TAXONOMIC AND PHYLOGENETIC
CONSIDERATIONS
Bentham and Hooker (1862-67) include the Sapindaceae and the Anacardiaceae in the order Sapindales of Disciflorae along with the Sabiaceae. They divide the family Sapindaceae into five subfamilies viz. Sapindeae, Acerineae, Dodonaeae, Meliantheae and Staphyleae.

Hallier (1912) describes the Sapindaceae in the Aesculinae and the Terebinthaceae under Terebinthinae. He treated most of the Amentiferae (including the Casuarinaceae) as reduced descendants of Pistacia like Terebinthaceae (Anacardiaceae). The family is considered to have been derived from the Rutaceae.

Bessey (1915) and Rendle (1925) also treat these two families under Sapindales. In the Englerian scheme (Engler and Diels, 1936), the Sapindales are composed of 11 suborders and 23 families. The Anacardiaceae are placed under Anacardiinae while the family Sapindaceae finds itself in Icacinineae along with Icacinaceae, Aetoxicaceae, Aceraceae and Hippocastanaceae.

In the treatment of Hutchinson (1973) these two families are also classified under the Sapindales.

In the latest Engler's Syllabus the Anacardiaceae and the Sapindaceae are kept under Sapindales in association
with many families (Melchior, 1964). The latter family is with two subfamilies - Dodonaeoideae and Sapindoideae.

Takhtajan (1969, 1980) placed the family Anacardiaceae in the Rutales and the Sapindaceae under the Sapindales of Super order Rutanae. He further splits the Sapindaceae into two subfamilies - Dodonaeoideae and Sapindoideae.

Dahlgren (1980) includes the family Anacardiaceae (including Pistaciaceae and Julianiaceae) and Sapindaceae (including Stylobasidisiaceae) in Sapindales under Rutiflorae.

Cronquist (1981) has lumped many families of the Rutales and the Sapindales into his Sapindales including the Sapindaceae and the Anacardiaceae. He even submerged the small family Ptaeroxylaceae in the Sapindaceae with some hesitation. The Ptaeroxylaceae consist of two genera, e.g., Ptaeroxylon and Cedrelopsis and differ from typical Sapindaceae in having intrastaminal nectary disk which is modified into short gynophore.

A resume of the taxonomic treatment of these two families in the earlier and even in the current systems of classifications would reveal considerable diversity of opinion in regard to their position and association with other families in a group.
Cronquist (1981) is of the opinion that although a number of its families have in the past referred to several different orders, the Sapindales are a well characterized natural group. Only two families are really peripheral. It is the family Staphyleaceae which connects the Sapindaceae to the ancestral Rosales in the vicinity of the Cunoniaceae, and the Zygophyllaceae are suggestive of a connection with the Geraniales.

The present study brings forth certain parameters which are characteristic and distinctive to the taxa of these two families and may also be employed to delineate them. They have, however, limitations in a comprehensive assessment of the taxonomic and phylogenetic aspects of these families. Any such assessment has to consider data from other disciplines while employing anatomical evidence. Through the following paragraphs is attempted a discussion on the relationships of the two families.

The Sapindaceae are distinguished from the Anacardiaceae by the absence of resin ducts. The occurrence of resin canals is characteristic for the Anacardiaceae and is observed in petiole/petiolule and leaves of the present study. These canals are always associated with the phloem. Most of the plants have pinnate leaves in Sapindaceae; the woody climbers are with stipules. The leaves are pinnate and simple in the Anacardiaceae.
Majority of the plants show trilacunar three-traced node in both families. A single genus each of the two families, Cunania and Holigarna, is with unilacunar one-traced node. Multilacunar multi-traced node is found to be characteristic only in Semecarpus of the Anacardiaceae. Anatomy of the node presents evidence more to indicate similar development in the two families.

The venation pattern is pinnate, camptodromous-eucamptodromous in most of the plants in these families. It is craspedodromous in Cardiospermum and brochidodromous in Spondias. The transfusion tracheids are observed only in some sapindaceous plants and these are more in the nature of habitat responses rather than of any phyletic consequence.

The present account shows anomocytic, anisocytic, tetracytic, actinocytic and cyclocytic stomata in the Sapindaceae and anomocytic, anisocytic tetracytic and actinocytic in the Anacardiaceae. The occurrence of the adaxial stomata on or around the veins in hypostomatic leaves is interesting.

Plants of both the families show glandular hairs. Hutchinson (1973) has listed these two families in a group showing "glandular leaves". The plants of Anacardiaceae collectively known as "renghas" secrete a toxic substance—a resinous lacquer.
Papillose epidermis in *Semecarpus* and *Holigarna*, multicellded hypoderm of leaves in *Mangifera*, *Holigarna* and also in *Gluta* of Anacardiaceae (Wilkinson, 1983) are of diagnostic value as also the single layered hypoderm of *Cupania* of Sapindaceae. They may be significant ecological parameters but with little phyletic value.

Tannins and calcium oxalate crystals are common in most of the plants in these families (cf. Cronquist, 1981).

Heimsch (1942) has studied the wood anatomy in the tribes of the Anacardiaceae where certain trends are indicated. More species of the Mangiferae have homogeneous rays and bands of parenchyma than any others. The greatest proportion of ring porous forms with advanced stages of vessel aggregation occur in the Rhoideae and all the species of the Spondiae have septate fibres, while these are lacking from the Semecarpeae. The septate fibres are characteristic of the Sapindaceae (Heimsch, 1942) and the family is highly specialized with respect to rays than the other families in the group.

The lianas of Sapindaceae are adapted to cope with the climbing woody habit in such a way that they have to develop a characteristic stem-anomalii. The plants of Anacardiaceae, on the other hand, have undergone various possible adaptive features to resist the tropical environment
and protect themselves from the attack of various macro- and microorganisms.

It is thus evident that two families do share certain characters that enable one to align them as has been done by most taxonomists. There appears to be more in common in between them - features very similar - that leads one to infer that they are better considered as parallel derivatives from a common or similar ancestral stock/s. They have departed more in respect to floral characteristics which in a way demonstrate adaptive radiations with respect to adaptations at evolutionary diversification, rather than revealing the origin of one from the other. There is certainly no case for a linear lineage amongst them. Both are similarly situated with a fair share of disparate characteristics of diagnostic value. However, there do exist a number of features which help delineate the two families and certain others which show advanced features. The above discussion reveals that the Anacardiaceae are not at a comparatively low level of evolution.

A discussion on the closely related families of the Sapindaceae and Anacardiaceae is now attempted in regard to their taxonomic alignments.

The genera comprising the Aceraceae, Melianthaceae, Staphyleaceae and Hippocastanaceae were included in the Sapindaceae in the system of Bentham and Hooker (1862-67).
The family Aceraceae (Acer and Dipteronia) is distinguished from the Sapindaceae by opposite, usually palmate leaves, actinomorphic flowers, and the fruit a schizocarp or samara. These two families are closely related to each other in many respects. The wood anatomy also suggests close affinity, except for the absence of septate fibres in Aceraceae (Heimsch, 1942). The tribe Harpullieae of the Sapindaceae may be regarded as providing the closest approach of the family to the Aceraceae (Cronquist, 1981). However, Hallier (1912) regards the Anacardiaceae as ancestral to the Aceraceae.

Gurke (1895) treats the Melianthaceae as a distinct family and shows the affinities with Sapindaceae but indicates rather notable differences between Greyia and other two genera Bersama and Melianthus. Hallier (1912) considers the Melianthaceae to be a part of the Sapindaceae. This family differs in the resupinate flowers by twisting of pedicel, stipules intrapetiolar often large, nodes multilacunar, stamens often usually connate and typically 4, pollen grains trinucleate and tricolporate, seeds with copious endosperm, plants not saponiferous, not producing mucilage, and without proanthocyanin.

Hutchinson (1973) has raised Greyia to the status of the new family, the Greyiaceae in the Cunoniales while retaining Bersama and Melianthus in the Melianthaceae under
Sapindales. On the basis of anatomy, Heimsch (1942) justifies the segregation of this genus as a separate family but places it near to the Melianthaceae. He finds no support for including the family in the Cunoniales. Takhtajan (1969) placed Greyiaceae near to Melianthaceae under Sapindales. In his later contribution (Takhtajan, 1980) the Greyiaceae has been kept under suborder Saxifragineae of the order Saxifragales of Super order Rosanae. Dahlgren (1980) treats the Melianthaceae under Sapindales with uncertain position. The wood structure of the Melianthaceae is considered to be more specialized than that of Sapindaceae (Cronquist, 1981).

The family Staphyleaceae is distinguished by absence of ellagic acid, not cyanogenic, not saponiferous, without iridoid compounds, cup-like intrastaminal disc, more numerous ovules, abundant endosperm and straight embryo. Different authors have included this family in various orders. Bessey (1915), Rendle (1925), Wettstein (1935) treat it under Celastrales. This family is placed in the Sapindales (sensu stricto) by Hutchinson (1973). Hallier (1912) transfers them to his Rosales and believes them to be allied to Cunoniaceae and Saxifragaceae. Based on the cytological evidence, Foster (1933) concludes that they have had a common origin with the Aceraceae.
Cronquist (1981) is of the opinion that the Calastrales and Sapindales are derived in parallel lines from the Rosales and the three different ordinal positions for the Staphyleaceae do not require any great conceptual difference as to their relationships. The Staphyleaceae would be anomalous under the Calastrales due to their compound leaves. Cronquist further states that they form a connecting link between the Cunoniaceae (Rosales) and the Aceraceae and Sapindaceae (Sapindales) and could with almost equal propriety be put in either order.

On the whole the Staphyleaceae have progressed along the sapindalean road than the Cunoniaceae. Cronquist (1981) prefers to retain the Cunoniaceae in Rosales and refers the Staphyleaceae to the more advanced order Sapindales.

It is interesting and significant that the Staphyleaceae have the same basic chromosome number (13) as the Aceraceae. The characteristic inflated capsules of *Staphylea* are similar to *Koelreuteria* of the Sapindaceae. If the Staphyleaceae are included in the Sapindales, they may be regarded as most archaic family in the order because of primitive wood structure, mostly stipulate leaves, several ovules in each locule, well developed endosperm and sometime separate carpels. Cronquist is not averse to placement of the family in the Rosales near Cunoniaceae if these
characters are found sufficiently convincing for such an alignment.

Apart from Bentham and Hooker (1862-67) the genera of Hippocastanaceae are also treated in the Sapindaceae by many authors (Hallier, 1912; Hutchinson, 1973). The family is characterized by palmately compound leaves, nodes trilacunar, sometimes pentalacunar, large flowered thyrses, pollen grains binucleate and tricolporate, the leathery capsule with a large usually solitary seed, and the chromosome number, $x = 20$.

The families Hippocastanaceae (Aesculus and Billia) and Aceraceae are very closely related to Sapindaceae especially to the tribe Harpulliae (Radkofer, 1890; 1931-1934; Muller and Leenhouts, 1976; Takhtajan, 1980). Both Aceraceae and Hippocastanaceae could with nearly the same right be added to the Sapindaceae as two more tribes (Muller and Leenhouts, 1976).

The monotypic Chinese genus Bretschneidera is removed from the Hippocastanaceae and placed into a separate family Bretschneideraceae (earlier this genus was treated in Sapindaceae); Pax (1895) included it in Hippocastanaceae. Dahlgren (1980) keeps the family Bretschneideraceae in the Sapindales but considers the position uncertain. Takhtajan (1980) treats the family near to Sapindaceae and
Hippocastanaceae. According to Cronquist (1981) this monotypic genus would be anomalous in either family because of its perigynous flowers, mainly large and pluriseriate wood rays and myrosin cells. On the basis of occurrence of myrosin cells, it is sometimes referred to Capparales but otherwise it appears to have little in common with that group. Breitschneideraceae are presumed to have close affinity with the Moringaceae (Lawrence, 1951).

Although on the anatomical basis, particularly in regard to the occurrence of resin ducts, Burseraceae and Anacardiaceae are very closely allied, in the Englerian system (1931), these two families are treated in different orders because of their different floral characters. However, many authors consider them to be closely related.

Based on wood structure, Webber (1941) and Heimsch (1942) conclude that the Anacardiaceae, Burseraceae, Sapindaceae, Rutaceae, Meliaceae and Simarubaceae form a natural group. Heimsch (1942) states that the Anacardiaceae and Burseraceae are very similar and go together. These two families are distinct from others in regard to many wood anatomical features. Webber (1941) on the other hand concludes that the wood structure of Burseraceae, Anacardiaceae, Simarubaceae, Rutaceae and Meliaceae is more suggestive of the probable common ancestry of all five
families. She considers the Anacardiaceae and Burseraceae to be the least specialized of the group and suggests that the traumatic canals of the Simarubaceae and Rutaceae may indicate their origin from plants such as the Burseraceae and Anacardiaceae that have normal intercellular canals in their rays.

The taxonomic position of the genus *Filicium* studied for this contribution has been called into question. Bentham and Hooker (1862-67) include this genus in the Burseraceae. Hutchinson (1973) also treats it under the Burseraceae, while many taxonomic accounts keep *Filicium* in the Sapindaceae (Cooke, 1903; Gamble, 1935; Willis, 1966; Mukherjee, 1980).

During the studies on the anatomy of vegetative organs of many dicot families, Metcalfe and Chalk (1950) have described this genus in the Sapindaceae. The family Burseraceae is characterized by the occurrence of resin canals (Webber, 1941; Heimsch, 1942; Metcalfe and Chalk, 1950). The petiolule and the leaf of *Filicium* do not show the presence of such resin canals as indicated by the present study. The petiolule anatomy is more or less similar to that of the sapindaceous plants. The nodes are mostly pentalacunar in the Burseraceae (Cronquist, 1981); in *Filicium* the node is trilacunar and three-traced. The
The chromosome number in Burseraceae is $x = 11, 13, 23$. while in Sapindaceae $x = 10-16$ (Cronquist, 1981). *Filicium* has $2n = 32$ (Guervin, 1961) and thus the genus has found a place in Sapindaceae (Fedorov, 1974). It is interesting that the rachis of the pinnate leaf of *Filicium* and that of *Sapindus saponaria* are similar and winged.

Data on the anatomical studies of *Filicium* i.e., absence of resin canals, similar petiolar anatomy, trilacunar three-traced node, glandular hairs etc. justify the alignment of the genus within Sapindaceae rather than in the Burseraceae.

The above discussion, while adducing data of pertinent phylogenetic significance would also reveal that considerable scope for further studies exists. A more comprehensive discussion should await studies on more genera of these two families. It is also apparent that many genera which have been worked out in respect to certain aspects need further studies in other disciplines, particularly floral anatomy. These should be of great help although it is a difficult task as there exists a practical difficulty - one has to get rid of tanniferous material from flowers.
Key to the genera and species

Anatomical parameters based on the studied aspects in this contribution are found to be helpful in delineating the genera and species of the Sapindaceae and the Anacardiaceae presented below:

KEY TO THE GENERA OF SAPINDACEAE

1. Node - Trilacunar, three-traced, adaxial hypoderm absent in leaf/leaflets:

2. Collenchyma hypodermal in petiole/petiolule:

3. Hypodermal collenchyma in four bands:
   Vascular bundles four, cuticular bands on adaxial epidermis, striations on abaxial surface, crystals of one type, stomata, anomocytic, anisocytic, amphistomatic leaf
   Cardiospermum

3. Hypodermal collenchyma in ring:

4. Peltate scales, individual vascular bundles capped outside by sclerenchymatous bands

5. Bundle sheath of parenchymatous layer transfusion tracheids at the apex of leaf, amphistomatic leaf
   Dodonaea

5. Bundle sheath of parenchymatous and sclerenchymatous layers, no transfusion tracheids, hypostomatic leaf
   Filicium
4. Peltate scales absent, sclerenchymatous cylinder/two arc-shaped sclerenchyma in a ring surrounds the vascular tissue:

6. Transfusion tracheid present:

7. Stomata anomocytic, cyclocytic, anisocytic, few abaxial epidermal cells do not develop striations, glandular and non-glandular trichomes one-celled

*Erioglossum*

7. Stomata anomocytic, cuticular striations on both the epidermis, trichomes 1-many celled, uniseriate, glandular trichomes multicelld

*Allophyllus*

6. Transfusion tracheids absent:

8. Cuticular striations on both the epidermis, groups of sclereids in cortex

* Sapindus

8. Cuticular striations on adaxial epidermis, sclereids absent

*Schleicheria*

2. Hypodermal collenchyma absent in petiole/petioulule:

9. Vascular bundles in a ring in petiolule, crystals of both types, stellate trichomes absent

*Lepisanthes*

9. Vascular cylinder in petiolule, crystals of one type, stellate trichomes

*Harpullia*
1. Node - unilacunar, one traced, adaxial hypoderm in leaf

   Cupania

KEY TO THE GENERA OF ANACARDIACEAE

1. Epidermis papillose

2. Node multilacunar, multi-traced, hypoderm none in leaf

   Semecarpus

2. Node unilacunar, one-traced, hypoderm in leaf

   Holigarna

1. Epidermis not papillose, node trilacunar, three-traced :

3. Leaf isobilateral, amphistomatic

   Schinus

3. Leaf dorsiventral, hypostomatic :

4. Petiolule/petiole with collenchyma :

5. Collenchyma hypodermal in petiolule/petiole :

6. Trichomes stellate, glandular hairs many-celled, prominent pits in epidermal cell walls

   Lannea

6. Trichomes not stellate, glandular hairs variable

   Rhus

5. Collenchyma cortical in petiolule/petiole :
7. Sclerenchymatous patches in a ring, encasing vascular tissue in petiole; cuticular striations, venation pinnate, eucamptodromous
   *Buchanania* (lanzan)

7. Sclerenchyma absent in petiolule, cuticular striations absent, venation pinnate, brochidodromous
   *Spondias*

4. Petiolute/petiole without collenchyma:

8. Leaf with hypoderm and peltate scales, but without cuticular striations:
   *Mangifera*

8. Leaf without hypoderm and peltate scales, but with cuticular striations:

9. Vascular bundles in petiole/petiolute enclosed by a ring of sclerenchyma, crystals clustered; phloem and pith with secretory ducts, none in cortex; stomata mostly anomocytic
   *Buchanania* (axillaris)

9. Vascular bundles only capped by sclerenchyma, phloem and cortex with secretory ducts, none in pith; stomata anomocytic, anisocytic, tetracytic and actinocytic
   *Anacardium*
KEY TO THE SPECIES OF RHUS

1. Leaf epidermis with cuticular striations
   \[ \textit{Rhus myaoensis} \]

1. Leaf epidermis without cuticular striations:

2. Stomata large, trichomes 1-3 celled, thick-walled, crystals none in peltiolute
   \[ \textit{Rhus parviflora} \]

2. Epidermal cell walls not so thick, stomata small, trichomes 1-many celled, solitary and clustered, crystals in peltiolute
   \[ \textit{Rhus javanica} \]

KEY TO THE SPECIES OF BUCHANANIA

1. Collenchyma cortical in petiole, crystals clustered, trichomes 1-many celled, uniseriate
   \[ \textit{Buchanania lanzan} \]

1. Collenchyma absent in petiole, trichomes 1-2 celled, sometimes tufted
   \[ \textit{Buchanania axillaris} \]
SUMMARY
The vegetative anatomy of 11 species with two varieties thereof and 10 genera of Sapindaceae, and 12 species of 9 genera belonging to the Anacardiaceae is studied.

The leaves are alternate and exstipulate. The node is trilacunar and three-traced in the majority of the plants with a single genus in each family having a unilacunar one-traced condition. However, multilacunar multi-traced node is characteristic only of *Semecarpus* of Anacardiaceae. The unilacunar and multilacunar nodes are considered to be derived from the predominant trilacunar one. These two nodal types are described for the first time for both the families.

The anatomy of the petiole/petiolule shows varied distribution of the collenchymatous and sclerenchymatous mechanical tissues. The distribution and organisation of the vascular tissue and the occurrence of resin ducts only in Anacardiaceae are significant. The calcium oxalate crystals are not uncommon.

In Sapindaceae, collenchyma occurs in the form of patches or as a ring in the hypodermal region. The amount of collenchyma is comparatively more on the abaxial or adaxial sides of the petiole/petiolule in many plants. In *Cunania* and *Sapindus*, cortical sclereids function as
additional peripheral mechanical tissue. In Lepisanthes and Harpullia where hypodermal mechanical tissue is absent, the mechanical strength appears to be chiefly provided by the thick-walled epidermis and the thick cuticle. In most of the plants a sclerenchymatous ring encloses the vascular tissue. The vascular bundles remain distinct or form a continuous cylinder. In Dodonaea, the number of vascular bundles is three, the median one large and abaxially located in the petiole. Cardiospermum has four vascular bundles.

In anacardiaceous plants collenchymatous tissue occurs in the hypodermal or cortical region. It may be absent as in Mangifera, Anacardium etc. Sclerenchymatous tissue develops a cylinder or remains capped to each individual vascular bundle as in Anacardium and Holigarna. It may be absent in Lannea and Spondias. The vascular bundles are discrete or interconnected to develop a cylinder. The phloem is always associated with characteristic schizogenous resin ducts. In many cases, the resin ducts are encased by phloic sclerenchyma. The resin ducts may also be present in the cortex and/or pith of the petiole/petiolum in Holigarna, Anacardium.

The leaf anatomy reveals the dorsiventrality of the organ in all the plants except Schinus (Anacardiaceae). In the latter plant the leaf is isobilateral. The adaxial
epidermal cells are always larger with thick cuticle. The leaves are mostly hypostomatic. The guard cells have ledges in a few of the plants of Anacardiaceae.

The mesophyll is differentiated into one- or two-2-layered upper palisade and lower spongy tissue of varied layers. A single-layered parenchymatous hypoderm occurs in Cupania (Sapindaceae). In Mangifera and Holigarna (Anacardiaceae) the leaf hypoderm is many-layered. Semecarpus and Holigarna (Anacardiaceae) develop papillose epidermis on abaxial surface.

In many plants, sclerenchymatous fibers extend through the mesophyll. Bundles sheath extensions are observed in a few plants of Anacardiaceae. Most of the mesophyll cells are tanniniferous. In anacardiaceous plants, the resin ducts also occur in the mesophyll.

The venation pattern is of the pinnate, camptodromous-eucamptodromous type in majority of the plants. In Cardiospermum (Sapindaceae) it is craspedodromous while in Spondias (Anacardiaceae), it is camptodromous-brochidodromous. The marginal ultimate venation is incomplete or fimbriate. The areole development is imperfect or perfect. Tracheary idioblasts of varying shape and size occur in many plants. The occurrence of transfusion tracheids only in Cardiospermum,
Dodonaea, Erioglossum and Allophylus of Sapindaceae is interesting.

The epidermal cells are mostly polygonal or irregular with anticlinal walls straight or undulating. Cuticular striations occur in many plants and these may be on both the surfaces of the leaf or restricted to only one surface. The strands of cuticle are characteristic on adaxial surface in Cardiospermum. Few or many cells do not develop such striations on abaxial surface in Erioglossum and Cupania respectively.

The leaves are materially hypostomatic, although morphologically amphistomatic. Anomocytic, anisocytic, tetracytic and actinocytic stomata occur in plants of both families. In Erioglossum (Sapindaceae), apparently cyclocytic stomata also occur. More than one type of stomata on the same surface of the organ is recorded in a few plants. Various stomatal anomalies are seen.

Glandular and non-glandular trichomes, and scales are of various types. The scales are characteristic in Dodonaea and Filicium (Sapindaceae), and Mangifera and Holigarna (Anacardiaceae). Harpullia of the former family and Lannea of the latter family have stellate hairs. The glandular hairs are variable in most of the plants.
A comprehensive discussion of the taxonomic and phylogenetic aspects is attempted in the light of the present study and in reference to earlier literature. It is evident that the Sapindaceae and Anacardiaceae do share certain characters that enable one to align them. There appears more in common in between them that leads one to infer that they are better considered as parallel derivatives from a common or similar ancestral stock/s. A discussion on the very closely related families of Sapindaceae and Anacardiaceae is attempted in regard to their taxonomic alignment. The taxonomic position of the genus *Filicium* within the Sapindaceae is justified on the basis of the present study.

A key based on the anatomical features for the delineation of the genera and species of Sapindaceae and Anacardiaceae is presented.