and included species; i.e., 22/400 symbolizes four hundred species representing twenty-two genera. The sizes of families given in the large tables are only approximations.

Family	HCl/Me + ?	th.	Leuco +	-anthoc	yan.	Ehrlich '	rest M	Syring +	3. (1:1 H2SC	4) Test R	HCN Test + ?		Jugl. 1 +	osts •	Flu +	0 °. ®	Raph.	Gluc +	itol	Sedohe +	pt.	Ci L	.g.& H II	-W. Test III	ts IV	OR
Hamam. 24/90	11/23	1/1	11/21			та фин фил били били (1997) та та фија (1997) та та с	ଟ/1ର୍ଚ 3/3 R		ł	2/2	10/19)	12/24	and David Data David Society of Barr Barr Barr	4/7		4/6	C?		4/7		4/8		1/1			7/15
Myroth. 1/1-2	1/1	•	1/1				1/1 P				1/1		1/1		1/1		1/1	C?		1/1		1/1					
Platan. 1/5	1/3		1/3				1/2				1/1	1/3			1/2	1/1	1/1	C?		1/1		1/1			1/2		
Cunon. 30/200	3/4		4/5				1/1 3/3 R				3/4	2/2	4/5					C?									
Euptel. 1/3	1/2					*					1/2		1/1		1/2		1/2	C?									
Stachyur. 1/4	1/1	1/1	1/1		1/1		1/1 1/1 P	1/1					1/2					C?						1/2			
Eucomm. 1/1		1/1		1/1		1/1		1/1					1/1					C?	1						1/1		
Cercid. 1/1		1/1		1/1			1/1 P			1/1			1/1		1/1		1/1	C?		1/1		1/1				1/1	
Trocho. 1/1	1/1		1/1					•		1/1			1/1					C?									
Buxac. 7/40		4/10	2/2		3/10	2/1 1/1	4 1/1 LGG 3/4 P		1/	1 3/7	1/1 F	5	4/13		4/6		1/1	C?				2/2				1/1	
Daphniph。 1/25	1/1		1/1			1/1?					1/1		1/1		1/1			C?									
Coriar. 1/13	1/1				1/4	1/3	3			1/1	1/1		1/4		1/3	1/1	1/2	C?								1/1	1/1
Pittos. 9/200		5/10		1/1	5/11	4/8	\$ 1/1 P			5/5	1/5Pr		6/17		2/5	2/2	1/1	C?						1/1			
Hydrang. 40/500	8/51	11/56	6/7	4/4 1/481	4/8	4/5	5 3/5 1/1 R 3/11 F 1/1 0	5	4/	'14 5/1	5 8/29 1/2 I	3/5	13/51		6/15	6/15		+			1/4 1/1?	4/13	7/14	3/4	3/3	2/12	
Saxifrag. 35/550	2/2		7/11	2/2	1/1		5/7 1/1 P	1/1	2/	3	11/26	1/2 2/2	14/55		2/2		1/1	+		1/1	4/16	\$/20		1/3	4/4	9/14	1/1
																		a - Cardover, and a family of the			Bl=black OR="Oxal C=calciv	r, GG=g: .is read m oxal:	rey-gre ction", ate cry	en, M=m P=pink stals o	agenta, , Pr=pu ther th	0=oran rple, R an raph	ge =red ides

(i) The <u>Hamamelidaceae</u>

(ii) Families which have been associated with the <u>Hamamelidaceae</u> in an order <u>Hamamelidales</u>

TABLE III

Chemical characters of the <u>Cunoniaceae</u>

Genus and number of spp.	•	HC1/ Meth.	LA. Test	Ehr- lich	Syrin- gin	HCN Test	Jugl. Tests	Fluor.	Ra- phides	Gluci- tol	Sedo- hep.	Cig.& HW.
Ackama	(2)	+1	+1	Rl	Rl	+1			C?			
Callicoma	(2)	+1	+1	Rl	Rl	-1			С?			
Ceratopetalum	(5)	+2	+2	M1 R1	R2	-2			С?			
Cunonia	(1)		+1						C?			
Davidsonia	(1)					+1			C?			
Geissois	(6)					-1			С?			
<u>Schizomeria</u>	(7)					-1			C?			

M=magenta; R=red; C=calcium oxalate crystals other tahn raphides

TABLE 1	IV
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Chemical	characters	of	the	Buxaceae

Genus and number of sp	p.	HC1/ Meth.	LA. Test	Ehr- lich	Syrin- gin	HCN Test	Jugl. Tests	Fluor.	Ra- phides	Gluci- tol	Sedo- hep.	Cig.& HW.
Buxus	(25)	- 3	- 5	- 3 P 1	- 2 +? 1	- 5	- 1	- 1	С		- 1	IV 1
Not(h)0buxus	(1)								С			
Pachysandra	(4)	- 3	- 3	- 1 P 1	- 3	- 3	- 2		C?		- 1	
Sarcococca	(5)	- 3	- 2 + 1	GG 1 P 2	- 2	- 4	- 2		C?			
Simmondsia	(1)	- 1	+ 1	Ml	P 1	- 1	- 1		C			
Styloceras	(3)								C?			

M=magenta; P=pink; GG=grey-green; C=calcium oxalate crystals other than raphides

TABLE V

Chemical characters of the Pittosporaceae

Genus and number of sp	p.	HC1/ Meth.	LA. Test	Ehr- lich	Syrin- gin	HCN Test	Jugl. Tests	Fluor.	Ra- phides	Gluci- tol	Sedo- hep.	Cig.& HW.
Billardiera	(9)	- 1	- 1	- 1	- 1	- 2			C ?			
^B ursaria	(3)	- 1	- 1	- 1	- 1	- 2		+ 1	C?	·		
^C itriobatus	(4)	- 1	- 1	P 1	- 1	- 2	- 1		С			
Hymenosporum	(1)					- 1			-?			
Pittosporum	(70)	- 6	- 7 ? 1	- 5	- 1 Pr 5	- 9	- 4	- 1 + 1	С			
<u>Sollya</u>	(2)	- 1	- 1	- 1	- 1	- 1			C?			II l

P=pink; Pr=purple; C=calcium oxalate crystals other than raphides

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Chemical characters of the <u>Hydrangeaceae</u>

Genus and number of s	pp∙	HCl/ Meth.	LA. Test	Ehr- lich	Syrin- gin	HCN Test	Jugl. Tests	Fluor.	Ra- phides	Gluci- tol	Sedo- hep.	Cig.& HW.
Anopterus	(2)	+ 1	+? 1	R 1	R 1	- 1			-?			
Bauera	(4)	+ 1	+ 1	M 1	R 1	- 1			-?			
<u>Carpenteria</u>	(1)	- 1	- 1	- 1		- 1	- 1	+ 1	-?			Il
<u>Carpodetus</u>	(7)	- 1	? 1	01		- 1			С			
<u>Decumaria</u>	(2)	- 1										
Deinanthe	(1)					- 1			+			II 1
<u>Deutzia</u>	(40)	- 11			R 1 +?_4	- 9			-?		- 2 ? 1	I 2
Dichroa	(10)	- 1			- 2		- 1	+ 1	-?			III 1
<u>Escallonia</u>	(60)	+ 8	+] D1 /		R 5	- 2			-?			III 1
<u>Fendlera</u>	(3)	- 1	DL 4		- 1				-?			
<u>Hydrangea</u>	(80)	- 9	? 1	- 1 D 1	- 9 B 2	- 8	- 3	+ 3	+		- 3	I3
<u>Itea</u>	(6)	+ 2	+ 2 + 1	Ml	R 1	+ 1			C		- 1	IV 4
Jamesia	(1)	+ 1			R 1	+ 1			-			III 1

(continued on next page)

TABLE	VΤ

(continued)

Genus and number of sp	p•	HC1/ Meth.	LA. Test	Ehr- lich	Syrin- gin	HCN Test	Jugl. Tests	Fluor.	Ra- phides	Gluci- tol	Sedo- hep 	Cig.& HW.
Kirengeshoma	(1)	- 1	- 1		? 1	- 1			-			Il
Philadelphus	(50)	- 27 + 4	- 5 + 5	- 2 P 7	- 2 ? 3 P 2	- 12	- 8	+ 8	-?		- 7	I5 II1
<u>Quintinia</u>	(5)				1 2	- 1			С			
Ribes	(140)	+ 31	+ 7	M 3 D 2	R 16	- 12	- 1	+ 1	-?		+ 4	IV 8
<u>Schizophragma</u>	(4)	- 2	÷⊥	ŗ	+: 0	- 1			+			Il
<u>Whipplea</u>	(2)	- 1	- 1	- 1	- 1		- 1	+ 1	-?			Il

M=magenta; R=red; Bl=black; OR="<u>Oxalis</u> reaction" P=pink; C=calcium oxalate crystals <u>other</u> than raphides

TABLE VII

Chemical characters of the <u>Saxifragaceae</u> (s.s.)

Genus and number of sp	p•	HC1/ Meth.	LA. Test	Ehr- lich	Syrin- gin	HCN Test	Jugl. Tests	Fluor.	Ra- phides	Gluci- tol	Sedo- hep.	Cig.& HW.
Aceriphyllum	(1)				R 1	- 1						OR 1
Astilbe	(20)		+ 2		R 1	- 4			-?			
Bergenia	(10)		+ 2		R 4	- 1			-?		+ 2	III 1
<u>Boykinia</u>	(8)		+ 1		R 3	- 4			-?		- 2	IV 2
Brexia	(1)	+ 1							С			
Chrysosplenium	(60)			M 1			- 1	- 1	-?		+ 1	IVI
Francoa	(2)		- 1		+ 1	- 2			-?			
<u>Heuchera</u>	(30)		+ 1	Мl	? 2	- 7	- 1		-?	- 1	- 4	III 1
<u>Mitella</u>	(10)				R 1	- 2			-?		- 2	IV I
Parnassia	(45)					- 1			-?		+ 1	III 1
Peltiphyllum	(1)					+? 1			+		- 1	IVI
Rodgersia	(2+)	+ 1			R 5	- 4			+ 4		- 4	II 3 IV 1

(continued on next page)

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(continued)

Genus and number of	spp.	HC1/ Meth.	LA. Test	Ehr- lich	Syrin- gin	HCN Test	Jugl. Tests	Fluor.	Ra- phides	Gluci- tol	Sedo- hep.	Cig.& HW.
<u>Saxifraga</u>	(325)		+ 3	M 3	R 3	- 24			-?		- 5 + 12	IV 5
<u>Tanakea</u>	(1)			Γ⊥	R 1	- 1		-?		+ Τ ζ		
Tellima	(1)		+ 1		R 1	- 1			-?		- 1	IV 1
<u>Tiarella</u>	(4)		+? 1	Мl	R 2	- 2			C			II I 1
Tolmiea	(1)		+ 1	мı	+? 1	- 1			-?		- l	IV 1

M=magenta; R=red; OR="<u>Oxalis</u> reaction"; C=calcium oxalate crystals <u>other</u> P=pink than raphides

DISCUSSION OF RESULTS

(i) The Hamamelidaceae

The first problem is that of establishing for the <u>Hamamelidaceae</u> a set of chemical characters which can be used as a basis of comparison with other families in the same way that morphological or anatomical features can be used.

Of the approximately ninety species in twenty-three genera which are included in the <u>Hamamelidaceae</u> [in the sense of Harms (1932)], some twenty-five species representing twelve genera and four of the five sub-families recognized by Harms have been tested.

Those species tested (11/21) have been consistently positive to the leuco-anthocyanin test; of twenty-five species in twelve genera tested, only one,<u>Sinowilsonia</u> <u>henryi</u> Hems., is negative to the HCL/methanol test. Similarly, nineteen species, representing ten genera, are negative to the "syringin" test, giving pink or red colours. Of four species which showed only yellowing in the xylem, one was <u>Sinowilsonia henryi</u>.

All species tested (12/24) are negative to the HCN test.

Those species tested with the Ehrlich reagent (11/21), are negative, giving pink, red or magenta colours. The "juglone" tests, done on seven species in four genera,

have all been negative, showing only development of a yellow colour in the aqueous layer. None of those species examined (4/6) showed any fluorescence.

Results of cigarette and hot-water tests (7/15) have been recorded as "<u>Oxalis</u> reaction" or delayed "<u>Oxalis</u> reaction". The only exception is <u>Disanthus</u> <u>cercidifolius</u> Maxim., which was recorded as "II".

None of the species examined (4/8) contained detectable amounts of glucitol or sedoheptulose.

Examination of those species on which "syringin" tests were done showed no sign of raphides and Metcalfe and Chalk (1950) make no mention of their occurrence in any of the hamamelidaceous genera.

The genera tested are arranged in the following manner, according to the classification of Harms:

Disanthus Disanthoideae Hamamelis Loropetalum Hamamelideae richocladus Eustigmateae Corylopsideae Corylopsis Hamamelidoideae Fothergilla Parrotia Fothergilleae Distylium Distylieae Sycopsis Sinowilsonia Bucklandioideae Bucklandia Liquidambaroideae Liquidambar

At the present time, there is no chemical evidence to suggest that any of these sub-families should be raised to familial rank. Various authors have separated from the <u>Hamamelidaceae</u> a number of "splinter families", such as <u>Rhodoleiaceae</u>, <u>Bucklandiaceae</u>, <u>Altingiaceae</u>, <u>Liquidambara</u>-<u>ceae</u>, <u>Fothergillaceae</u>, <u>Parrotiaceae</u> and <u>Disanthaceae</u>, but there is little evidence to suggest that such extreme splitting is warranted.

Harms (1930) says that <u>Disanthus</u> Maxim. is the most primitive member of the familiy, and sets it aside as the only genus in the sub-family <u>Disanthoideae</u>. <u>D. cercidi</u>-<u>folius</u> Maxim., the only species, agrees with the general fa familial characters, except in the case of the cigarette and hot-water tests, which were recorded as "II", and the Ehrlich test which gave a red spot. These are minor differences and do not constitute strong enough evidence to raise the Disanthoideae to familial rank.

At the other end of the family, the <u>Liquidambaroideae</u> were thought by Harms to perhaps differ enough from the rest of the family to be made a family in their own right. <u>Altingia</u> Nor., of three south-east Asian species, has not been tested. Testing of two of the four species of <u>Liquidambar</u> L. shows no departure from the general characters of the family. However, all species of <u>Liquidambar</u>, in particular, L. orientalis Mill., produce storax, a resinous material.

This again, is not strong enough evidence to support the creation of a separate family for <u>Liquidambar</u> and <u>Altingia</u>.

In discussing the anatomical characters of the <u>Hamameli-daceae</u>, Harms (l.c.) mentions some facts which might come under the head of comparative chemistry. Although none of the genera examined have been reported to contain raphides, several do have calcium oxalate crystals of other sorts.

Harms points out that in the mesophyll of leaves of <u>Altingia, Bucklandia, Liquidambar</u> and <u>Rhodoleia.</u> that is, in four of the five genera of the <u>Bucklandioideae</u> of Niedenzu (1891), clustered crystals occur. In a similar position in leaves of the rest of the members of the family, only single crystals are found. However, this distinction breaks down in considering the distribution of crystals in the stem.

According to Harms, <u>Liquidambar</u> and <u>Altingia</u> differ from the other genera examined in that both have medullary secretory canals, a phenomenon seen also in the incompletely known genus<u>Ostrearia</u> Baill. It is indeed interesting to note that Solereder (1899b) reports the occurrence of cluster crystals in the mesophyll of leaves of <u>Ostrearia</u>, a fact suggesting that Ostrearia might well be placed in or near the Liquidambaroideae of Harms.

So, examination of representatives of four of the five sub-families recognized by Harms, including four of the five tribes of the <u>Hamamelidoideae</u>, indicates that the <u>Hamamelida</u>-<u>ceae</u> form a chemically homogeneous group.

In brief, one may tentatively say that the chemical characters of the <u>Hamamelidaceae</u> are the following: (i) they are positive to the leuco-anthocyanin and HCl/methanol tests; (ii) they are negative to the Ehrlich test, giving pink to magenta colours; (iii) they are negative to the "syringin" test, showing development of pink or red in the xylem and bast fibres; (iv) they lack raphides, although other types of calcium oxalate crystals are present; (v) they are negative to the HCN test; (vi) they are negative to the "juglone" test and show no fluorescence; (vii) they do not contain detectable amounts of glucitol or sedoheptulose.

(ii) Families which have been associated with the Hamamelidaceae in an order Hamamelidales.

Twenty families have been associated with the <u>Hamamelidaceae</u> in an order <u>Hamamelidales</u> by various authors. These families are the <u>Myrothamnaceae</u>, <u>Platanaceae</u>, <u>Cunoniaceae</u>, <u>Eupteleaceae</u>, <u>Bruniaceae</u>, <u>Stachyuraceae</u>, <u>Eucommiaceae</u>, <u>Cercidiphyllaceae</u>, <u>Tetracentraceae</u>, <u>Trochodendraceae</u>, <u>Buxaceae</u>, <u>Daphniphyllaceae</u>, <u>Altingiaceae</u>, <u>Coriariaceae</u>, <u>Pittosporaceae</u>, <u>Hydrangeaceae</u>, <u>Saxifragaceae</u>, <u>Byblidaceae</u>, <u>Podostemaceae</u> and <u>Hydrostachyaceae</u>.

Of thirteen authors who have recognized an order <u>Hamam</u>elidales, eleven have placed the <u>Platanaceae</u> in it, and eight

have included the <u>Myrothamnaceae</u>. Comparison of the chemical characters of these families with those of the <u>Hamameli-</u> <u>daceae</u> suggests that they are indeed closely related.

The <u>Myrothamnaceae</u> agree with the <u>Hamamelidaceae</u> in all characters tested, while the <u>Platanaceae</u> differ only in the presence of cyanogenetic compounds in the three species tested, and in a slower reaction to the cigarette and hot-water tests.

(a) <u>Platanaceae</u>

The presence of a cyanogenetic compound in species of <u>Platanus</u> is no obstacle to relating it closely to the <u>Hamameli-daceae</u>. The extensive investigations of Dillemann (1953) om the transmission in interspecific crosses of <u>Linaria</u> of the character responsible for the presence of cyanogenetic compounds indicates that in this genus, at least, the presence of these compounds is determined by a single gene, acting independently of those controlling morphological characters. If this be generally true, cyanogenetic glycosides could have arisen quite independently many times during the course of evolution.

The quantity of cyanogenetic compound in <u>Platanus</u> has been vividly expressed by Greshoff (1909), who said:

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

(b) <u>Cunoniaceae</u>

Representatives of four genera; viz., Ackama Cunn.,

<u>Callicoma</u> Andr., <u>Ceratopetalum</u> Smith, <u>Cunonia</u> L., and <u>Schizo-</u> <u>meria</u> Don, have been tested and the results indicate that the <u>Cunoniaceae</u> are generally similar to the <u>Hamamelidaceae</u>.

Several of the cunoniaceous genera are peculiar in that they have been reported to accumulate large amounts of aluminium; genera especially note-worthy in this respect are <u>Anodopetalum</u> Cunn., <u>Ceratopetalum</u> Smith, <u>Gillbeea</u> F. Mull., <u>Platylophus</u> Don, <u>Schizomeria</u> Don, <u>Spiraeanthemum</u> Gray, and <u>Stollea</u> Schlect. (Webb, 1954).

The chemical similarities between the <u>Cunoniacege</u> and the <u>Hamamelidaceae</u> are not inconsistent with suggestions that these two families are related, and there are sufficient correspondences in other characters to make it seem possible that the <u>Cunoniaceae</u> should be placed near the <u>Hamamelidaceae</u>.

(c) Eupteleaceae

The incomplete evidence available for the <u>Eupteleaceae</u> (see table I), based on results obtained from <u>Euptelea poly</u>-<u>andra S.& Z. and E. Francheti</u> van Tiegh., suggests that this family might be included in the <u>Hamamelidales</u> as Wettstein (1935) and others have done.

(d) Bruniaceae

A striking omission is the fact that results are available for none of the <u>Bruniaceae</u>. Seeds of <u>Berzelia</u> <u>lanuginosa</u> Brongniart and <u>Brunia</u> <u>albiflora</u> Phillips were obtained and germinated. but at the time of writing the plants were not

large enough to test. It would be most interesting to test mature specimens of bruniaceous plants, as this family might prove to show many similarities to the <u>Hamamelidaceae</u>.

Of the five families just discussed, that is, the <u>Myro-thamnaceae</u>, <u>Platanaceae</u>, <u>Cunoniaceae</u>, <u>Eupteleaceae</u> and <u>Bruniaceae</u>, it seems certain that the first two are closely related to the <u>Hamamelidaceae</u>, a conclusion which is supported by chemical evidence as well as by evidence provided by other disciplines. The <u>Cunoniaceae</u> and <u>Eupteleaceae</u> show similarities with the <u>Hamamelidaceae</u> in regard to chemistry, but the <u>Eupteleaceae</u> differ sufficiently in regard to other characters to make it <u>unlikely</u> that they should be included in an order <u>Hamamelidales</u>.

Reactions given by representatives of these families to six tests are shown in the table below:

	HC1/ Meth.	LA. Test	Syring. Test	Ehrl. Test	HCN Test	Jugl. Tests
Hamam.	+	+	R	М	_	-
Myrotham.	+	+	R	Р	-	-
Platan.	+	+	R	М	+	-
<u>Cunoniac</u> .	+	+	R	R	+	
Eupteleac.	+		R			
Bruniac.						

M=magenta; R=red; P=pink

Thus, one might tentatively propose an order <u>Hamameli-dales</u>, including the <u>Hamamelidaceae</u>, <u>Myrothamnaceae</u>, <u>Platana-ceae</u>, and perhaps the <u>Cunoniaceae</u>. This suggestion is based on only preliminary evidence, but at our present state of knowledge, there is no chemical evidence against, and much for such a grouping.

(e) <u>Stachyuraceae</u>

Results obtained from <u>Stachyurus chinensis</u> Franch. and <u>S. praecox</u> S.& Z. are mixed (see table I). Material of <u>S</u>. <u>chinensis</u> from two sources has been recorded in one case as positive to the HCl/methanol test, in the other case, as negative. However, the positive reaction to the "syringin" test recorded for <u>S</u>. <u>chinensis</u> is a strong suggestion that <u>Stachyurus</u> is not closely related to the <u>Hamamelidaceae</u>.

It would be exceedingly interesting to determine the composition of seed oil of <u>Stachyurus</u>, for several authors have suggested that the <u>Stachyuraceae</u> are closely related to the <u>Flacourtiaceae</u>, which latter family is peculiar in that some members contain fatty acids of the chaulmoogric acid series. The most common of these are chaulmoogric and hydnocarpic acids, which are unsaturated, cyclic acids.

Benson (1957) includes <u>Stachyurus</u> in his order <u>Violales</u>, which is equivalent to the sub-order <u>Flacourtiineae</u> in the <u>Parietales</u> of the 11th "Syllabus" (1936). Of the other families which Benson includes in this order (<u>Violales</u>), the <u>Canellaceae</u>, <u>Flacourtiaceae</u>, <u>Turneraceae</u> and <u>Passifloraceae</u>

are known to contain cyanogenetic glycosides (Gibbs, 1954). The apparent absence of HCN from <u>Stachyurus</u> suggests that it might be out of place in this series. On the other hand, it could be argued that the power of synthesis of cyanogenetic compounds has been lost by <u>Stachyurus</u>, as may also be the case in the <u>Violaceae</u>, which seem to lack cyanogenetic compounds.

The mixed results from <u>Stachyurus</u> make it difficult to reach any conclusions about its possible relationships with the <u>Pittosporaceae</u> or the <u>Camelliaceae</u> (see page 19). (f), (g), (h) <u>Cercidiphyllaceae</u>, <u>Eucommiaceae</u>, <u>Trochodendraceae</u>

The little families <u>Cercidiphyllaceae</u>, <u>Eucommiaceae</u> and <u>Trochodendraceae</u> may be conveniently discussed together. <u>Cercidiphyllum</u>, <u>Eucommia</u>, <u>Trochodendron</u> and <u>Tetracentron</u>, as well as <u>Euptelea</u>, have often been placed together, as by Oliver (1895) who joined them in his family <u>Magnoliaceae</u>, or by Hallier (1912) who included them all in his <u>Hamameli</u>-<u>daceae</u>.

The family <u>Cercidiphyllaceae</u>, that is, <u>Cercidiphyllum</u> <u>japonicum</u> S.& Z., is negative to the HCl/methanol test (see table I). It is also negative to the "syringin" test, showing only yellowing in the cortex. On two occasions, <u>C. japonicum</u> from McGill has given questionably positive results to the leuco-anthocyanin test, although Bate-Smith and Metcalfe (1957) report a clearly positive reaction.

These reactions to the HCl/methanol and "syringin" tests

suggest that <u>Cercidiphyllum</u> is not closely related to <u>Eupte-</u> <u>lea</u>, as has been thought by <u>Maximowicz</u> (1872) and Prantl (1891). Certainly, these results do not support Solereder (1899), who considered <u>Cercidiphyllum</u> and <u>Eucommia</u> to each constitute a tribe of the <u>Hamamelidaceae</u>.

The <u>Eucommiaceae</u> differ from the <u>Hamamelidaceae</u> in several respects (see table I). <u>Eucommia ulmoides</u> Oliv., the only member of the family, is positive to the "syringin" and Ehrlich tests, but is negative to the HCl/methanol test. The presence of aucubin as reported by Plouvier (1944), and suggested by the positive reaction to the Ehrlich test, is probably the cause of the questionable leuco-anthocyanin test.

Tippo (1938) suggested that the <u>Eucommiaceae</u> had arisen from a developmental line leading from hamamelidaceous ancestors to the <u>Urticales</u>. He later modified his views, saying that the <u>Eucommiaceae</u> form a direct link between the <u>Hamamelidaceae</u> and <u>Urticales</u> and should be included in this latter group, close to the <u>Ulmaceae</u>.

Chemical evidence suggests that Tippo's earlier idea is the better. The occurrence in <u>Eucommia</u> of rather substantial amounts of gutta-percha [2.35% dry weight of leaves, according to Tomaszewska and Tomaszewski (1956)] and of aucubin present two peculiarities of metabolism which suggest that it is misplaced in being treated as a direct link between the <u>Hamamelidaceae</u> and the <u>Ulmaceae</u>.

It seems unlikely that in a path of development from a hamamelidalian ancestor through a "Eucommia-type" to Ulmus

that the power of synthesis of the compound(s) responsible for a positive reaction to the HCl/methanol reagent should have been lost and then regained, while independently the abilities to produce gutta-percha and aucubin were gained and then lost.

In spite of morphological and anatomical evidence to the contrary, on chemical grounds it is very difficult to imagine <u>Eucommia</u> as a direct link between the <u>Hamamelidaceae</u> and the <u>Ulmaceae</u>. Tippo's earlier suggestion that <u>Eucommia</u> is an off-shoot of a developmental line leading from the <u>Hamamelidaceae</u> to the <u>Ulmaceae</u> is better supported by the chemical facts.

The family <u>Trochodendraceae</u> includes <u>Trochodendron</u> <u>aralioides</u> S.& Z., and according to some authors, <u>Tetra-</u> <u>centron sinense</u> Oliv., as well. The chemical information available for this family is based on tests done on <u>Tr</u>. <u>aralioides</u>, which is positive to the leuco-anthocyanin and HCl/methanol tests. None of the tests used in this work have been done on <u>Tetracentron</u>.

Comparison of the chemical characters of these families just discussed, shows that they have only few characters in common. The table on the following page shows the characters of these families as well as those of <u>Euptelea</u> and of the Hamamelidaceae.

Comparison of these families with the <u>Hamamelidaceae</u> does not suggest that <u>Cercidiphyllum</u> or <u>Eucommia</u> should be included

	HCl/ Meth.	LA. Test	Syring. Test	HCN Test	Ehrl. Test	Cig. Test
Eucom.	-	?	÷	-	+	III
Euptel.	+		R	-		
Cercid.	÷.	?	-	-	P	III
Trocho.	+	+	-	-		
Hamamel.	+	+	R	-	М	OR

M=magenta; R=red; P=pink; OR= "Oxalis reaction"

should be included in the <u>Hamamelidaceae</u>, or even in an order <u>Hamamelidales</u>. <u>Trochodendron</u> agrees with the <u>Hamamelidaceae</u> in regard to three characters, but differs so greatly in morphological and anatomical features to make it very unlikely that <u>Trochodendron</u> should be placed near the <u>Hamamel-</u> <u>idaceae</u>.

Thus one may conclude that each of these four genera is best placed in a distinct family, none of which should be included in the <u>Hamamelidales</u>.

(i) <u>Buxaceae</u>

The family <u>Buxaceae</u> has been included in an order <u>Hamam-</u> <u>elidales</u> by four authors, while Hallier (1912) actually placed the buxaceous genera in his family <u>Hamamelidaceae</u>.

Those members of the <u>Buxaceae</u> tested have all been negative to the HCl/methanol test, although <u>Simmondsia</u> and <u>Sarco-</u> <u>cocca</u> <u>Hookeriana</u> Baill. are positive to the leuco-anthocyanin test (see table IV). The majority of species tested are negative to the "syringin" test, and show no development of red. The one exception is <u>Simmondsia Californica</u> Nutt. which developed a rose-pink colour in the xylem. There is a questionably positive test reported for <u>Buxus</u> <u>sempervirens</u> L.

van Tieghem (1897) had separated a family <u>Simmondsia</u>-<u>ceae</u> [Simmondsia only] from the <u>Buxaceae</u>, and there is some evidence to support this split. The differing reactions of <u>Simmondsia to</u> the leuco-anthocyanin and syringin test have already been mentioned.

Simmondsia Californica is of economic importance, yielding a "seed oil", actually a non-fatty liquid wax. This has been reported by Eckey (1954) to consist chiefly of ll-eicosenoid acid, 13-docosenoid (erucic) acid, docosenol and eicosenol. There are no comparable reports from others of the <u>Buxaceae</u>, although the leaf wax of <u>Buxus sempervirens</u> is said to be largely myricyl alcohol and palmitic acid.

Evidence obtained from the distribution of alkaloids indicates that <u>Simmondsia</u> is similar to the rest of the family. Martin-Sans (1930) reported the presence of alkaloids in <u>Simmondsia</u>, <u>Fachysandra</u>, <u>Sarcococca</u>, <u>Styloceras</u> and <u>Buxus</u>, but made no attempt to isolate these compounds.

On chemical grounds, the <u>Buxaceae</u> cannot be included in an order <u>Hamamelidales</u>, as Hutchinson and Takhtajan have done, and they can certainly not be placed in the <u>Hamamelidaceae</u> as Hallier did.

(j) Daphniphyllaceae

<u>Daphniphyllum</u> Bl., the only member of this family has usually been included in the <u>Euphorbiaceae</u>; on chemical grounds it is difficult to agree or disagree with this position as the <u>Euphorbiaceae</u> give very mixed results.

<u>D. macropodium</u> Miq., the only species tested, is positive to the HCl/methanol test, and is perhaps positive to the leuco-anthocyanin test. The results of this latter test are difficult to evaluate, as the leuco-anthocyanin test in this case is obscured by rapid blackening of the leaf material, probably a result of the presence of asperuloside as reported by Trim and Hill (1952).

The chemical characters of <u>D</u>. <u>macropodium</u> show some similarities to the corresponding characters of the <u>Hamameli-</u> <u>daceae</u>, but the differences in other respects are so sharp that it seems most unlikely that the family belongs in the <u>Hamamelidales</u>.

(k) <u>Altingiaceae</u>

This family has been segregated from the <u>Hamamelidaceae</u> by various authors, the first one to do so being Lindley (1846), who included in it <u>Altingia</u> Nor. and <u>Liquidambar</u> L. Takhtajan (1954) places a family <u>Altingiaceae</u> in his order <u>Hamamelidales</u>, but one cannot tell if he would include <u>Liquidambar</u> in the family. If both genera be included in the family, it is equivalent to the sub-family <u>Liquidambaroideae</u> of Harms, which has already been discussed on pages 82 and 83.

In any case, there seems to be no doubt that the family should be included in any order <u>Hamamelidales</u> which is proposed.

(1) Coriariaceae

<u>Coriaria</u> Niss. ex L., the only member of the <u>Coriaria</u>-<u>ceae</u>, differs from the <u>Hamamelidaceae</u> in several respects (see table I).

Easterfield and Aston (1901) found in various parts of a number of species a poisonous non-nitrogenous glycoside, tutin, the empirical formula of which is $C_{17}H_{20}O_7$. They also found in <u>Coriaria japonica</u> A. Gray an unidentified compound, $C_{15}H_{18}O_4$, which they called coriamyrtin. Maranon (1932) later found coriamyrtin in <u>C. intermedia</u> Matsumura and established the empirical formula as $C_{15}H_{18}O_5$. Kariyone and Okuda (1953) confirmed this and determined the structure:



coriamyrtin
^This is a rather unusual structure and it is difficult to assign coriamyrtin to any class of compounds. Karrer (1958), in his work on plant constituents, places it among a group of miscellaneous substances which have no particular features in common.

The characters of <u>Coriaria</u>, both chemical and morphological, make it seem most unlikely that <u>Coriaria</u> should be placed in the <u>Hamamelidaceae</u>, the family in which Hallier included it. (m) Pittosporaceae

This family belongs to the group negative to the HCl/ methanol and leuco-anthocyanin tests. This fact makes it unlikely that the family is close to the sub-family <u>Escal</u>-<u>lonioideae</u> of the <u>Saxifragaceae</u>, a position which Rendle (1938) and Gundersen (1950) assigned to it. <u>Escallonia</u> and <u>Anopterus</u>, two members of the <u>Escallonioideae</u>, are both strongly positive to the HCl/methanol test. The <u>Pittosporaceae</u> are further distinguished from the <u>Escallonioideae</u> by the presence of cortical resin canals in the former group.

This combination of chemical and anatomical characters strongly suggests that the <u>Pittosporaceae</u> do not belong near the <u>Hamamelidaceae</u> and should not be included in an order Hamamelidales.

(n) <u>Hydrangeaceae</u>

The family <u>Hydrangeaceae</u> of Gundersen is quite mixed in regard to chemical characters (see table VI and page 98). Of the genera tested, seven are positive to the HCl/methanol

test, while ten are negative. Gundersen did suggest that the sub-families <u>Iteoideae</u>, <u>Escallonioideae</u> and <u>Ribesioideae</u> might be raised to familial rank, but of those sub-families presumably remaining in the <u>Hydrangeaceae</u> (s.s.), the <u>Baueroideae</u> are positive to the HCl/methanol test and the <u>Hydrangeoideae</u> are generally negative. The <u>Pterostemonoideae</u> have not been investigated.

If the genera tested be fitted into Hutchinson's latest scheme (1959), in which the woody members of the <u>Saxifraga</u>-<u>ceae</u> (s.l.) are divided among six families, namely, the <u>Hydrange</u>-<u>aceae</u>, <u>Escalloniaceae</u>, <u>Philadelphaceae</u>, <u>Pterostemonaceae</u>, <u>Grossulariaceae</u> and <u>Baueraceae</u>, there are still difficulties.

Of five genera which Hutchinson places in his <u>Escallonia</u>-<u>ceae</u>, that is, <u>Anopterus</u> Labill., <u>Carpodetus</u> Forst., <u>Escallonia</u> Mutis ex L.f., <u>Itea</u> Gronov. ex L. and <u>Brexia</u> Nor. ex Thou., four are HC1/methanol positive, while <u>Carpodetus</u> is negative. Similarly, seven members of Hutchinson's <u>Philadelphaceae</u> have been tested; all are negative except <u>Jamesia</u> Torr. et Gray, which is strongly positive.

As shown on page 98, comparison of the evidence given by the chemical characters with the disposition of the woody members of the <u>Saxifragaceae</u> (s.l.) given by Engler (1928) shows no exact correspondences.

Ten species of <u>Escallonia</u> have been reported to contain asperuloside (Plouvier, 1956). This compound is likely responsible for the blue-black darkening noted in leuco-antho-

Comparison of the views of three authors concerning the

position of the woody saxifragaceous genera

tested in this work.

	HC1/ 1	Engler (1928)	Hutchin. (1959) Gunder, (1950)
Anopterus	+	Escalloniod.	Escalloniac.	Escallonioid.?
Bauera	+	Escallonioid.	Escalloniac.	Baueroid.
<u>Carpenteria</u>	-	Philadelpheae	Philadelphac.	Hydrangeoid.?
Carpodetus	-	Escallonioid.	Escalloniac.	Escallonioid.?
Decumaria	-	Hydrangeeae	Hydrangeac.	Hydrangeoid.?
Deutzia	-	Philadelpheae	Philadelphac.	Hydrangeoid.?
<u>Dichroa</u>	-	Hydrangeeae	Philadelphac.	Hydrangeoid.
<u>Escallonia</u>	÷	Escallonioid.	Escalloniac.	Escallonioid.
Fendlera	-	Philadelpheae	Philadelphac.	Hydrangeoid.?
<u>Hydrangea</u> r	nixed	Hydrangeeae	Hydrangeac.	Hydrangeoid.
Itea	+	Iteoid.	Escalloniac.	Iteoid.
Jamesia	+	Philadelpheae	Philadelphac.	Hydrangeoid.?
Philadelphus	mix.	Philadelpheae	Philadelphac.	Hydrangeoid.
Kirengeshoma	-	Kirengesh-oid.	Hydrangeac.	Hydrangeoid.?
Ribes	+	Saxifragoid.	Grossulariac.	Ribesioid.
Schizophragma	<u>a</u> –	Hydrangeeae	Hydrangeac.	Hydrangeoid.?
Whipplea	-	Philadelpheae	Philadelphac.	Hydrangeoid.

cyanin tests done on four species. However, results of leuco-anthocyanin and Ehrlich tests done on one species each of <u>Anopterus</u> and <u>Carpodetus</u> do not suggest that aucubin or asperuloside is present in these species. It should be noted that both these species give rather unusual reactions to the Ehrlich test, <u>Anopterus glandulosa</u> Labill. giving a red spot, and <u>Carpodetus serratus</u> Forst. giving an orange spot.

A careful study of the woody genera of the <u>Saxifra-gaceae</u> (s.l.) and of certain genera which have been variously placed in the family <u>Cunoniaceae</u> or in a family <u>Escalloni-aceae</u> by various authors, should be made. The available chemical evidence does support divisions along the lines of the sub-families as described by Engler (1928), but there are certain genera which seem out of place in their respective groups. The ultimate result will likely be the raising of some sub-families to familial rank, and a redisposition of certain genera.

(o) <u>Saxifragaceae</u>

There is comparatively little information available concerning the chemical characters of members of the <u>Saxifraga</u>-<u>ceae</u> of Gundersen, but it indicates that they would be generally positive to the HCl/metanol test if they were woody.

It is questionable if there are chemical grounds for separating the woody and herbaceous members of the <u>Saxifra-</u> <u>gaceae</u> (s.l.) as Gundersen, Hutchinson and others have done,

although Favarger (1957) who investigated the distribution of anthocyanins in the root-caps and apical meristems of members of the <u>Saxifragaceae</u>, reports that those lacking anthocyanins are all woody. It also seems that accumulation of sedoheptulose is generally restricted to herbaceous members, although it has been reported from four species of <u>Ribes</u> (see tables I, VI, and VII).

The same may be said for the <u>Saxifragaceae</u> (s.s.) as for the <u>Hydrangeaceae</u>; that is, that although they show some chemical similarities to the <u>Hamamelidaceae</u>, they differ sufficiently in morphological characters to exclude them from an order <u>Hamamelidales</u>.

(p) <u>Byblidaceae</u>, <u>Podostemaceae</u>, <u>Hydrostachyaceae</u>

Unfortunately, no chemical information is available concerning any of these families.

(iii) Chemical characters of the <u>Rosaceae</u>

Genus and number of sp	p.	HC1/ Meth.	LA. Test	Ehr- lich	Syrin- gint	HCN Test	Jugl. Tests	Fluor.	Ra- phides	Gluci- tol	Sedo- hep.	Cig.& HW.
<u>Acaena</u>	(130)		- 2	P 2	R 2	- 7	- 2	- 1	-?	+ 1	- 1	I II 1
<u>Agrimonia</u>	(10)		+ 1			- 3			-?			II 1
Alchemilla	(75)					- 1			-?			III l
Amelanchier	(15)	+ 3	+ 3	M 2	R 1	+ 7	- 2	+ 2	-?			I 3
Aronia	(3)	+ 1			R 1	+ 3			-?			
Cercocarpus	(10)	+ 2	+ 1	Ml	R 2	+ 3	- 2		-?			
Chaenomeles	(3)	+ 2	+ 1	M 1	R 1	+ 3	- 2	- 1 + 1	-?	+ 2	- 2	
<u>Chamaemeles</u>	(1)			Ρ⊥		+ 1		+ <u>T</u>				
<u>Chrysobalanus</u>	(4)	+ 1	+ 1	мı	R 1	- 1			С	- 1		
<u>Cotoneaster</u>	(50)	+ 5	+ 6	R 5	R 4	+ 21	- 4	-1	-?	+ 6	- 3	I7 TTT1
Cowania	(3)			Ml				ر ،				TTT
<u>Crataegus</u>	(100)	+ 8	+ 7	M 5	R 3	- 5	- 7	- 2	-?	+ 4	- 2	I 7
Cydonia	(5)	- 1 + 1	+ 2	P 2 M 1	Rl	+ 7 + 3	- 1	+) + 1	-?			I 2
Docynia	(3)	+ 1			Rl	+ 1						
Dryas	(2)	+ 1			R 1	- 1						

TABLE VIII	
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Chemical characters of the <u>Rosaceae</u>

TABLE VIII

(continued)

Genus and number of	spp.	HC1/ Meth.	LA. Test	Ehr- lich	Syrin- gin	HCN Test	Jugl. Tests	Fluor.	Ra- phides	Gluci- tol	Sedo- hep.	Cig.& HW.
Emplectocladus	(1)					+?						
<u>Eriobotrya</u>	(12)	+ 1	+ 1	Ρl	R 1	+ 1			-?	+ 1	- 1	
<u>Exochorda</u>	(3)	+ 2	+ 2		R 2	+ 3			-?			
<u>Fallugia</u>	(1)		- 1									
Fragaria	(10)		+ 1						-?			III l
Geum	(40)					+ 1			-?			I 1
Heteromeles	(2)	+ 1	+ 1		R 1	+ 1			-?			
<u>Kageneckia</u>	(3)					+ 2						
<u>Kerria</u>	(1)	+ 1	+ 1	Ml		+ 1	- 1	- 1	-?	+ 1	- 1	
Lyonothamnus	(1)	+ 1			R l	- 1			-?			
Malus	(15)	+ 2	+ 3	P 2	R 2	+ 1	- 1	- 1	-?	+ 1		II 1
Mespilus	(40)		+ 1			- 2			-?			II 1
Neillia	(6)	+ 5	+ 1	Мl	R 6	- 5	- 1	+ 1	С			II 1
<u>Neviusia</u>	(1)	+ 1	- 1		R 1	+ 6			-?			
<u>Nuttallia</u>	(1)					+ 1			-?			

TABLE VIII

(continued)

Genus and number of s	spp.	HC1/ Meth.	LA. Test	Ehr- lich	Syrin- gin	HCN Test	Jugl. Tests	Fluor.	Ra- phides	Gluci- tol	Sedo- hep.	Cig.& HW.
Osteomeles	(10)	+ 2	+ 2	M 2	R 2	+ 1	- 1		-?	+ 2	- 1	
Peraphyllum	(1)					+ 1						
<u>Photinia</u>	(30)	+ 2			R 2	+ 7			-?			
<u>Physocarpus</u>	(5)	+ 1			R 1	- 2			-?			
<u>Potentilla</u>	(300)	+ 3	+ 20	M 2	R 3	- 4	- 1	- 1	-?			II 1
Poterium	(1)		- 9	Γ⊥		- 1						TA T
P <mark>rinsepia</mark>	(1)?	+ 3			R 1	+ 2						
Prunus	(85)	+ 12	+ 9	M 1	R 9	+ 25	- 7	+ 7	-?	+ 7	- 5	I-IV
Pygeum	(20)		- 1	ro		+ 3			-?			
Pyracantha	(3)	+ 2			R 2	+ 2			-?	+ 2		
Pyrus	(65)	+ 2	+ 3		R 2	+ 11			-?	+ 4		I 3
<u>Quillaja</u>	(3)	+ 1		Ρl		- 1 - 1	B 1		-?	- 1	- 1	1- 2
Rhaphiolepis	(4)	+ 2	+ 1	Ρl	R 2	- 3	- 1		-?			
Rhodotypus	(1)?	+ 1	+ 1		Rl	+ 3			-?			
<u>Rosa</u>	(150)	+ 4	+ 9 - 2	M 4 - 1	R 4	+ 1 - 4	- 1	+ 1	-?	- 0		I-III OR 1

TABLE VIII

(continued)

Genus and number of s	pp.	HC1/ Meth.	LA. Test	Ehr- lich	Syrin- gin	HCN Test	Jugl. Tests	Fluor.	Ra- phides	Gluci- Sedo- tol hep.	Cig.& HW.
Rubus	(225)	+ 1	- 2	Ml	R 1	- 6	- 1	- 1	-?		I-III
<u>Sanguisorba</u>	(30)					- 1			-?		II 1
Sorbus	(80)	+ 6	+ 3	M 2 P 2	R 2	+ 3	- 2	- 1 + 1	-?	+ 4	I 1 II 2
<u>Spiraea</u>	(50)	+ 11	+ 10	M 4 P 3	R 10	- 10 + 5	- 3	+ 2	-?		II 8
Stephandra	(3)	+ 1		.)	R 1	- 1					
<u>Stranvaesia</u>	(7)	+ 1			Rl	+ 2					

M=magenta; R=red; OR="Oxalis reaction"; B=blue; C=calcium oxalate crystals other than raphides

(iii) Chemical characters of the Rosaceae

Since the <u>Hamamelidaceae</u> have so often been placed near the <u>Rosaceae</u>, the chemistry of this latter family was investigated.

The <u>Rosaceae</u> are a large group which is divided into six sub-families in the llth "Syllabus" (1936). This classification is followed in this discussion.

sub-family	tribes
I <u>Spiraeoideae</u>	Spiraeeae Quillajeae Holodisceae
II <u>Pomoideae</u>	
III <u>Rosoideae</u>	<u>Kerrieae</u> <u>Potentilleae</u> <u>Filipenduleae</u> <u>Cercocarpeae</u> <u>Sanguisorbeae</u> <u>Roseae</u>
IV <u>Neuradoideae</u>	
V <u>Prunoideae</u>	

VI Ohrysobalanoideae

Division of the Rosaceae according to the 11th "Syllabus"

The <u>Rosaceae</u> have been much split, each of the subfamilies having been raised to familial rank at one time or another. However, the most recent authors keep the family intact, although some do exclude the <u>Chrysobalanoideae</u>.

Members of five of these six sub-families have been

tested. Only the <u>Neuradoideae</u> are not represented, although this group would be particularly interesting to test. The two genera, <u>Neurada</u> L. and <u>Grielum</u> L., which are included in this sub-family have sometimes been placed in the <u>Geraniaceae</u>. Agardh (1858) who recognized a family <u>Neuradeae</u>, said that it is quite similar to the <u>Geraniaceae</u>. However, Engler (in Focke, 1888) said that the <u>Neuradoideae</u> are close to the <u>Rosoideae</u> and are possibly derived from the Potentilleae.

In regard to reaction to the HCl/methanol test, leucoanthocyanin test, Ehrlich test and "syringin" test, the five sub-families investigated form a homogeneous group. Those species tested are positive to the HCl/methanol and leucoanthocyanin tests, give magenta spots with Ehrlich's reagent and give a red reaction to the "syringin" test. It should be mentioned that the information available for the <u>Chrysobalanoideae</u> in regard to these tests is based only on <u>Chrysobalanus Icaco L.</u> (see table VIII).

However, if certain other sorts of compounds be considered, it is seen that the sub-families do show some differences. Cyanogenetic compounds seem to be restricted to the sub-families <u>Spiraeoideae</u> (<u>Spiraea</u>, <u>Exochorda</u> and <u>Kageneckia</u>), <u>Pomoideae</u> (except <u>Rhaphiolepis</u>), <u>Rosoideae</u> (tribes <u>Kerrieae</u>, <u>Cercocarpeae</u>, and <u>Potentilleae</u> [<u>Geum</u>]only) and <u>Prunoideae</u>. D-glucitol has so far been found only in members of the <u>Prunoideae</u>, <u>Pomoideae</u> and <u>Rosoideae</u> (tribe <u>Sanguisorbeae</u>). Distribution of these compounds is shown

in Appendix I.

The <u>Prunoideae</u> and the <u>Pomoideae</u> have often been separated from the <u>Rosaceae</u> (s.1.) as distinct families. The <u>Prunoideae</u> have been set apart as the <u>Amygdalaceae</u> (Bartling, 1830) and <u>Drupaceae</u> (de Candolle, 1805). The <u>Pomoideae</u> or some of the members of the sub-family, have been placed in families <u>Pomaceae</u> (Richard, 1808), <u>Mespilaceae</u> (Schultz, 1832) and <u>Malaceae</u> (Small, 1903).

These groups do seem to differ from the rest of the <u>Rosaceae</u> in that they contain both glucitol and cyanogenetic compounds, and it is possible that they should be made distinct families.

As mentioned on page 69, Endlicher (1840) noted that the "Amygdaleae" contain hydrocyanic acid and said that this is one feature distinguishing them from the "Chrysobalaneae" which lack it. However, ten years earlier Lindley (1830) had also recognized this difference and said that the presence of HCN in the <u>Amygdalaceae</u> distinguished them from the <u>Leguminosae</u> and the "Chrysobalaneae". Indeed, Lindley attached so much importance to this character that he characterized his family Amygdalaceae as:

"Polypetalous dicotyledons, with a superior solitary simple ovarium having a terminal style, regular perigynous indefinite stamens, a drupaceous fruit, an exalbuminous suspended seed, and alternate stipulate leaves yielding hydrocyanic acid."

Although many genera of the Rosaceae have been types of

families, there is, in general, insufficient chemical evidence to permit one to reach any conclusions concerning the validity of these segregations. However, there is one notable exception.

The sub-family Chrysobalanoideae has been made a family by several authors, the first to do so being Brown (1818b). <u>Chrysobalanus Icaco</u> L. lacks glucitol and cyanogenetic compounds, but this is not conclusive evidence that it differs from the other members of the <u>Rosaceae</u> (s.s.). If, however, the composition of seed oils be considered, it is seen that at least three genera of the,<u>Chrysobalanoideae</u> are distinctive in this respect.

Comparison of the principal fatty acids in seed oils from various species in four sub-families (no information available on the <u>Spiraeoideae</u> or <u>Neuradoideae</u>) shows that the <u>Chrysobalanoideae</u> differ sharply from the other three sub-families considered.

In all cases recorded, seed oils from members of the <u>Prunoideae</u>, <u>Pomoideae</u> and <u>Rosoideae</u> have contained either oleic or linoleic acid in the largest quantity (see Appendix II).

Records from three genera of the <u>Chrysobalanoideae</u> show that the seed oils are chiefly composed of acids of the C_{18} series; i.e., elaeostearic acid, licanic acid and parinaric acid. The first two are octadecatrienoic acids while parinaric acid is an octadecatetraenoic acid, the only one known

from a vegetable fat. Licanic acid is unique in that it contains a ketonic group.

Consideration of these seed oils throws light on the proper position of at least one genus. Lindley (1853) included <u>Prinsepia</u> Royle in his family <u>Chrysobalanaceae</u>, but the fact that <u>P. utilis</u> Royle contains HCN and has oleic and linoleic acids as the main constituents of the seed fat suggests that Lindley was in error. These findings do support those authors who place <u>Prinsepia</u> in the <u>Prunoideae</u>.

Thus the present chemical evidence suggests that if the <u>Chrysobalanoideae</u> be excluded, the <u>Rosaceae</u> form a quite homogeneous group. Reactions of members of the five subfamilies to some of the tests used are shown in the chart below:

	HCl/ Meth.	LA. Test	HCN Test	Gluci- tol	Lican.& Par. acids
Spiraeoid.	+	+	+		
Pomoideae	+	+	+	+	-
<u>Rosoideae</u>	+	+	+	+	-
Prunoideae	+	+	+	+	-
Chrysobal.	+	+	-	-	+

Comparison of the characters of the <u>Rosaceae</u> (excluding the <u>Chrysobalanoideae</u>) with those of the <u>Hamamelidaceae</u> suggests that these two families are probably not so closely re-

lated as to be placed in the same order. The two families are compared in regard to six characters in the table below:

	HC1/ Meth.	LA. Test	Syring.	HCN	Gluci- tol	Fluor.
Hamamel.	+	+	R	-	-	-
Rosaceae	+	+	R	+	+	+

However, it does seem likely that the <u>Hamamelidaceae</u> and the <u>Rosaceae</u> are related, and there is no chemical evidence which would indicate that the <u>Hamamelidaceae</u> could not have been derived from rosalian ancestors.

In discussing the families which have been included in an order <u>Hamamelidales</u>, seven of the families which are included in the <u>Rosales</u> in the llth "Syllabus" have been mentioned. As material of a member of yet another family which Engler and Diels (1936) place in the <u>Rosales</u> was available, this was also tested.

The little family <u>Crossosomataceae</u> (Engler, 1897) includes only <u>Crossosoma</u> Nutt. with two or three species. Good material of <u>C. californicum</u> Nutt. was available at McGill and a complete series of tests was carried out.

Results from <u>C</u>. <u>bigelovii</u> S. Wats. amd <u>C</u>. <u>californicum</u> Nutt. indicate that the family is negative to the HCl/methanol and leuco-anthocyanin test. <u>C</u>. <u>californicum</u> is negative to the HCN and "juglone" tests and shows no fluorescence. It

does not contain detectable amounts of glucitol and gives a rather weak reaction (III) to the cigarette and hot-water tests. The most striking feature of both species is that they are strongly positive to the "syringin" test. In the case of <u>C</u>. <u>californicum</u>, syringin was identified chromato-graphically.

These results offer no support for placing the <u>Crosso-</u> <u>somataceae</u> near the <u>Rosaceae</u>. However, they do support those who feel that the <u>Crossosomataceae</u> are related to the <u>Paeoniaceae</u>. Three species of Paeonia are negative to the HCl/methanol test and these same three species have been recorded as being questionably positive to the "syringin" test. This is not conclusive evidence, but it does suggest that <u>Crossosoma</u> does not belong in the <u>Rosales</u>.

Of the seventeen families included in the <u>Rosales</u> of the llth "Syllabus", nine, that is, <u>Saxifragaceae</u>, <u>Pitto-</u> <u>sporaceae</u>, <u>Cunoniaceae</u>, <u>Myrothamnaceae</u>, <u>Hamamelidaceae</u>, <u>Eucommiaceae</u>, <u>Platanaceae</u>, <u>Crossosomataceae</u> and <u>Rosaceae</u>, have been discussed.

These families show no degree of homogeneity, six being positive to the HCL/methanol test, and three, negative. They are equally mixed in regard to other characters. The <u>Pittosporaceae</u>, <u>Eucommiaceae</u> and <u>Crossosomataceae</u> in particular, seem to be out of place in the <u>Rosales</u>.

Thus it seems that the <u>Rosales</u> are a rather unnatural group, and that a rearrangement of these families should be made.

(iv) The "<u>Amentiferae</u>"

//etn. ? -]]]	- 1/7 1/1	1/3 2/9	1/481 1/1	1/1	1/3Gr	M 1/1 P	Syring +	^g • (1:: ? 	1 H ₂ SO4) 1/2	Test R 1/4P	+	lest ?	-	Jugl. +	Tests	Fluor +		Raph.	Gluc itol	Sedohe +	pt.	I	Gig.& H. II	-W. Test III	ts IV C	R
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TABLE	Х
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Chemical	characters	of	the	Salicaceae

Genus and number of	spp.	HCl/ Meth.	LA. Test	Ehr- lich	Syrin- gin	HCN Tèst	Jugl. Tests	Fluor.	Raph- ides	Gluci- tol	S h do- hep.	Cig.& HW.
Populus	(20)	+ 5	+ 3	Ml		- 1	- 1	- 1	С?	- 1	- 1	I 3 II 1
<u>Salix</u>	(160)	+ 3	+ 6	M 1 P 1	Rl	+ 2 - 1	- l	- 1	C?		- 1	III II III III 1

M=magenta; R=red; P=pink; C=calcium oxalate crystals other than raphides

ΤA	BLE	XI

Chemical characters of the Myricaceae

Genus and number of	spp.	HC1/ Meth.	LA. Test	Ehr- lich	Syrin- gin	HCN Test	Jugl. Tests	Fluor.	Raph- ides	Gluci- tol	Sedo- hep.	Cig.& HW.
Comptonia	(1)	+ 1		Pl	R 1		Rl	- 1	C?			
Myrica	(40+)	+ 8	+ 2	P 2	P 2 - 2	- 2	G 4	- 1 + 2	C	- 1	- 1	IV l

P=pink; R=red; G=green; C=calcium oxalate crystals other than raphides

TABLE XII

Chemical characters of the <u>Juglandaceae</u>

Genus and number of sp	p•	HC1/ Meth.	LA. Test	Ehr- lich	Syrin- gin	HCN Test	Jugl. Tests	Fluor.	Ra- phides	Gluci- tol	Sedo- hep.	Cig.& HW.
Alfaroa	(1)								-?			
Carya	(12)	+ 9	+ 6	M 1 P 4	R 3	- 7	- 6 + 2	- 6 + 2	-?	- 5	- 6	IV 6 OR 1
<u>Engelhardtia</u>	(10)	+ 1	+ 1	R I M I	Rl	- 1	- 1	- 1	-?			III 1
Juglans	(12)	+ 9 ? 2	+ 3 Bl 1	P 2 - 2	P 1 - 2	- 4	+ 11	- 6	-?	- 3	- 2	II 6 III 1
<u>Platycarya</u>	(2)	- 2 + 1			Rl		+ 1	+ 1	-?			II l
<u>Pterocarya</u>	(4)	+ 3	+ 1	Ρl	R 2	- 1	+ 3 - 1		-?	- 1	- 1	II 2

M=magenta; R=red; P=pink; Bl=black; OR="Oxalis reaction"

TABLE XIII

Chemical characters of the Betulaceae

Genus and number of sp	pl	HC1/ Meth.	LA. Test	Ehr- lich	Syrin- gin	HCN Test	Jugl. Tests	Fluor,	Ra- phides	Gluci- tol	Sedo- hep.	Cig.& HW.
Alnus	(25)	+ 6	+ 5 - 1	M 1 P 4	R 3	- 6	- 3 RO 2	+ 2 - 3	-?	- 4	- 4	
<u>Betula</u>	(40)	+ 18	+ 13	P 12 R 1	R 13	- 15	- 9 G 4	- 9 + 4	-?	- 9	- 9 + 4	I-IV
<u>Carpinus</u>	(21)	+ 3	+ 1 - 1	P 2	Ρl	- 3	- 2	- 1 + 1	-?	- 2	- 2	I 1 III 1
<u>Corylus</u>	(8)	+ 4	+ 4	M 1 P 1	R 2	- 3	- 3	- 3	-?	- 1	- 1	II 1 III 1
<u>Ostrya</u>	(4)	+ 1	+ 1	R 1		- 1	- 1	- 1	-?	- 1	- 1	II 1
<u>Ostryopsis</u>	(2)								-?			

M=magenta; R=red; P=pink; RO=red-orange; Y=yellow-green; G=green

ΤA	BLE	XIV

Chemical characters of the Fagaceae

Genus and number of sp	p.	HCl/ Meth.	LA. Test	Ehr- lich	Syrin- gin	HCN Test	Jugl. Tests	Fluor.	Ra- phides	Gluci- tol	Sedo- hep.	Cig.& HW.
<u>Castanea</u>	(40)	- 2 + 1	- 3	P 2 - 1	P 2	- 2	- 1 G 2	- 3	C?	- 3	- 3	III 1 IV 2
<u>Castanopsis</u>	(35)	+ 1			P 1	- 1			C?			
Fagus	(4)	+ 1	+ 2	P 1		- 1	- 1	- 1	C?	- 1	- 1	II 2
Lithocarpus	(100)	+ 1							C?			
Nothofagus	(12)					- 1			C ?			
Quercus	(300)	+ 31	+ 14 - 6	M 5 P 13 - 2	P 15	- 19	- 18 G 3	- 12 + 7	С	- 6	- 9	II 6 III 12 IV 4

M=magenta; P=pink; G=green; C=calcium oxalate crystals other than raphides

TABLE X	V
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Chemical characters of the Urticaceae

Genus and number of sp	p.	HC1/ Meth.	LA. Test	Ehr- lich	Syrin- gin	HCN Test	Jugl. Tests	Fluor.	Ra- phides	Gluci- tol	Sedo- hep.	Cig.& HW.
Boehmeria	(60)		? 1						Cy			
<u>Gesnouinia</u>	(1)	+ 1	+ 1	Ml	R 1	- 1	- 1		Cy			
<u>Laportea</u>	(40)					- 2			+ Су			
<u>Parietaria</u>	(7)		+ 1			- 1			Су			Il
Pilea	(140)		+ 1	Ρl		- 1			Су			
Procris	(5)		+ 1	GG 1	- 1		- 1	+ 1	Cy			
<u>Urtica</u>	(30)		- 1	P 1		- 1			Су			I l II l

M=magenta; R=red; P=pink; GG=grey-green; Cy=cystoliths

TABLE XVI

Chemical characters of the <u>Ulmaceae</u>

Genus and number of sp	p.	HCl/ Meth.	LA. Test	Ehr- lich	Syrin- gin	HCN Test	Jugl. Tests	Fluor.	Ra- phides	Gluci- tol	Sedo- hep.	Cig.& HW.
Aphananthe	(5)								С			
<u>Celtis</u>	(75)	- 5 ? 1	- 3 ? 1	Gr 4	- 5	- 1 ? 3	- 2	- 2	Cy	- 2	- 2	II 2
Hemiptelea	(1)	+ 1	? 1	Ρl	Ρl	- 1	- 1	- 1	C?	- 1	- 1	Il
Planera	(1)	+ 1			Ρl	- 1	- 1	- 1	C			
Trema	(30)	+ 1 - 1			- 1	+ 2	- í	+ 1	Су			
Ulmus	(18)	+ 8	+ 4	Р3	R 3	- 3	- 3	+ 1	C	- 1	- 1	I 4 II 1
Zelkova	(4)	+ 2	+ 1	Ml	R 2	- 2	- 1	- 1	С	- 1	- 1	II 1

M=magenta; P=pink; R=red; Gr=grey; C=calcium oxalate crystals other Cy=cystoliths than raphides

Genus and number of sp	p•	HC1/ Meth.	LA. Test	Ehr- lich	Syrin- gin	HCN Test	Jugl. Tests	Fluor.	Ra- phides	Gluci- tol	Sedo- hep.	Cig.& HW.
Artocarpus	(60)		+ 1						С			
Brosimum	(10)	- 1	- 1	Ρl	- 1	- 1	- 1	+ 1	С			
Broussonetia	(3)	- 1			- 1				Cy		- 1	
<u>Cannabis</u>	(1)		- 1			- 1			-?			III 1
<u>Cudrania</u>	(4)		- 2						С			
Dorstenia	(120)		- 2	P 1	- 1		- 1	- 1	С			
Ficus	(800)	+ 5	+ 5 - 3	M 2 P 1	R 1 - 1	- 7	- 6	+ 6	Cy	- 2	- 2	III 1 IV 1
Humulus	(2)		+ 1	- 2					-?			Il
Maclura	(1)	- 1	- 1	- 1			- 1	- 1	С		- 1	II 2
<u>Malaisia</u>	(2)					- 2			Cy			
Morus	(12)	- 3	- 2	- 2		- 2	- 2	- 2	Cy		- 1	II 2
<u>Pseudolmedia</u>	(5)	- 1	- 1	- 1	- 1	- 1	- 1	- 1	⊸?			

TABLE XVII

Chemical characters of the Moraceae

M=magenta; P=pink; R=red; C= calcium oxalate crystals <u>other</u> than raphides Cy=cystoliths

;

(iv) The "Amentiferae"

In this discussion, the "<u>Amentiferae</u>" include eleven of the first thirteen orders of dicotyledons according to the llth "Syllabus"; that is, <u>Verticillatae</u>, <u>Salicales</u>, <u>Garryales</u>, <u>Myricales</u>, <u>Balanopsidales</u>, <u>Leitneriales</u>, <u>Juglandales</u>, <u>Julianiales</u>, <u>Batidales</u>, <u>Fagales</u> and <u>Urticales</u>.

Some authors consider these orders to form a natural group, while others feel that they have had varied origins, showing similar features as the result of convergent evolution.

The "<u>Amentiferae</u>" are a group of plants, generally woody, which have simple flowers, naked or haplochlamydeous, gathered into catkins or aments in most cases. Some taxonomists, notably Engler, have felt that these plants have primitively simple flowers and have therefore placed them at the beginning of the dicotyledons. Others feel that the apparently primitive characters are the result of reduction, many believing that a number of the amentiferous orders have been derived from hamamelidalian ancestors.

The families which have been investigated form, with two striking exceptions, a chemically homogeneous series. The families <u>Garryaceae</u> and <u>Leitneriaceae</u> are negative to the HCl/methanol test, while members of the other nine families tested are generally positive.

(a) Garryaceae

The family Garryaceae includes only Garrya Dougl. with

about thirteen species. Those species tested (7) are negative to the HCl/methanol test, although two of them, \underline{G} . <u>fadyenii</u> Hook. and <u>G</u>. <u>fremontii</u> Torr., showed development of a pink colour in the cortex when "syringin" tests were done.

Leuco-anthocyanin tests done on four species gave questionable results, being obscured by rapid darkening of the leaf material. This is probably caused by aucubin which has been reported from six species. Ehrlich tests on <u>G. Lindheimeri</u> Torr. and <u>G. fadyenii</u> Hook. were positive, although <u>G. elliptica</u> Dougl. ex Lindl. and <u>G. rigida</u> gave grey spots.

All species tested have been negative to the HCN and "juglone" tests. When "juglone" tests were done on bark of <u>G. fremontii</u> and <u>G. veatchii</u> Kellogg, a deep green colour slowly developed in the aqueous (lower) layer. A similar phenomenon has been seen in species of <u>Quercus</u>, <u>Castanea</u>, <u>Betula</u> and <u>Myrica</u>, but it is not known what substance or substances are responsible for this greening.

A number of interestin diterpenoid alkaloids have been reported from <u>Garrya</u>, among them, garryine, veatchine, garryfoline and cuauchichicine (Wiesner et al, 1952; Djerassi et al, 1955).

These results suggest that <u>Garrya</u> does not belong among the amentiferous families (see table IX) and certainly has no

close connection with the <u>Hamamelidaceae</u>. It therefore seems that the family is best placed near the <u>Cornaceae</u>, a position to which Moseley and Beeks (1955) have assigned it, or even in the <u>Cornaceae</u>.

The presence of aucubin in <u>Garrya</u> strengthens this view, for aucubin was first found in the genus <u>Aucuba</u> which is usually included in the <u>Cornaceae</u>. However, aucubin in <u>Garrya</u> does not constitute evidence against relating it to the <u>Rubiales</u>, as suggested by Gundersen (1950), for aucubin has been found in <u>Rubia</u>.

(b) Leitneriaceae

Leitneria floridana Chapm., the only member of the family, is negative to the HCl/methanol and leuco-anthocyanin tests, facts which suggest that it belongs neither among the "Amentiferae" nor near the <u>Hamamelidaceae</u>.

(c) <u>Casuarinaceqe</u>

Results from three of the approximately thirty-five species of <u>Casuarina</u>, that is, <u>C</u>. <u>equisetifolia</u> L., <u>C</u>. <u>glauca</u> Sieb. and <u>C</u>. <u>torulosa</u> [Dryand. in] Ait., indicate that the family is positive to the HCl/methanol and leuco-anthocyanin tests (see table IX).

This evidence is not inconsistent with inclusion of the <u>Casuarinaceae</u> among the amentiferous orders.

(d) <u>Salicaceae</u>

Those members of the <u>Salicaceae</u> which have been tested are generally positive to the HC1/methanol and leuco-antho-

cyanin tests, and show development of a red colour in aqueous sulphuric acid. Some characters of the family are shown in table X.

Cyanogenetic compounds have been reported to occur in <u>Salix amygdalina</u> L. and <u>S. triandra</u> L. [synonymous with <u>S</u>. <u>amygdalina</u> according to the Index Kewensis] by Henry (1906), but these reports could not be checked and should perhaps, be regarded with doubt.

The Salicaceae are particularly rich in phenolic and flavonoid glycosides. One phenolic glycoside, salicin, is known to occur in both <u>Salix</u> and <u>Populus</u>, while the closely related compound populin, has been reported from six species of <u>Populus</u> and one species of <u>Salix</u>. The report of populin from <u>S. purpurea</u> L. should, perhaps, be questioned.



Picein, the glucoside of p-hydroxyacetophenone, has been reported from species of both <u>Salix</u> and <u>Populus</u> and chrysin (5,7-dihydroxyflavone) is known from several species of <u>Populus</u>.

The distribution of salicin and populin suggests that <u>Salix</u> and <u>Populus</u> are closely related. Rosenthaler (1948) points out that salicin occurs in <u>Salix</u>, the older genus

of the two, while the more complex substance, populin, which is benzoyl salicin, occurs in the younger genus <u>Populus</u>.

Populin is known only from this family, although salicin has been reported to occur in such diverse species as <u>Viburnum prunifolium, Genista monosperma</u>, and <u>Filipendula</u> ulmaria.

The fact that either salicin or populin has been reported from every species of the <u>Salicaceae</u> investigated, but from no other amentiferous family, rather supports the suggestion of Hjelmqvist (1948) that the <u>Salicaceae</u> may stand somewhat apart from the rest of the "<u>Amentiferae</u>". However, there is no chemical evidence which suggests that the family should be removed from the "Amentiferae".

Four families, <u>Myricaceae</u>, J<u>uglandaceae</u>, <u>Betulaceae</u> and <u>Fagaceae</u>, may now be conveniently treated together. . The <u>Myricaceae</u> and <u>Juglandaceae</u> have been joined in an order <u>Juglandales</u> by Rendle (1938) and Gundersen (1950), while the <u>Betulaceae</u> and <u>Fagaceae</u> are usually placed together in the order Fagales.

(e) Myricaceae

The family <u>Myricaceae</u> belongs to the HCl/methanol positive series (see table XI). The most distinctive feature seen in the chemistry of this family is the development in the aqueous layer of "juglone" tests of a deep green colour. The colour appears gradually over a period of days, and seemingly is caused by the slow diffusion downward of some compound originally dissolved in the ethereal phase. It was noted in tests done on <u>Myrica cerifera</u> (bark), <u>M. Gale</u> (bark) and <u>M. Harwegii</u> (bark). The same, or a very similar phenomenon, has been observed in species of <u>Betula</u>, <u>Quercus</u>, <u>Castanea</u> and <u>Garrya</u>.

It was first thought that a flavonoid might be responsible for this greening, an idea based on the fact that alkaline of myricitrin solutions are green. Furthermore, species of <u>Myrica</u>, <u>Betula</u>, and <u>Quercus</u> are known to contain flavonoids, myricitrin having been reported from <u>M. Gale</u>, <u>M. Nagi</u> and <u>M. rubra</u>, while quercitrin is known to occur in species of both <u>Betula</u> and <u>Quercus</u>.

Accordingly, four flavonoids, chrysin, hesperidin, quercetin and quercitrin, as well as chlorogenic acid, caffeic acid and quinic acid, were subjected to the conditions of the "juglone" test. In no case was greening observed. So at this time, the identity of the compound or compounds responsible for development of this green colour remains unknown.

The taxonomy of the <u>Myricaceae</u> is rather confused, some authors including all species in the <u>genus</u> Myrica L., while others have spread the forty-five or fifty species over as many as nine genera. The most widely accepted split is the segregation of <u>Comptonia</u> L. from <u>Myrica</u>.

In the eighth edition of Gray's "Manual of Botany" (1950) these genera are separated, in part, on the basis of leaf characters. In <u>Myrica</u>, the leaves are entire or incised and are not subtended by stipules, while <u>Comptonia</u> has leaves which are pinnatifid and stipulate. The present evidence shows that <u>Myrica</u> and <u>Comptonia</u> agree in regard to all characters except reaction to the "juglone" tests. As mentioned before, three species of <u>Myrica</u> have shown development of a green colour, but leaves and bark of <u>Comptonia peregrina</u> Coult. var. <u>asplenifolia</u> both gave a red reaction.

(f) Juglandaceae

The chemical information available for the <u>Juglandaceae</u> is based on testing of representatives of five genera (see table XII).

Most of the species of the <u>Juglandaceae</u> tested have been positive to the HCl/methanol test, although several species of <u>Juglans</u> are only weakly positive. <u>J. Lindsii</u> (Jepson) Jepson, <u>J. major</u> Heller, <u>J. nigra</u> L., <u>J. regia</u> L. and <u>J. stenocarpa</u> Maxim. have been recorded as negative or "purple 1". However, leuco-anthocyanin tests on three species have been clearly positive.

A feature apparently unique to the <u>Juglandaceae</u> is the presence of the naphthoquinone juglone, which probably occurs in the plant as the glucoside of hydrojuglone (1,4,5-trihydroxynaphthalene). It has been found in every species of <u>Juglans</u> tested, as well as in species of <u>Carya</u>, <u>Pterocarya</u> and <u>Platycarya</u>. The distribution of this compound throughout the family is shown in Appendix III. Heimsch and Wetmore (1939) who investigated the wood anatomy of the <u>Juglandaceae</u>, concluded that <u>Juglans</u> and <u>Pterocarya</u> are very much alike. ^Chemically, they seem to be more closely related that other members of the family. They are similar in reaction to the HCl/methanol test, species of both genera giving rather weakly positive results (none recorded as "purple 4"). They are also alike in that juglone is generally distributed throughout all parts of the plant.

Heimsch and Wetmore also reported that <u>Carya</u> shows many specialized characters. Chemically, <u>Carya</u> differs from <u>Juglans</u> and <u>Pterocarya</u> in several respects. There is a quantitative difference in regard to the HCl/methanol test, <u>Carya</u> giving a more intense reaction. Juglone is much less widely distributed in <u>Carya</u> than in <u>Juglans</u> and <u>Pterocarya</u>, having been found only in leaves of <u>C</u>. <u>illinoensis</u> Wang. and bark of <u>C</u>. <u>ovata</u> (Miller) Koch.

Results of cigarette and hot-water tests also show that <u>Carya</u> stands apart. Six species of <u>Carya</u> are negative to these tests, while six species of <u>Juglans</u> and one of <u>Ptero-</u> <u>carya</u> have been recorded as "II".

There is still more chemical evidence which indicates that <u>Carya</u> differs from <u>Juglans</u> and <u>Pterocarya</u>. Gibbs (1958b) has shown that in regard to seasonal variation in water content of wood, <u>Juglans</u> and <u>Pterocarya</u> behave very much alike, while <u>Carya</u> gives consistently lower values. There is also

variation in regard to seed fats, those of <u>Juglans</u> and <u>Ptero-</u> <u>carya</u> containing much linoleic or linolenic acid, but very little oleic acid; <u>Carya</u>, however, has much oleic acid but only small amounts of linoleic and linolenic acid.

Thus, there seems to be very strong chemical evidence that <u>Carya</u> differs from <u>Juglans</u> and <u>Pterocarya</u>.

Various authors, such as Gundersen (1950), Rendle (1938) and Bessey (1915), have suggested that the <u>Juglandaceae</u> are closely related to the <u>Myricaceae</u>, Rendle and Gundersen both including the <u>Myricaceae</u> in an order <u>Juglandales</u>. There is no strong chemical evidence against this, the families agreeing in several characters.

However, neither juglone nor any similar compound has been reported from the <u>Myricaceae</u>. It is not known what compound causes the appearance of the red colour in "juglone" tests done on leaves and bark of <u>Comptonia peregrina</u> var. <u>asplenifolia</u>, but Thomson (private communication to Gibbs, 1959) has said that naphthoquinones with hydroxyl groups in the quinone ring give red alkaline solutions. Identification of this compound as a naphthoquinone would greatly strengthen the argument for relating the <u>Myricaceae</u> and the <u>Juglandaceae.</u>

(g) <u>Betulaceae</u>

Of the six genera usually placed in the <u>Betulaceae</u>, representatives of all except <u>Ostryopsis</u> have been tested.

The Betulaceae belong to the group positive to the HCl/

methanol test. <u>Carpinus japonica</u> Bl. and <u>Alnus rugosa</u> (DuRoi) Spreng. have given negative reactions to the leucoanthocyanin test, but both are strongly positive to the HCl/methanol test. The characters of those members tested are shown in table XIII.

In the case of five species of <u>Betula</u>, namely, <u>B</u>. <u>atrata</u> Domin (bark), <u>B</u>. <u>fontinalis</u> Sarg. (bark), <u>B</u>. <u>glandulosa</u> Michx. (bark), <u>B</u>. <u>pendula</u> Roth (bark) and <u>B</u>. <u>populifolia</u> Marsh (bark), a deep green colour developed in the lower layer of the "juglone" tests. The nature of the substance responsible is not known.

Except for the five species of <u>Betula</u> mentioned above, and two species of <u>Alnus</u>, the <u>Betulaceae</u> tested showed only a yellow reaction to the "juglone" tests.

When "juglone" tests were done on leaves of <u>Alnus crispa</u> (Ait) Pursh and <u>A. maximowiczii</u> Callier, a red-orange colour, similar to that recorded for <u>Comptonia</u>, developed in the aqueous layer. No compound has been recorded in <u>Alnus</u> which would seem likely to give such a colour under the conditions of the test.

Several flavonoid compounds, including myricitrin, have been reported from members of the <u>Betulaceae</u>. The chemical relations between these compounds may be shown in the following manner:

 + rhamnose

 quercitrin

 -OH

 myricitrin

 hyperoside
Several authors, including Hutchinson (1926, 1959), have split the <u>Betulaceae</u> into the <u>Betulaceae</u> (s.s.)(<u>Alnus</u> and <u>Betula</u>) and the <u>Corylaceae</u> (<u>Carpinus</u>, <u>Ostrya</u>, <u>Corylus</u> and <u>Ostryopsis</u>).

In regard to the major chemical characters, <u>Alnus</u>, <u>Betula</u>, <u>Carpinus</u>, <u>Corylus</u> and <u>Ostrya</u> seem to form a homogeneous group. Distribution of hyperoside, quercitrin and myricitrin was compared, but this gave no evidence that the family should be split. Distribution of these flavonoids is shown in Appendix IV and in the small table below:

	hyperoside	quercitrin	myricitrin	
Alnus	+	+	-	
Betula	+	+	+	
Carpinus	+	+	+	
Corylus	+	+	+	
<u>Ostrya</u>	+	+	-	

Similarly, distribution of certain cyclic acids was considered; again no evidence for a split was found (see Appendix V). Six species of <u>Alnus</u> contain large amounts of protocatechuic acid, but six species of <u>Betula</u> lack it.

Thus, while there may be cytological and morphological grounds for splitting the <u>Betulaceae</u>, our present evidence indicates that the family is chemically homogeneous. (h) Fagaceae

Some chemical information is available for representatives of six genera of the Fagaceae; i.e., <u>Castanea</u>, <u>Castan-</u> <u>opsis</u>, <u>Fagus</u>, <u>Lithocarpus</u>, <u>Nothofagus</u> and <u>Quercus</u>.

The <u>Fagaceae</u> are quite similar to the <u>Betulaceae</u>, being generally positive to the HCl/methanol test, although three species of <u>Castanea</u>, <u>C</u>. <u>crenata</u> S.& Z., <u>C</u>. <u>dentata</u> (Marsh) Burkh. and <u>C</u>. <u>mollissima</u> Bl., have given negative reactions to the leuco-anthocyanin test (see table XIV). Isenberg and Buchanan (1945) recorded a positive HCl/methanol test done on <u>Castanea</u> <u>ashei</u> Sudw. ex Ashe and wood of <u>Castanea</u> <u>crenata</u> was recorded as "purple 2" when tested in December; when material from the same tree was tested in June, it was negative.

Material from <u>Quercus acutissima</u> Carruth., <u>Q. cerris</u> L., <u>Q. dentata</u> Thunb., <u>Q. liaotungensis</u> Koidz., <u>Q. prinus</u> L. and <u>Q. rubra</u> L. has given only negative reactions to the leucoanthocyanin test, although all species of <u>Quercus</u> tested have been positive to the HCl/methanol test. These results suggest that the distribution of the compounds which are responsible for positive reactions to the HCl/methanol and leuco-anthocyanin tests may be limited in <u>Castanea</u> and <u>Quercus</u>. It is possible that these substances could occur only in the leaves, and not in the wood of a given plant (see page 62).

Development of a green colour in the aqueous layer of "juglone" tests, similar to that seen in species of <u>Betula</u>

and <u>Myrica</u>, was noted in <u>Castanea dentata</u> Thunb.(bark), <u>C</u>. <u>sativa</u> Mill. (bark), <u>Quercus muchlenbergii</u> Engelm. (bark), <u>Q. robur</u> L. (bark) and <u>Q. rubra</u> L.(bark). Again, the substance responsible for this greening is not known.

The <u>Fagaceae</u> are known to contain flavonoids, a fact which supports their relation to the <u>Betulaceae</u>. Quercitrin has been reported from several species of <u>Quercus</u>, and, by chromatographic methods, quercetin has been detected in leaves of <u>Castanea crenata</u>, <u>C</u>. <u>dentata</u>, and <u>C</u>. <u>mollissima</u>.

Bark or wood of species of <u>Quercus</u>, <u>Castanea</u> and <u>Litho-</u> <u>carpus</u> has long been used in the tanning of hides, as some members of these genera are very rich in tannins. It is interesting to note that Mayer and Kurz (1959) have reported the occurrence of hamameli-tannin in bark of <u>Castanea sativa</u>. Previously, it had been found only in <u>Hamamelis virginiana</u>. On hydrolysis, hamameli-tannin yields two molecules of gallic acid and one of the branched-chain sugar, hamamelose:



hamameli-tannin

Representatives of the subgenera Lepidobalanus (white

oaks) and <u>Erythrobalanus</u> (red and black oaks) of the genus <u>Quercus</u> were compared. These groups differ in regard to various morphological, anatomical and physiological characters, but in regard to the tests used in this work, there are no apparent differences, except a quantitative one in reaction to the HCl/methanol test, those species in the sub-genus <u>Lepi</u>dobalanus giving rather stronger reactions.

After having discussed the available information concerning the chemistry of the <u>Myricaceae</u>, <u>Juglandaceae</u>, <u>Betulaceae</u> and <u>Fagaceae</u>, it seems apparent that if the <u>Juglandaceae</u> be excluded, these families form a quite closely-knit group (see table below).

	HC1/ Meth.	LA. Test	Jugl. Tests	Flavon- oids	Cig.& HW.
<u>Myrićaceae</u>	+	+	G	+	4
Betulaceae	+	+	G	+	1-4
Fagaceae	+	+	G	+	1-4
Juglandaceae	+	+	+	-	2-4

G=green

The present evidence indicates that the <u>Myricaceae</u> and <u>Juglandaceae</u> are not so closely related so as to be included in the same order. However, it does suggest that the <u>Betula-</u> <u>ceae</u>, <u>Fagaceae</u> and <u>Myricaceae</u> form a homogeneous group. In this work, the order <u>Urticales</u>, including the <u>Mora-</u> <u>ceae</u>, <u>Ulamceae</u> and <u>Urticaceae</u>, has been included among the "<u>Amentiferae</u>".

(i) <u>Urticaceae</u>

The small amount of information available on the chemistry of the <u>Urticaceae</u> indicates that the family belongs to the series positive to the HCl/methanol test. The information is summarized in table XV.

Several genera of the <u>Urticaceae</u> possess stinging hairs on leaves and stems; among these may be mentioned <u>Fleurya</u>, <u>Girardina</u>, <u>Hesperocnide</u>, <u>Laportea</u>, <u>Urera</u> and <u>Urtica</u>, <u>Laportea</u> and <u>Urtica</u> being the common nettles of North America. Emmelin and Feldberg (1949) report the occurrence of histamine and acetylcholine in leaf hairs of <u>Urtica dioica</u> L. and <u>U. urens</u> L., and suggest that these are the substances which cause the characteristic reactions to nettle stings.

Various types of crystals have been reported to occur in members of the <u>Urticaceae</u>, cystoliths being among the most common. These are formed by the deposition of calcium carbonate on outgrowths of the cell wall, and particularly common in epidermal cells. Raphides have been reported from six species of Laportea.

(j) <u>Ulmaceae</u>

The chemical information used in this work is based on tests made on representatives of six genera (see table XVI). Chemically, the <u>Ulmaceae</u> form a mixed group, divided along the lines of the division of the family into the sub-families Ulmoideae and Celtidoideae as given in the 11th "Syllabus".

Of the <u>Ulmoideae</u>, representatives of <u>Ulmus</u> and <u>Planera</u> have been tested, all being positive to the HCl/methanol test. Among the <u>Celtidoideae</u>, members of <u>Celtis</u>, <u>Trema</u>, <u>Zel-</u> <u>kova</u> and <u>Hemiptelea</u> (sometimes included in <u>Zelkova</u>) have been tested; <u>Celtis</u> and <u>Trema</u> are negative to the HCl/methanol test, but <u>Hemiptelea</u> and <u>Zelkova</u> are strongly positive.

Recently Plouvier (1958) has reported that quebrachitol (<u>levo</u>-inositol methyl ether) occurs in nine species of <u>Cel</u>-<u>tis</u> and in <u>Pteroceltis tatarinowii</u> Maxim., the only species of the genus. However, he could not find it in five species of <u>Ulmus</u>, and even more interesting, Plouvier was unable to detect quebrachitol in <u>Zelkova crenata</u> Spach or in <u>Hemiptelea</u> <u>Davidii</u> Planch. This indicates that a further search for this compound among members of the <u>Ulmaceae</u> would be of great interest.

Examination of the principal fatty acids of the seed fats of the <u>Ulmaceae</u> indicates that the sub-families differ in regard to this character. Data from Eckey (1954) and from Sørensen and Søltoft (1958) show that oils of then species of <u>Ulmus</u> contain capric acid in largest amount, while those of two species of <u>Celtis</u> are richest in linoleic acid. However, seed oil of <u>Zelkova serrata</u> (Thunb.) Makino has been reported by Hopkins and Chisholm (1959) to contain capric acid to the extent of 73 percent of the total fatty acids, the highest percentage yet found in a natural fat.

Thus the present chemical evidence indicates that the

<u>Ulmoideae</u> and <u>Celtidoideae</u> do differ, perhaps enough so that the <u>Celtidoideae</u> should be separated as a distinct family.

In this case, it seems that <u>Zelkova</u> should be removed to the <u>Ulmaceae</u> (s.s.), although a search of the literature has revealed no suggestions that <u>Zelkova</u> does not belong in the <u>Celtidoideae</u>, and it shows no striking morphological differences from the other members of the sub-family.

(k) <u>Moraceae</u>

Of the four sub-families into which the family <u>Moraceae</u> is divided in the llth "Syllabus", namely the <u>Moroideae</u>, <u>Artocarpoideae</u>, <u>Cannaboideae</u> and <u>Conocephaloideae</u>, representatives of the first three have been tested.

The present evidence suggests that the family is generally negative to the leuco-anthocyanin and HCl/methanol tests, although Bate-Smith and Lerner (1954) record a positive leuco-anthocyanin test dome on <u>Artocarpus incisa</u> Linn. f. and five species of <u>Ficus</u> have been positive to the HCl/methanol test.

It is indicated that the genera most often placed in a distinct family <u>Artocarpaceae</u> (Brown, 1818b) (<u>Artocarpus</u>, <u>Brosimum</u>, <u>Broussonetia</u>, <u>Cudrania</u> and <u>Pseudolmedia</u> of those tested) are negative to the leuco-anthocyanin test. Further work should be done on <u>Artocarpus</u> to determine if the single positive result represents the "rule" or an exception to it.

If Tippo's idea that the <u>Urticaceae</u> form the climax of the <u>Urticales</u>, while the <u>Ulmaceae</u> and <u>Moraceae</u> represent branches from the main line of development is corredt, it is apparent that the <u>Moraceae</u> and the sub-family <u>Celtidoideae</u> of the <u>Ulmaceae</u> have undergone rather drastic chemical changes. (1) <u>Other families</u>

In the llth "Syllabus" there are included among the "<u>Amentiferae</u>" four small families, the <u>Batidaceae</u>, <u>Balanopsida-</u> <u>ceae</u>, <u>Julianiaceae</u> (each made the type of a family), and the <u>Rhoipteleaceae</u> (included in the <u>Urticales</u>), concerning which, there is no chemical information available.

On the basis of the present chemical evidence, it may be concluded that, if the <u>Garryaceae</u> and the <u>Leitneriaceae</u> be excluded, the "<u>Amentiferae</u>" form a natural group, being, in the main, positive to the HCl/methanol and leuco-anthocyanin tests. Three families, the <u>Myricaceae</u>, <u>Betulaceae</u> and <u>Fagaceae</u>, form a particularly closely-knit group.

There is no evidence which indicates that the <u>Myrica-</u> <u>ceae</u> and the <u>Juglandaceae</u> are closely related; in fact, it is possible that resemblances of this latter family to the other members of the "<u>Amentiferae</u>" are the result of parallel evolution and that if it is desired to make the <u>"Amentiferae</u>" a natural group, the <u>Juglandaceae</u> should be excluded.

There is no evidence which suggests that the "<u>Amentiferae</u>" cannot be regarded as derivatives of hamamelidalian ancestors.

SUMMARY

(i) Chemical characters have been used in investigating the relationships of the <u>Hamamelidaceae</u> and those families which have been included in an order "<u>Hamamelidales</u>", as well as those of the <u>Rosaceae</u> and the "<u>Amentiferae</u>".

The chemical characters (founded on results of a series of standard tests) of the <u>Hamamelidaceae</u>, based on testing of twenty-five species representing twelve genera, have been established. The characters of the species tested are the following: (a) they are positive to the HC1/methanol test; (b) they are positive to the leuco-anthocyanin test; (c) they give a red reaction to the "syringin" test; (d) they give a magenta spot with Ehrlich's reagent; (e) they are negative to the HCN test; (f) they are negative to the "juglone" test; (g) they show no fluorescence in "juglone" tests; (h) they lack raphides; (i) they lack detectable amounts of glucitol and sedoheptulose; (j) they give the "Oxalis reaction" to the cigarette and hot-water tests.

These characters have been compared with those of the other families dealt with in this work. Other things being equal, it is assumed that those families which show the closest correspondences in chemical characters are the most closely related.

(ii) The chemical evidence indicates that the <u>Platanaceae</u> and <u>Myrothamnaceae</u> can be included in an order <u>Hamamelidales</u>. The families <u>Cunoniaceae</u> and <u>Eupteleaceae</u> have not been

thoroughly enough tested, but, at the present time, there is no chemical evidence against the inclusion of these families in the <u>Hamamelidales</u>.

(iii) Of the other families which have been included in an order <u>Hamamelidales</u>, namely, the <u>Stachyuraceae</u>, <u>Buxaceae</u>, <u>Eucommiaceae</u>, <u>Daphniphyllaceae</u>, <u>Trochodendraceae</u>, <u>Pitto-sporaceae</u>, <u>Daphniphyllaceae</u>, <u>Trochodendraceae</u>, <u>Pitto-sporaceae</u>, <u>Hydrangeaceae</u>, <u>Saxifragaceae</u> (s.s.), <u>Coriaria-ceae</u>, <u>Tetracentraceae</u>, <u>Byblidaceae</u>, <u>Podostemaceae</u>, <u>Hydro-stachyaceae</u> and <u>Bruniaceae</u>, there is available no chemical evidence concerning the last five named. None of the remaining nine families show enough correspondences with the <u>Hamamelidaceae</u> in regard to chemical and morphological characters, to warrant inclusion in an order <u>Hamamelidales</u>. (iv) The chemistry of the <u>Rosaceae</u> has also been investigated. If the <u>Chrysobalanoideae</u> be excluded, the family is quite homogeneous. The <u>Rosaceae</u> are particularly distinguished by the occurrence of glucitol and cyanogenetic compounds.

The present chemical evidence indicates that the <u>Rosa-</u> <u>ceae</u> and the <u>Hamamelidaceae</u> differ sufficiently to make it unlikely that these families should be placed in the same order.

Representatives of the family <u>Crossosomataceae</u> were also tested; the evidence shows that this family should be excluded from the Rosales.

The families discussed in this work represent nine of the seventeen included in the <u>Rosales</u> in the llth "Syllabus". In regard to chemical characters, these families do not form a homogeneous group. Six families, <u>Rosaceae, Hamamelidaceae, Cunoniaceae, Saxifragaceae</u> (s.l.), <u>Myrothamnaceae</u> and <u>Platanaceae</u>, are HCl/methanol positive, while the <u>Pittosporaceae</u>, <u>Eucommiaceae</u> and <u>Crossosomata**v**eae</u> are negative.

(v) The chemistry of the "<u>Amentiferae</u>", that is, eleven of the first thirteen orders of dicotyledons according to the llth "Syllabus", has been studied. Material of four families, <u>Julianiaceae</u>, <u>Rhoipteleaceae</u>, <u>Batidaceae</u> and <u>Balanopsidaceae</u>, was not available for testing.

The chemical evidence indicates that, if the <u>Garryaceae</u>, <u>Leitneriaceae</u>, and perhaps the <u>Juglandaceae</u>, be excluded, the "<u>Amentiferae</u>" form a natural group,

It is suggested that the sub-family <u>Celtidoideae</u> of the <u>Ulmaceae</u> should be raised to familial rank, although, if this be done, <u>Zelkova</u> (including <u>Hemiptelea</u>) should be removed to the <u>Ulmaceae</u> (s.s.).

There is no chemical evidence against the view that the "<u>Amentiferae</u>" have been derived from hamamelidalian ancestors.

(vi) On the basis of chemical evidence, one may conclude

that the families <u>Hamamelidaceae</u>, <u>mPlatanaceae</u> and <u>Myro-thamnaceae</u> can be included in an order <u>Hamamelidales</u>, which should be excluded from the <u>Rosales</u> of the llth "Syllabus". The present information gives no evidence against the view that these families have been derived from rosalian ancestors.

APPENDIX I

Distribution of Cyanogenetic Compounds and of D-Glucitol

among Representatives of five Sub-families

of the <u>Rosaceae</u>

Sub-family Tribe Genus	HCN	Glucitol
<u>Spiraeoideae</u> Spiraeeae		
Aruncus	-	-
Neillia	-	
Physocarpus	-	
Spiraea	+	
Stephandra	-	
Quillajeae		
Exochorda	+	
Kageneckia	+	
Quillaja	-	-
Pomoindeae		
Amelanchier	+	
Aronia	+	
Chaenomeles	+	+
Chamaemeles	+	
Cotoneaster	+	+
<u>Crataegus</u>	+	+
Cydonia	+	
Docynia	+	

Sub-family Tribe Genus	HCN	Glucitol
Pomoideae (cont'd)		
Eriobotrya	+	+
Heteromeles	+	
Malus	+	· +
Mespilus	+	
Osteomeles	+	+
Peraphyllum	+	
Photinia	+	
Pyracantha	+	+
Pyrus	+	+
Rhaphiolepis	-	
Sorbus	+	+
<u>Stranvaesia</u>	+	
<u>Rosoideae</u> Kerrieae		
Kerria	+	
Neviusia	+	
Rhodotypus	+	
Potentilleae	-	
Dryas	-	
Geum	+	
Potentilla	-	
Rubus	-	

APPENDIX I (continued)

Sub-family Tribe Genus	HCN	Glucitol
Rosoideae (cont'd) Cercocarpeae		
Cercocarpus	+	
Sanguisorbeae		
Acaena	-	+
Agrimonia	-	
Alchemilla	-	
Poterium	-	
Sanguisorba	-	
Roseae		
Rosa	-	
Prunoideae		
Emplectocladus	?	
<u>Nuttallia</u>	+	
Prinsepia	+	
Prunus	+	+
Pygeum	+	
Chrysobalanoideae		
Chrysobalanus	-	-

APPENDIX I (continued)

APPENDIX II

Principal Fatty Acids of the Seed Oils of some Members

of the	Rosaceae
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sub-family and species	principal fatty acid	% total fatty acids	au- thori- ty
Pomoideae			
Crataegus oxyacantha L.	oleic	82	H
<u>Cydonia vulgaris</u> Pers.	ole ic linoleic	45 42	E
Prunoideae			
<u>Prinsepi</u> a <u>utilis</u> Royle	linoleic oleic	44 33	E
Prunus amygdalus L.	oleic	77	E
P. armeniaca L.	oleic	60-79	Е
<u>P. cerasus</u> L.	oleic linoleic	49 42	E
P. domestica L.	oleic	72	E
P. laurocerasus L.	oleic	73	H
<u>P. lusitanica</u> L.	oleic linoleic	58 32	Н
Rosoideae			
<u>Rosa canina</u> L.	linoleic	54	Е
<u>R. rubiginosa</u> L.	linoleic	74	
Rubus caesius L.	linoleic	76	Н

sub-family and species	principal fatty acid	% total fatty acids	au- thor- ity
Chrysobalanoideae			
Couepia grandiflora Benth.	licanic		K
Licania arborea Seem.	licanic	74	E
L. crassifolia Benth.	licanic	70+	K
L. rigida Benth.	licanic	74-82	E
Parinarium campestre Aubl.	elaeosteario	: 49	Е
P. corymbosum Miq.	licanic	62	Е
P. glaberrinium Hassk.	parinaric	70	
<u>P. laurinum</u> A. Gray	parinaric	53	Ε
<u>P. macrophyllum</u> Teipm.& Benn.	elaeostearic	: 31	E
P. sherbroense	licanic	44	E

APPENDIX II (continued)

K..... Karrer (1958) E.... Eckey (1954) H.... Hilditch (1940)

APPENDIX III

Distribution of Juglone among some Members of

the Juglandaceae

species	present	absent
Juglans cinerea L.	stems (B) leaves (S)	
<u>J. cordiformis</u> Maxim.	wood (G) bark (G) leaves (G)	
<u>J. intermedia</u> Carr. var. <u>vilmoreana</u> Carr.	wood (G) bark (G) leaves (G)	
<u>J. Lindsii</u> (Jepson) Jepson	wood (G) bark (G) leaves (G)	
J. <u>major</u> Heller	wood (G) bark (S) leaves (S)	
J. <u>mandshurica</u> Maxim.	wood (G) bark (G) leaves (G)	
J. nigra L.	bark (G) fruit (B)	wood (G) leaves (G)
<u>J. regia</u> L.	leaves (B) bark (B) fruit (B) roots (B)	
<u>J. rupestris</u> Engelm.	wood (G) bark (G) leaves (G)	
<u>J. Sieboldiana</u> Maxim.	wood (G) bark (G) leaves (G)	
J. <u>stenocarpa</u> Maxim.	wood (G) bark (G) leaves (G)	

APPENDIX III (continued)

species	present	absent
<u>Carya cordiformis</u> (Wang.) K. Koch		bark (G) leaves (G) fruit
<u>Carya glabra (Mill.)</u> Sweet		stem (B) leaves (B) fruit (B)
<u>C. illinoiensis</u> Wang.	leaves (S)	stem (B)
<u>C. laciniosa</u> (Michx. f.) Loud.		wood (G) bark (S) leaves (G)
<u>C</u> . <u>ovalis</u> Sarg.		wood (G) bark (G) leaves (G)
<u>C. ovata</u> (Mill.) K. Koch	bark (S) leaves (S)	
<u>C. pallida</u> (Ashe) Engl.& Graebn.		leaves (S) bark (S)
<u>C</u> . tomentosa		bark (S)
Engelhardtia pterocarpa (Oerst.) Standley		fruit (S) leaves (S) bark (S) wood (S)
<u>Platycarya</u> <u>strobilacea</u> S.& Z.	bark (G) leaves (G)	wood (G)
<u>Pterocarya</u> <u>caucasica</u> Mey	stems (B) leaves (B)	
Pt. Rehderiana	wood (G) bark (G) leaves (G)	

species	present	absent
Pt. rhoifolia S•& Z.		₩ood (G) bark (G)
<u>Pt. stenoptera</u> C. DC	wood (G) bark (G) leaves (G)	
(B¢ Brissemoret and (G) Gibbs, unpublish (S) results of author	Combes (1905) ed data r	

APPENDIX III (continued)

APPENDIX IV

Distribution of Hyperoside, Quercitrin and Myricitrin

among Representatives of five Genera of

the <u>Betulaceae</u> (Hänsel and Hörhammer, 1954)

		•	
species	Hyper.	Quercit.	Myricit.
<u>Alnus glutinosa</u> Gaertn.	x	x	
<u>A. hirsuta</u> Turcz.	x	x	
A. incana Moench.	x		
<u>A. i. var. orbicularis</u>	x	x	
A. japonica S.& Z.	x	x	
A. rugosa (DuRoi) Spreng.	x		
A. serrulata Willd.		x	
A. subcordata C.A. Mey	x	x	
<u>A. tinctoria</u> Sarg.	x	x	
Betula albo-sinensis Burk.		x	x
<u>B. andrewsii</u> Nelson		x	x
B. coerula-grandis Blanch.		x	x
<u>B. ermani</u> Cham.	x	x	
<u>B. fontinalis</u> Sarg.		x	x
B. insignis Franch.	X	x	
<u>B. koehnei</u> Schneid.		x	x
B. nana L.	x	x	
B. papyrifera Marsh		x	x (a)
B. pendula Roth	x	x	(a)
B. p. var. purpurea		x	x

species	Hyper.	Quercit.	Myricit.
B. pubescens Ehrh.	x	x	(a)
<u>B. utilis</u> Don var. <u>prattii</u>	x	x	
Carpinus betulus L.		x	x
<u>C. b. var. pyrimidalis</u>		x	x
<u>C. caroliniana</u> Walt.	x-	x	
<u>C. orientalis</u> Mill	x	x (b)	
<u>C. turczaninovii</u> Hance	x	x	
<u>C. yedoënsis</u> Maxim.	x	x	
Corylus americana Walt.		x	x
<u>C</u> . avellana L.		x	x
<u>C. a. var. pendula</u>		x	x
<u>C. colurna</u> L.	x	X X	
<u>C. maxima</u> Mill.		x	X
<u>Ostrya japonica</u> Sarg.	x	x	

(a)--- myricetin-3-digalactoside (b)--- quercetin

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APPENDIX V

Distribution of certain cyclic Acids among Representa-

tives of four Genera of the Betulaceae

(Horhämmer and Scherm, 1955)

	species	caffeic	chlor- ðgenic	gallic	proto- cate- chuic
Alı	<u>nus rugosa</u> Spreng.	(+)	•	+	+++
<u>A</u> .	<u>firma</u> S.& Z.	++	++	-	+++
<u>A</u> .	<u>cordata</u> Desf.	+	-	-	+++
<u>A</u> .	<u>incana</u> Moench.	(+)	++	-	++
<u>A</u> .	rubra Bong.	+	-	-	+++
<u>A</u> .	<u>pubescens</u> Tausch	+	++	+	+++
Bet	<u>tula lutea</u> Michx.	-	-	+	-
<u>B</u> .	pubescens Ehrh.	-	++	+	-
<u>B</u> .	<u>lenta</u> L.	-	-	+	-
<u>B</u> .	<u>fruticosa</u> Pall.	-	+	+	-
<u>B</u> .	<u>excelsa</u> Ait	-	+	++	-
<u>B</u> .	pumila L.	(+)	-	+	-
Ca	rpinus aschonowski	<i>,</i> ,			
<u>c</u> .	Maxim. <u>caroliniana</u> Walt.	(+) -	+++ +++	+++ +++	+ +
<u>c</u> .	<u>cordata</u> Bl.	+	+++	+++	+
<u>C</u> .	<u>orientale</u> Mill	(+)	+++	+++	+
<u>C</u> .	<u>yedoënsis</u> Maxim.	-	+++	+++	-
<u>Co</u> :	rylus <u>colurna</u> L.	-	++ +	-	-
<u>C</u> .	mandshurica Maxim.	-	++	+	-
<u>c</u> .	sieboldiana Bl.	-	++	+	-

(+)=uncertain reaction; +=clear reaction ++=stronger reaction; +++=very strong reaction

APPENDIX VI

Composition of Seed Oils of some Members of the <u>Ulmaceae</u> (expressed as % total fatty acids)

species	caprylic Cg	capric C10	lauric ^C 12	myris- tic ^C 14	palmi- tic ^C 16	stear- ic ^C 18	oleic	lin- oleic	author- ity
<u>Celtis integrifolia</u> Lam.						14	13	74	E
<u>C. occidentalis</u> L.						6	18	77	E
<u>Trema guinensis</u> Priemer					12	6			Е
<u>Ulmus americana</u> L.	5	61	6	5	3		11	9	Е
<u>U. campestris</u> L.		50							Е
<u>U. carpinifolia</u> Borkh. var. <u>cornubiensis</u>	6	69	5	3	5	12			SS
<u>U. carpinifolia</u> var. propendens	2	54	3	3	7	31			SS
U. fulva Michx.	4	64	6	4	7	15			SS
<u>U. glabra</u> Mill.	6	72	5	3	5	8			SS
<u>U. glabra</u> var. <u>cornuta</u>	3	58	4	4	8	23			SS
<u>U. glabra</u> var. <u>pendula</u>	5	69	4	3	5	14			SS

(continued on next page)

	APPENDIX	VI	(continued)
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species	caprylic Cg	capric C10	lauric C ₁₂	myris- tic ^C 14	palmi- tic ^C 16	stear- ic ^C 18	oleic	lin- oleic	author- ity
<u>U. laevis</u> Pall.	l	66	5	3	6	20			SS
<u>U. manshurica</u> Nakai	2-11	55 - 59	2-8	1 - 3	12-21		5-8		SS
U. procera Salisb. var. purpurea	3	68	5	4	7	12			SS
U. pumila L.	3	66	4	4	8	16			SS
Zelkova serrata (Thunb.) Mak.	8	73	3	1	2	1	3	3	HC

E..... Eckey (1954) SS..... Sørensen and Søltoft (1958) HC..... Hopkins and Chisholm (1959)

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