Wood Anatomy of Pittosporaceae

by

Sherwin Carlquist

Lawai, Kauai, Hawaii
March, 1981
ALLERTONIA is a series of occasional papers intended to serve for publication of longer studies presenting results of original botanical or horticultural research undertaken by members of the staff of the Pacific Tropical Botanical Garden or in collaboration with the Garden and its programs.

The title commemorates the late Mr. Robert Allerton (1873–1964). His generosity and guidance, as one of its first Trustees, were instrumental in the establishment of the Pacific Tropical Botanical Garden.

EDITORIAL COMMITTEE

A. C. Smith, Editor  L. Constance
J. L. Brewbaker  C. H. Lamoureux
S. Carlquist  W. L. Theobald, ex officio

Numbers of ALLERTONIA are priced individually. Standing orders may be placed by writing:

Publications Secretary  Pacific Tropical Botanical Garden
P.O. Box 340  Lawai, Kauai, Hawaii 96765

Volume 2, to date, consists of:

   By Steven P. Darwin  Price: $4.00

No. 2. The Vegetation of Eastern Samoa.
   By W. Arthur Whistler  Price: $16.00

No. 3. Anatomy and Systematics of Balanopaceae.
   By Sherwin Carlquist  Price: $6.00

No. 4. The Genus Galium Section Lophogalium (Rubiaceae) in South America.
   By Lauramay T. Dempster  Price: $4.00

No. 5. Comparative Wood Anatomy and Evolution of the Cunoniaceae.
   By William C. Dickison  Price: $5.50

No. 6. The Vegetation of Late, Tonga.
   By W. R. Sykes  Price: $4.00

No. 7. Wood Anatomy of Pittosporaceae.
   By Sherwin Carlquist  Price: $5.00

© 1981, by Pacific Tropical Botanical Garden
INTRODUCTION

Although the family Pittosporaceae is moderately large (containing about 240 species), wood anatomy has been described for only a few species. Some of the species from Taiwan and Japan have been considered by Kanehira (1921, 1926), and a few from Hawaii have been treated by Brown (1922). Aside from their brief descriptions, we have only the condensed accounts of Solereder (1908) and Metcalfe and Chalk (1950), in which features are cited for genera, often without mention of species because of the abbreviated format necessary in such works. For a family of its size, Pittosporaceae have been curiously neglected by wood anatomists. One can only suspect that the habit of most species is related to this neglect. Few species are medium-sized trees; most range from small shrubs to small trees. None are herbaceous, and all could be described as having dense wood. Wood samples of angiosperms traditionally have not been collected for woody plants in the smaller size classes—or at least such families have been collected to a lesser extent than desirable. Some species of Pittosporum, such as the Hawaiian and New Caledonian species, often have numerous, long, sparsely branched stems rather than trunks, so that wood collectors are not attracted so readily to preparing wood specimens. Even though a few members of the family do form sizable trees, both these and smaller-sized trees of Pittosporaceae often grow in open areas near forests rather than in dense forests; because of the non-forest habitat of these species, they may be bypassed by wood collectors. Unfortunately, the presence of wood samples in xylaria has played a preponderant role in deciding which angiosperm families are studied with respect to wood anatomy. The range in habit and habitat of Pittosporaceae is wide. The family can be found in regions of great aridity, such as the Nullarbor Plain of Australia, and also in wet montane areas of New Caledonia and the Hawaiian Islands. Thus, the family should be an important group for analyzing relationships between ecology and wood anatomy. Such relationships do exist, in fact, and are discussed with respect to the various features of wood anatomy below.

Pittosporaceae are a family of considerable phylogenetic interest. Opinion on the relationships of the family is highly polarized at present, with both rosalean and umbellalean placements claimed. Wood anatomy has at least a few features pertinent in this controversy, as discussed in the terminal section of this paper.

1This paper is based on research aided by a grant from the National Science Foundation, DEB 77-12600. For aid in accumulation of data, I wish to thank Mr. Chris Carpenter, Dr. Larry DeBuhr, Mr. Robert Gillaspy, Mr. Jeffrey R. Hogue, Mr. David C. Michener, Dr. Gary Wallace, and Dr. David Wheat. Wood samples were kindly provided by institutions and individuals listed in TABLE 1. For assistance in field work and in obtaining material, thanks are due Mr. Alan Marks, Mr. Joel S. Horn, Dr. William L. Stern, Dr. Robert F. Thorne, and the botanical staff of O.R.S.T.O.M., Anse Vata, New Caledonia.

2Claremont Graduate School, Pomona College, and Rancho Santa Ana Botanic Garden, Claremont, California 91711.
This account of wood anatomy of Pittosporaceae is by no means exhaustive, although I have tried to sample the family in terms of geographic distribution, ecological ranges, and systematic groupings. The family is exclusively native to the Old World, ranging from tropical and southern Africa and Madagascar through the Middle East, southeastern Asia, China, Japan, Malesia, Australia, and high Pacific islands from New Zealand and New Caledonia to Hawaii in the North Pacific and Rapa and Henderson Island in the South Pacific. The family is absent in North and South America, Europe, and the U.S.S.R. A good distribution map for *Pittosporum* is given by van Steenis and van Balgooy (1966). Of the treatments more recent than those of Pax (1891) and Pritzel (1930), one can recommend the tabular summary of species by regions given by Cufodontis (1960); the survey of the family and its possible history, centering on New Guinean species, given by Schodde (1972); the resumé of Australian and New Zealand species, with a précis of the family as a whole, offered by Cooper (1956); and the monograph of Pacific species of *Pittosporum*, with comments on broader aspects, by Haas (1977).

Of the genera other than *Pittosporum*, *Citriobatus* has the widest distribution: northern and eastern Australia, Java, Celebes, the Philippines, and New Guinea. *Citriobatus* totals six species at present (Willis, 1966; Schodde, 1972). Other genera and the species they contain according to Willis (1966) are: *Billardiera* (ten: many parts of Australia); *Bursaria* (three: Australia); *Cheiranthera* (two in southwestern and two in southeastern Australia); *Hymenosporum* (one: New Guinea and northeastern Australia); *Marianthus* (15: various parts of Australia); *Pronaya* (one: Western Australia); and *Sollya* (two: Western Australia). As Bennett (1972) notes, *Billardiera* and *Marianthus* have traditionally been distinguished by a baccate fruit in the former and a capsular fruit in the latter. She claims that they have been incorrectly defined, if one takes into account floral features, and recommends combination of the two genera. Bennett (1972) also recombined the Western Australian species of *Marianthus* under *Billardiera*. *Rhytidosporum* is a dubious segregate of *Marianthus* (McGillivray, 1975). The total number of species of *Pittosporum* cited by Cufodontis (1960), 199, may be expected to vary. Cufodontis recognized 23 Hawaiian species, but Haas (1977) reduced that number to twelve. However, new species of *Pittosporum* have been added by Bakker (1958) and Schodde (1967). The New Caledonian species of *Pittosporum*, although numerous, appear to be distinctive, and a sharp reduction in the large number of species on that island is not to be expected (45 are cited by Cufodontis). There are probably only a small number of *Pittosporum* species yet to be discovered: represented by shrubs or small trees of open habitats or low forest, *Pittosporum* is less likely to elude plant collectors than other genera. We may expect the number of valid species in the genus to hover near 200.

The geographical sources for the woodsamples used in the present study are as follows:

**Australia:**

Southwestern Australia: *Billardiera bicolor*, *Marianthus procumbens*, *Pittosporum phyllareoides*, and *Sollya heterophylla*.

Eastern Australia: *Bursaria incana*, *B. spinosa*, *Pittosporum rhombifolium*, *P. undulatum* (the last-named from cultivation).

Northeastern Australian forests: *Citriobatus lancifolius*, *Hymenosporum flavum*, *Pittosporum bicolor*, *P. ferrugineum*. 
Queensland rain forests: Bursaria tenuifolia.
New Guinea, montane forest: Pittosporum berberidoides, P. ramiflorum var. pregnans.
Solomon Islands: Pittosporum cravenianum.
Lord Howe Island: Pittosporum erioloma.
Norfolk Island: Pittosporum bracteolatum.
New Zealand:
  Lowland and widespread: Pittosporum cornifolium, P. eugenioides, P. ralphii, P. tenuifolium.
  Higher elevations: Pittosporum divaricatum, P. turneri.
New Caledonia:
  Lowlands, drier areas: Pittosporum deplanchei, P. gomonenense, P. haematomallum.
  Uplands, forest margins: Pittosporum dognyense, P. mouanum, P. pancheri, P. paniense, P. pronyense.
Fiji and New Caledonia: Pittosporum rhytidocarpum. (The New Caledonian record is probably erroneous, since the species is considered a Fijian endemic by Haas (1977); the record is based on USW-4582 listed in Table 1, originally distributed by the Philadelphia Technical Museum and possibly from Fiji rather than New Caledonia as labeled.)
Philippines: Pittosporum pentandrum.
Hawaiian Islands: Pittosporum acuminatum, P. gayanum, P. glabrum, P. hosmeri, P. napaliense.
Japan: Pittosporum tobira (specimen cultivated in California).
India: Pittosporum floribundum, P. glabratum.
Africa:
  West Africa: Pittosporum mannii.
  Central tropical Africa: Pittosporum malosanum, P. spathicalyx.
  South Africa: Pittosporum viridiflorum.

Although the present coverage represents only approximately a quarter of the valid species of the genus, two areas are deficiently sampled: Madagascar (none of the twelve species) and mainland Asia (two of the 30 species). However, a more thorough coverage at this time would be very difficult to achieve. The few additional species which could be obtained without great difficulty might not add new aspects to an appreciable extent. One would like to investigate Pittosporum sect. Chelidospermum, the section noted by Schodde (1972) as having primitive characteristics, but no wood samples of its species are available, to my knowledge. However, as will be noted, the most startlingly primitive features in wood anatomy for the genus prove to occur in a species of the wettest area on New Caledonia, P. paniense.

MATERIALS AND METHODS

Approximately half of the species in this study were seen growing and were collected by me. I regret that a larger proportion could not have been seen in the field, for more information on the ecology of species in the family could thereby have been gleaned. For facts on ecology and habitats of species known to me only as wood samples, floristic and monographic works cited later in the discussion of anatomical features were used.
### Table 1. Wood Features

<table>
<thead>
<tr>
<th>Species</th>
<th>Collection</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Billardiara bicolor (Putterlick) F. M. Bennett</td>
<td>Carlight 5932 (RSA)</td>
<td>315</td>
<td>28</td>
<td>378</td>
</tr>
<tr>
<td>Bursaria incana Lindl.</td>
<td>CQTw, s.n.</td>
<td>125</td>
<td>46</td>
<td>618</td>
</tr>
<tr>
<td>B. spinosa Cav.</td>
<td>FPAw-7151</td>
<td>145</td>
<td>37</td>
<td>495</td>
</tr>
<tr>
<td>B. tenutifolia F. M. Bailey</td>
<td>FPAw-8152</td>
<td>268</td>
<td>33</td>
<td>430</td>
</tr>
<tr>
<td>Citriobatus lancifolius F. M. Bailey</td>
<td>CQTw, s.n.</td>
<td>50</td>
<td>60</td>
<td>623</td>
</tr>
<tr>
<td></td>
<td>FPAw-10026</td>
<td>99</td>
<td>57</td>
<td>569</td>
</tr>
<tr>
<td></td>
<td>SFCw-D3894</td>
<td>182</td>
<td>63</td>
<td>526</td>
</tr>
<tr>
<td>Caryocar brasiliensis (P. K.)</td>
<td>SFCw-R977-191</td>
<td>25</td>
<td>53</td>
<td>781</td>
</tr>
<tr>
<td>Maranthus procumbens Benth.</td>
<td>Carlight 5352 (RSA)</td>
<td>195</td>
<td>35</td>
<td>396</td>
</tr>
<tr>
<td>Pittophorus acuminatum H. Mann</td>
<td>Stern &amp; Carlight 1281 (RSA)</td>
<td>100</td>
<td>37</td>
<td>627</td>
</tr>
<tr>
<td>P. berberidoides Burkii</td>
<td>FPAw-773</td>
<td>60</td>
<td>55</td>
<td>688</td>
</tr>
<tr>
<td>P. bicolor Hook.</td>
<td>FPAw-2760</td>
<td>162</td>
<td>34</td>
<td>599</td>
</tr>
<tr>
<td>P. bracteolatum Endl.</td>
<td>SFCw-R654-33</td>
<td>71</td>
<td>40</td>
<td>727</td>
</tr>
<tr>
<td>P. cornifolium A. Cunn.</td>
<td>WZw, s.n.</td>
<td>116</td>
<td>28</td>
<td>526</td>
</tr>
<tr>
<td>P. cravenianum Schodde</td>
<td>FPAw-3767</td>
<td>38</td>
<td>62</td>
<td>773</td>
</tr>
<tr>
<td>P. deplanchei Bronnz. &amp; Gris</td>
<td>Carlight 15615 (RSA)</td>
<td>126</td>
<td>38</td>
<td>995</td>
</tr>
<tr>
<td>P. divaricatum Cockayne</td>
<td>Alan Marks, s.n.</td>
<td>375</td>
<td>19</td>
<td>451</td>
</tr>
<tr>
<td>P. dogyense Guillaumin</td>
<td>Carlight 15561 (RSA)</td>
<td>135</td>
<td>38</td>
<td>436</td>
</tr>
<tr>
<td>P. echioloma C. Moore</td>
<td>SFCw-R638-11</td>
<td>116</td>
<td>32</td>
<td>535</td>
</tr>
<tr>
<td>P. eugenioides A. Cunn.</td>
<td>SFCw-33660</td>
<td>170</td>
<td>30</td>
<td>487</td>
</tr>
<tr>
<td>P. ferrugineum Ait. f.</td>
<td>FPAw-NGF-1592</td>
<td>78</td>
<td>68</td>
<td>737</td>
</tr>
<tr>
<td>P. floribundum Wight &amp; Arn.</td>
<td>FPAw-24829</td>
<td>67</td>
<td>62</td>
<td>853</td>
</tr>
<tr>
<td>P. gayanum Rock</td>
<td>FPAw-873</td>
<td>77</td>
<td>75</td>
<td>821</td>
</tr>
<tr>
<td>P. glabratum Lindl.</td>
<td>Stern &amp; Carlight 1239 (RSA)</td>
<td>145</td>
<td>36</td>
<td>588</td>
</tr>
<tr>
<td>P. glabrum Hook. &amp; Arn.</td>
<td>FPAw-14731</td>
<td>131</td>
<td>34</td>
<td>578</td>
</tr>
<tr>
<td></td>
<td>FPAw-21961</td>
<td>150</td>
<td>37</td>
<td>532</td>
</tr>
<tr>
<td></td>
<td>Stern &amp; Carlight 1368 (RSA)</td>
<td>126</td>
<td>41</td>
<td>701</td>
</tr>
<tr>
<td></td>
<td>Stern &amp; Carlight 1373 (RSA)</td>
<td>181</td>
<td>41</td>
<td>765</td>
</tr>
<tr>
<td>P. gomonenense Guillaumin</td>
<td>Carlight 5341 (RSA)</td>
<td>192</td>
<td>31</td>
<td>617</td>
</tr>
<tr>
<td>P. haematomallum Guillaumin</td>
<td>Carlight 5282 (RSA)</td>
<td>76</td>
<td>47</td>
<td>633</td>
</tr>
<tr>
<td>P. horseri Rock</td>
<td>FPAw-Y1890</td>
<td>92</td>
<td>33</td>
<td>453</td>
</tr>
<tr>
<td>P. luffense Guillaumin</td>
<td>Guillaumin 7577 (RSA)</td>
<td>313</td>
<td>41</td>
<td>546</td>
</tr>
<tr>
<td>P. malosanum Baker</td>
<td>FPAw-15392</td>
<td>100</td>
<td>53</td>
<td>671</td>
</tr>
<tr>
<td>P. mannii Hook. f. var. mannii</td>
<td>WIBw-MC-148</td>
<td>112</td>
<td>39</td>
<td>669</td>
</tr>
<tr>
<td></td>
<td>WIBw-MC-171</td>
<td>115</td>
<td>47</td>
<td>559</td>
</tr>
<tr>
<td>P. mannii var. rupica (Leon.) Cuf.</td>
<td>F. Meyer 8839 (NA)</td>
<td>81</td>
<td>68</td>
<td>705</td>
</tr>
<tr>
<td>P. mousanum Guillaumin</td>
<td>Carlight 15603 (RSA)</td>
<td>106</td>
<td>46</td>
<td>838</td>
</tr>
<tr>
<td>P. nataliense Sherff</td>
<td>Stern &amp; Carlight 1344 (RSA)</td>
<td>111</td>
<td>22</td>
<td>623</td>
</tr>
<tr>
<td>P. pancheri Bronnz. &amp; Gris</td>
<td>Carlight 5320 (RSA)</td>
<td>159</td>
<td>35</td>
<td>672</td>
</tr>
<tr>
<td>P. paniense Guillaumin</td>
<td>Carlight 15378 (RSA)</td>
<td>243</td>
<td>45</td>
<td>875</td>
</tr>
<tr>
<td>P. pentandrum (Blanco) Merr.</td>
<td>FPAw-610</td>
<td>64</td>
<td>74</td>
<td>776</td>
</tr>
<tr>
<td>P. phylareoides DC.</td>
<td>Carlight 5135 (RSA)</td>
<td>193</td>
<td>26</td>
<td>412</td>
</tr>
<tr>
<td>P. pronyense Guillaumin</td>
<td>Carlight 5265 (RSA)</td>
<td>130</td>
<td>42</td>
<td>605</td>
</tr>
<tr>
<td>P. ralph T. Kirk</td>
<td>WZw, s.n.</td>
<td>142</td>
<td>35</td>
<td>561</td>
</tr>
<tr>
<td>P. ramiflorum Zoll. var. pregnans Schodde</td>
<td>FPAw-NGF-4859</td>
<td>65</td>
<td>53</td>
<td>711</td>
</tr>
<tr>
<td></td>
<td>SFCw-D1810</td>
<td>81</td>
<td>65</td>
<td>886</td>
</tr>
<tr>
<td></td>
<td>SFCw-D10-151-85</td>
<td>108</td>
<td>68</td>
<td>800</td>
</tr>
<tr>
<td>P. rhytidocarpum A. Gray</td>
<td>FPAw-23174</td>
<td>68</td>
<td>69</td>
<td>739</td>
</tr>
<tr>
<td></td>
<td>FPAw-23306</td>
<td>64</td>
<td>61</td>
<td>870</td>
</tr>
<tr>
<td>P. sphaerolobus De Wild.</td>
<td>USw-4582</td>
<td>64</td>
<td>67</td>
<td>853</td>
</tr>
<tr>
<td>P. tenulifolium Gaertn.</td>
<td>SFCw-R651-35</td>
<td>260</td>
<td>27</td>
<td>447</td>
</tr>
<tr>
<td></td>
<td>SFCw-R657-16</td>
<td>217</td>
<td>26</td>
<td>440</td>
</tr>
<tr>
<td>P. tobira (Thumb.) Ait. f.</td>
<td>cul. Claremont</td>
<td>204</td>
<td>31</td>
<td>500</td>
</tr>
<tr>
<td>P. turneri Petrie</td>
<td>WZw, s.n.</td>
<td>370</td>
<td>33</td>
<td>461</td>
</tr>
</tbody>
</table>

(Table 1 continued)
<table>
<thead>
<tr>
<th></th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
</tr>
</thead>
<tbody>
<tr>
<td>498</td>
<td>1.32</td>
<td>1.64</td>
<td>3.9</td>
<td>559</td>
<td>129</td>
<td>+</td>
<td>0.08</td>
<td>30</td>
<td>wb</td>
<td>wv</td>
<td></td>
</tr>
<tr>
<td>959</td>
<td>1.55</td>
<td>2.80</td>
<td>4.5</td>
<td>339</td>
<td>76</td>
<td>0</td>
<td>0.37</td>
<td>229</td>
<td>b</td>
<td>wv</td>
<td></td>
</tr>
<tr>
<td>814</td>
<td>1.64</td>
<td>1.80</td>
<td>4.6</td>
<td>409</td>
<td>116</td>
<td>0</td>
<td>0.26</td>
<td>129</td>
<td>0</td>
<td>mv, wv</td>
<td></td>
</tr>
<tr>
<td>791</td>
<td>1.84</td>
<td>4.60</td>
<td>4.4</td>
<td>297</td>
<td>106</td>
<td>+</td>
<td>0.12</td>
<td>52</td>
<td>b</td>
<td>mv, wv</td>
<td></td>
</tr>
<tr>
<td>694</td>
<td>1.11</td>
<td>1.83</td>
<td>5.8</td>
<td>579</td>
<td>106</td>
<td>+</td>
<td>1.20</td>
<td>748</td>
<td>Wb</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>811</td>
<td>1.43</td>
<td>2.73</td>
<td>5.0</td>
<td>376</td>
<td>114</td>
<td>+</td>
<td>0.58</td>
<td>330</td>
<td>W</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>903</td>
<td>1.44</td>
<td>1.96</td>
<td>5.0</td>
<td>298</td>
<td>156</td>
<td>0</td>
<td>0.92</td>
<td>633</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>1033</td>
<td>2.00</td>
<td>2.5</td>
<td>6.1</td>
<td>261</td>
<td>114</td>
<td>+</td>
<td>0.21</td>
<td>126</td>
<td>0</td>
<td>wv</td>
<td></td>
</tr>
<tr>
<td>464</td>
<td>2.00</td>
<td>3.6</td>
<td>715</td>
<td>262</td>
<td>+</td>
<td>0.18</td>
<td>713</td>
<td>wv</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>895</td>
<td>5.40</td>
<td>5.4</td>
<td>338</td>
<td>122</td>
<td>+</td>
<td>0.37</td>
<td>232</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>948</td>
<td>1.60</td>
<td>4.8</td>
<td>298</td>
<td>156</td>
<td>0</td>
<td>0.92</td>
<td>633</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>811</td>
<td>1.43</td>
<td>2.73</td>
<td>5.0</td>
<td>376</td>
<td>114</td>
<td>+</td>
<td>0.58</td>
<td>330</td>
<td>W</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>903</td>
<td>1.44</td>
<td>1.96</td>
<td>5.0</td>
<td>298</td>
<td>156</td>
<td>0</td>
<td>0.92</td>
<td>633</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>1033</td>
<td>2.00</td>
<td>2.5</td>
<td>6.1</td>
<td>261</td>
<td>114</td>
<td>+</td>
<td>0.21</td>
<td>126</td>
<td>0</td>
<td>wv</td>
<td></td>
</tr>
<tr>
<td>464</td>
<td>2.00</td>
<td>3.6</td>
<td>715</td>
<td>262</td>
<td>+</td>
<td>0.18</td>
<td>713</td>
<td>wv</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>895</td>
<td>5.40</td>
<td>5.4</td>
<td>338</td>
<td>122</td>
<td>+</td>
<td>0.37</td>
<td>232</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>948</td>
<td>1.60</td>
<td>4.8</td>
<td>298</td>
<td>156</td>
<td>0</td>
<td>0.92</td>
<td>633</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>811</td>
<td>1.43</td>
<td>2.73</td>
<td>5.0</td>
<td>376</td>
<td>114</td>
<td>+</td>
<td>0.58</td>
<td>330</td>
<td>W</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>903</td>
<td>1.44</td>
<td>1.96</td>
<td>5.0</td>
<td>298</td>
<td>156</td>
<td>0</td>
<td>0.92</td>
<td>633</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>1033</td>
<td>2.00</td>
<td>2.5</td>
<td>6.1</td>
<td>261</td>
<td>114</td>
<td>+</td>
<td>0.21</td>
<td>126</td>
<td>0</td>
<td>wv</td>
<td></td>
</tr>
<tr>
<td>464</td>
<td>2.00</td>
<td>3.6</td>
<td>715</td>
<td>262</td>
<td>+</td>
<td>0.18</td>
<td>713</td>
<td>wv</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>895</td>
<td>5.40</td>
<td>5.4</td>
<td>338</td>
<td>122</td>
<td>+</td>
<td>0.37</td>
<td>232</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>948</td>
<td>1.60</td>
<td>4.8</td>
<td>298</td>
<td>156</td>
<td>0</td>
<td>0.92</td>
<td>633</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

ON PP. 360 AND 361.)
Table 1. Wood features

<table>
<thead>
<tr>
<th>Species</th>
<th>Collection</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>P. undulatum Vent.</td>
<td>cult. Claremont</td>
<td>108</td>
<td>36</td>
<td>514</td>
</tr>
<tr>
<td>P. viridiflorum Sims</td>
<td>Carlquist 4998 (RSA)</td>
<td>175</td>
<td>46</td>
<td>426</td>
</tr>
<tr>
<td>Sollya heterophylla Lindl.</td>
<td>Carlquist 5276 (RSA)</td>
<td>480</td>
<td>32</td>
<td>404</td>
</tr>
<tr>
<td></td>
<td>Carlquist 5593 (RSA)</td>
<td>431</td>
<td>32</td>
<td>385</td>
</tr>
<tr>
<td></td>
<td>Carlquist 5733 (RSA)</td>
<td>240</td>
<td>38</td>
<td>349</td>
</tr>
<tr>
<td></td>
<td>Carlquist 6011 (RSA)</td>
<td>192</td>
<td>38</td>
<td>322</td>
</tr>
<tr>
<td></td>
<td>Carlquist 6039 (RSA)</td>
<td>418</td>
<td>38</td>
<td>398</td>
</tr>
</tbody>
</table>

Key to columns: 1, Number of vessels per sq. mm. of transection, mean. 2, Vessel diameter, mean, µm. 3, Vessel element length, mean, µm. 4, Imperforate element length, mean, µm. 5, Ratio, mean imperforate element length divided by mean vessel element length. 6, Number of vessels per group as seen in transection, mean. 7, Imperforate element wall thickness, mean, µm. 8, Multiseriate ray height, mean, µm. 9, Uniseriate ray height, mean, µm. 10, Helical sculpture on walls of secondary xylem vessels: + = present, 0 = absent. 11, "Vulnerability" ratio (vessel diameter divided by vessels per sq. mm.). 12, “Mesomorphy” ratio (vulnerability ratio multiplied by vessel element length). 13, Occurrence of rhomboidal crystals in rays: W = crystals

Because xylaria were necessarily an important source of materials for the study, I am grateful to curators of these collections, cited in Table 1 according to the abbreviations of Stern (1978). Where herbarium specimens document the collections, herbarium abbreviations are given according to the listings of Holmgren and Keuken (1974). Wood samples collected in the field were dried, with the exception of that of Pittosporum divaricatum, which had small stems suitable for preservation in an ethanol solution. In no case were mere twigs used as a basis for anatomical studies. Wood samples of some species which grow in humid areas could not be dried in air without the danger of molding. Many of these were treated according to the paraformaldehyde technique described earlier (Carlquist, 1980a); this method can be strongly recommended. Wood samples from xylaria can be assumed to represent large basal segments of trees or large shrubs. My own collections likewise represent samples of maximal size for any given species. However, some species (e.g., the New Caledonian ones) tend to produce only slender stems rather than large trunks.

Dried wood samples were subdivided and boiled preparatory to sectioning and maceration. Many woods of Pittosporaceae have very dense libriform fibers (or fiber-tracheids), and do not yield easily to sectioning. For these, Kukachka’s (1977) ethylene diamine method improved sectioning greatly. This method was modified by allowing longer treatment times and slightly higher concentrations than those specified by Kukachka. Use of a vacuum and use of weights on top of the wood samples during immersion in the ethylene diamine solution do not appear necessary. Wood sections were stained with safranin; in a few instances, haematoxylin was used as a counterstain. Macerations were prepared with Jeffrey’s fluid and stained with safranin. The use of polarizing discs of a simple sort permitted easy detection of crystalline materials during examination of wood sections. The nomenclature of Haas (1977) has been used for the Hawaiian species of Pittosporum. Accurate determination of New Caledonian species is difficult at the present moment. A wood sample supplied by a xylarium under the name “Pittosporum nigrum” should doubtless not be recognized under that nomen nudum; in Table 1 it has been referred to P. tenuifolium, in accordance with Cooper (1956). In Table 1 mean values are given for quantitative features. Means are based on 50 measurements each, except for vessels per sq. mm. and imperforate element diameter, which are based on ten measurements each.
ANATOMICAL DESCRIPTIONS

Vessel Elements.—As shown in nearly all of the transections, vessels in Pittosporum tend to be rounded rather than angular in shape (Figures 1, 3, 5, 9, 11, 15, 25, 33, 39, 45, 49, 53, 57, 61, 65, 69, 71, 73, 79, 81). The only exception to this at all would be in P. paniense (Figure 19). Vessels range from mostly solitary to aggregated in large groups, as the transections presented illustrate. The figures in Table 1 (column 6) reflect this clearly. The lowest figure recorded for vessels per group was 1.24 in P. paniense (Figure 19); the highest was 8.73 in P. turneri (Figure 45). In P. divaricatum (Figure 49), presence of vascular tracheids makes the number of vessels per group difficult to estimate, since very narrow vessels and vascular tracheids are not easily distinguished from imperforate tracheary elements in a transection. The large groups of narrow vessels in P. phyllareoides are not as conspicuous in transections (Figure 53) as in tangential sections (Figure 54). A few families, such as Asteraceae, show a great range in number of vessels per group (Carlquist, 1966). Others, such as Balanopaceae, are virtually uniform in this quantitative feature (Carlquist, 1980a). The figures for vessels per group in most Pittosporaceae are low. If a low number of vessels per group is indicative of mesomorphy (Carlquist, 1966, 1975a), Pittosporaceae could be said to be a basically mesic family—a generalization offered, in fact, by Schodde (1972). Pittosporum paniense, with its low figure for vessels per group, grows in a very wet area. Such species as Bursaria incana (Figure 1), B. spinosa (Figure 5), and P. phyllareoides (Figure 53) are not mesomorphic in their preferences, and this may well be correlated with the higher number of vessels per group in these species. High number of vessels per group in alpine New Zealand species such as P. turneri (Figure 45) and P. divaricatum (Figure 49) may reflect a form of physiological drought, the occurrence of frost, although summer drought in highly porous soils is certainly a possibility also.

Merely as a topographic feature of wood anatomy, the occurrence of various configurations in vessel groupings within Pittosporaceae is striking. Most species show a random type of grouping—the “pore multiples” of various authors (Figures 1, 3, 5, 9, 14, 15, 19, 25, 33, 49, 53, 57, 65, 69, 71, 73, 74, 77, 79, 81). Radial chains are very conspicuous in Pittosporum tenuifolium (Figure 39). In some portions of P. tobrica stems, marked diagonal arrangement of vessels is evident (Figure 61). In P. turneri...
(Figure 45), large diagonal and tangential patches of vessels can be identified.

Vessel diameter in Pittosporaceae is small compared with that in certain other families of dicotyledons, or compared with it in dicotyledons grouped according to any of several ecological categories (Carlquist, 1975a, p. 206). The average vessel diameter for Pittosporaceae here studied is 42.2 μm. However, this value actually falls close to the mode for dicotyledons as a whole (Carlquist 1975a, p. 159), despite its difference from the mean. Vessels in Pittosporaceae are too narrow (and simultaneously not dense enough) to be expected to conduct large volumes of water per unit time, despite the fact that some grow in sunny areas. Those species which do grow in dry areas have reduced leaf area (Bursaria spinosa), slender pendent isolateral leaves (Pittosporum phyllareoides), or some other mechanism capable of minimizing transpiration. One can hypothesize that species with leathery evergreen leaves (e.g., P. tobyra) transpire water slowly but steadily throughout the year. Measurements of transpiration would be very desirable in a family such as Pittosporaceae, in which species differ markedly in vessel diameter. Notably wide vessels occur in P. pentandra (Figure 57), P. rhytidocarpum (Figure 65), and P. mannii var. rupicola (Figure 81). One can guess that these all grow in tropical areas where abundant soil moisture coupled with high temperature results in almost constant transpiration of large volumes of water per unit time, as recently hypothesized (Carlquist, 1980b). Baas (1976) stressed a relationship between higher temperatures and greater vessel diameter. This holds true in wet tropics, but not in dry tropics (e.g., Galápagos Islands) or hot desert areas in various latitudes.

The number of vessels per sq. mm. of transection ranges widely within Pittosporaceae: from 25 in Hymenosporum flavum (Figure 9) to more than 400 in some collections of Sollya heterophylla (Figure 14). The number in Pittosporum divaricatum and P. turneri could not be determined accurately because vascular tracheids resemble libriform fibers in transections, and so the numbers for these species must be considered minimal. The figure for most Pittosporaceae ranges close to 100, a figure to be expected for mesic dicotyledons (e.g., Balanopaceae: Carlquist, 1980a). The low density of vessels in Hymenosporum meets expectations based on the ecology of that tree fairly well. The relatively high density in P. paniense (243 per sq. mm.) is much greater than in a selected group of mesic dicotyledons with primitive wood (Carlquist, 1975a, p. 206). Evidently “safety” is greater than in most dicotyledons from such habitats, although periods of intense sunshine and heat do occur on Mt. Panié, indicating that climatic extremes might make a greater than normal safety of value, despite the high rainfall on Mt. Panié. In Pittosporaceae as a whole, species from drier localities do have more numerous vessels per sq. mm. of transection than do mesic species (Table 1, column 1). Certainly the figures for the family run higher than in mesic dicotyledons with primitive wood (Carlquist, 1975a, p. 206), suggesting that Pittosporaceae have a greater degree of “safety” in their wood than do ancient mesophytes.

The mean vessel element length for Pittosporaceae as a whole is 605 μm. That length is close to the figure for dicotyledons as a whole (690 μm: Carlquist, 1975a, p. 159). There is a range of lengths within the family, however. Shorter lengths characterize species from drier areas, a correlation that I claimed earlier for Asteraceae, for example (Carlquist, 1966). The species from wetter areas, such as Pittosporum paniense, have longer vessel elements. The correlation is not primarily with size of plant: P. paniense is a relatively small shrub.
Vessel diameter, vessel element length, and number of vessels per sq. mm. of transection have been combined into ratios termed vulnerability (vessel diameter divided by vessels per sq. mm.) and mesomorphy (vulnerability ratio multiplied by vessel element length). Figures for these ratios are given for Pittosporaceae in Table 1. These ratios, originated recently (Carlquist, 1977a), are proving to be useful indicators within certain limits (Carlquist, 1980b). Within the genus Bursaria, these figures show *B. tenuifolia* to be the most mesomorphic species; it is native to the Atherton rain forest area of northern Queensland and is indeed more highly mesomorphic than the other species of the genus. The genera Billardiera, Marianthus, and Sollya, which have low figures for mesomorphy, grow in exposed sunny sites. Within the genus Pittosporum, the lowest values for the mesomorphy ratio can be said to belong to the species from alpine New Zealand, *P. divaricatum* and *P. turneri*. As noted above, these areas have frost in winter, and in summer low humidity and sudden drying of porous soils can occur. The high degree of safety conveyed by presence of numerous narrow vessels seems an expression of low mesomorphy in these species.

Low figures for the mesomorphy ratio can also be seen in *Pittosporum tobira*, which is native to sunny open lowlands on Kyushu and Shikoku, Japan (Ohwi, 1965). In cultivation, *P. tobira* is very drought-resistant. The same could be said of *P. phyllareoides*, distributed in the drier regions of Australia (Cooper, 1956). *Pittosporum rhytidocarpum*, a broad-leaved understory species of wet tropical forest, qualifies as mesomorphic according to the figures in Table 1. *Hymenosporum flavum* is also a mesomorph on this basis. Several of the New Caledonian species have rather low figures for the mesomorphy ratio. For example, both *P. gomonenense* and *P. lifuense* have mesomorphy figures which fall below 100. These two plants were found in dry, exposed lowland areas and have narrow, leathery leaves appropriate to xeromorphs, and so the low figures are not surprising. However, other New Caledonian species, such as *P. paniense*, and some Hawaiian species, such as *P. gayanum* and *P. hosmeri*, have rather low mesomorphy indices. These species grow in areas which can occasionally be very hot and sunny, and they are not understory species but emergents (often in a low scrubby vegetation). However, another factor may be considered: these species have a rather distinctive growth form. They are branched from near the base and have sparsely branched stems topped by leaf rosettes. They have no main trunk, and each of the stems has a rather finite diameter. The limited diameter may account for lowered vessel-element length, for vessel-element length tends to increase with age in a stem (Bailey and Tupper, 1918). The tendency for a stem to bear a single leaf rosette over a period of years without much increase in stem diameter would result in greater “safety” (or lower “vulnerability”) by virtue of presence of narrower vessels, more numerous per sq. mm. of transection. The correlates of vessel dimensions with various peculiar growth forms are worthy of further exploration.

Pittosporaceae are interesting in having a notable range in vessel features that correlates well with ecology. This range is not limitless, and a large portion of the family can be said to have rather stereotyped vessel features. The evergreen shrubby nature of many members of the family is equally stereotyped. Evergreen families tend to have a kind of buffering by the foliage, so that wood patterns in some cases are less direct reflections of the ecological conditions under which the family exists (Carlquist, 1980a, 1980b; van Vliet, 1979).

Perforation plates of Pittosporaceae have been reported to be exclusively simple
This is indeed true with the exception of one species: *Pittosporum paniense* (Figures 17-24). *Pittosporum paniense* has scalariform perforation plates exclusively, with four to 15 bars (mean: 8.2). One or several bars per plate are forked (Figures 22, 23). Bars may be slender (Figure 21) or wider (Figures 22, 23). Occasionally, two perforation plates are present at one end of a vessel (Figure 23), presumably where branching of a vessel occurs; a pair of perforation plates at the end of a vessel may also very occasionally be seen in the species with simple perforation plates. Bars of perforation plates in *P. paniense* may bear vestigial borders. The discovery of scalariform perforations in vessels of *P. paniense* was sufficiently unusual so that the validity of this observation was confirmed by preparing sections and macerations from twigs on the herbarium specimen as well as from the wood sample taken from the base of the plant.

If my (1975a) hypotheses concerning the ecology of species with scalariform perforation plates are correct, *Pittosporum paniense* should be native to a wet region and should be derived from ancestors which inhabited such places. This species is endemic to Mt. Panié, New Caledonia’s wettest mountain. Thus, in Pittosporaceae as in so many other families, New Caledonia appears to have been a refugium for plants with primitive xylem. However, one should add that wet valleys and wet upland areas rather than lowlands or macchie vegetation are the refugia on New Caledonia for the species with primitive woods.

*Pittosporum paniense* may or may not prove to be the only species of the family with scalariform perforation plates. Schodde (1972) suggests that *Pittosporum* sect. *Chelidospermum* contains a large number of features primitive for the family. The species in this section (*P. sinuatum* and *P. tenuivale* from New Guinea, *P. rubiginosum* from eastern Australia, and *P. suatinum* from the Solomon Islands) were not included in the present study because wood samples of them could not be secured. However, the gross morphology of New Caledonian species needs study, and when the results of such study are completed, perhaps a case may be made for some species of that island also having numerous primitive features.

The occurrence of scalariform perforation plates in one species of *Pittosporum*, in a family in which up to the present only simple perforation plates have been reported, should not be a surprise. Pittosporaceae may be related to families with scalariform perforation plates. More importantly, Bierhorst and Zamora (1965) report that the only species of the family they investigated, *P. paniculatum*, possesses primary xylem consisting of tracheids mixed with vessel elements bearing scalariform perforation plates; no simple perforation plates are present in the primary xylem. Primary xylem tends to be a refugium for primitive xylary features, as Bailey (1944) stated. However, many dicotyledonous families are advanced in primary as well as secondary xylem, and have only simple plates in vessel elements of the primary xylem (Bierhorst and Zamora, 1965). Therefore, the scalariform perforation plates in *P. paniense* are congruent with a family with basically primitive primary xylem, and *P. paniculatum* proves that primitive primary xylem is indeed present in the family.

A similar situation can be cited with regard to lateral wall pitting of vessels. All species of Pittosporaceae have an alternate pattern. In addition, some opposite pitting can be reported for *Pittosporum haematomalum*, *P. lifuense*, *P. pronyense*, and *P. ralphii*. The first three of these are New Caledonian species. *Pittosporum paniense* has intervascular pitting varying from near-scalariform and opposite (Figure 24) to
alternate (Figure 22). The presence of pitting types other than alternate could be considered remnants of primitive expressions, in accord with Frost (1931).

Vascular tracheids were observed in *Pittosporum divaricatum* (Figures 49–51) and *P. turneri* (Figures 45, 46). Vascular tracheids are characteristic of woods of xeric situations (Carlquist, 1975a, 1980b).

Caudate tips on vessel elements were frequently observed in wood macerations of Pittosporaceae. Presence of caudate tips might be related to the relatively long, proportionately narrow vessel elements in the family. Such proportions might tend to result in a fusiform rather than cylindrical shape for a vessel element, the perforation plate thereby formed laterally rather than terminally. Wood anatomists assume that little or no intrusive growth occurs as vessel elements mature from fusiform cambial initials. This assumption might be worthy of reinvestigation in a taxonomic group in which caudate vessel elements are common.

Helical sculpturing ("tertiary helical thickenings") occurs on vessels of numerous Pittosporaceae, as shown in Table 1, column 10. Helical thickenings were reported for the majority of genera in the family by Solereder (1908) and Metcalfe and Chalk (1950). I was not able to confirm the presence of helical sculpturing of vessels in *Hymenosporum flavum*. Helical sculpturing may be present as fine striae, as in *Pittosporum cornfolium*, *P. hosmeri*, and *P. turneri* (Figure 47). Moderately pronounced helical sculpture is shown here for *Bursaria spinosa* (Figure 8). Pronounced spiral bands, widely spaced, are shown here for *P. tenuifolium* (Figure 44), *P. divaricatum* (Figure 51), and *P. tobira* (Figure 63). Helical sculpture in vessels was found by Webber (1936) to be more abundant in vessels of desert shrubs than in those of shrubs from somewhat more mesic regions. One could say that this correlation, which has been validated in other studies (e.g., Carlquist, 1966), also holds for Pittosporaceae. One way of demonstrating this is by means of a quantitative comparison, using the mesomorphy index discussed earlier. If one determines the mean mesomorphy index for the 27 collections in which no helical sculpture is reported, one obtains the figure 377. The mean mesomorphy index figure for the 35 collections in which helices or striae are reported is 297, appreciably less. Thus, the correlation does appear confirmed. The explanation for why spirals should have selective advantage in xeromorphs is unclear (Carlquist, 1975a). Jeje and Zimmermann (1979) have shown lessened resistance to flow in vessels which possess helical sculpture. However, rapidity of conduction may not prove to be the prime selective factor. One would have to say that helical sculpture compensates for lack of wider vessels (wider vessels would promote rapid flow to a much greater extent). One would then have to hypothesize that selection disfavors wide vessels in such species. That situation is difficult to envision, at least in many cases: wider vessels can easily be achieved in earlywood, and be coupled with narrow vessels and their compensatory advantages in latewood. Climates with marked selective pressure for safety in vessels are seasonal ones, where formation of growth rings provides the obvious means of compensating earlywood flow capability with latewood safety potential (Carlquist, 1980b).

**Imperforate Tracheary Elements.**—The imperforate tracheary elements of Pittosporaceae range from moderately thin- to very thick-walled, as Table 1, column 7, as well as the various transections illustrated here, demonstrates. In some species, seasonal growth events are related to shift in wall thickness (Figures 49, 71).

Imperforate tracheary elements have either no borders on pits or very vestigial
ones, as shown in Figures 60 and 67. Vestigial borders of this sort were observed in *Pittosporum eugenioides*, *P. floribundum*, *P. glabrum*, *P. hosmeri*, *P. malosanum*, *P. mannii var. mannii*, *P. mannii var. rupicola*, *P. napaliense*, *P. rhombifolium*, *P. rhytidocarpum*, and *P. spathicalyx*. Because these borders are difficult to observe, more species than those listed very likely do have bordered pits on imperforate tracheary elements. Both presence of such borders and absence of them are reported for the family by Metcalfe and Chalk (1950). Thus, imperforate tracheary elements may be designated either as fiber-tracheids or libriform fibers. The presence of fiber-tracheids seems an indicator of a vestigial primitive feature retained by Pittosporaceae.

Imperforate tracheary elements are septate in some Pittosporaceae. Metcalfe and Chalk (1950) generalize that the family as a whole is characterized by septate imperforate tracheary elements, but I could not observe septa in an appreciable roster of species. Septa are figured here for *Pittosporum pentandrum* (Figure 60). The species in which I have observed septate imperforate tracheary elements include *Bursaria incana*, *B. spinosa*, *Citriobatus tenuifolius*, *Hymenosporum flavum*, *Pittosporum acuminatum*, *P. bicolor*, *P. bracteolatum*, *P. cravenianum*, *P. divaricatum*, *P. eugenioides*, *P. ferrugineum*, *P. floribundum*, *P. gayanum*, *P. glabratum*, *P. glabrum*, *P. hosmeri*, *P. malosanum*, *P. mannii var. mannii*, *P. mannii var. rupicola*, *P. napaliense*, *P. pentandrum*, *P. phyllareoides*, *P. rhombifolium*, *P. rhytidocarpum*, *P. spathicalyx*, *P. tenuifolium*, and *P. viridiflorum*.

If one divides mean imperforate tracheary element length by mean vessel element length for any species, one obtains a ratio (Table 1, column 5) which reflects the intrusiveness of imperforate tracheary elements as they mature from fusiform cambial initials. Ratios in Pittosporaceae range from 1.11 in *Bursaria tenuifolia* and *Pittosporum mouanum* to 1.84 in *B. spinosa* and 2.03 in *P. tenuifolium*. The majority of collections fall between 1.20 and 1.50, a rather narrow range. This moderate degree of intrusiveness of imperforate tracheary elements is found in families with relatively primitive xylem (Carlquist, 1975a). Very primitive dicotyledons with vessels would be expected to have a ratio which falls between 1.10 and 1.30, as in Bruniaceae (Carlquist, 1978). In a few cases, ratios below 1.00 have been reported, but ratios below 1.00 are probably not indicative of any greater primitiveness than ratios between 1.00 and 1.20 (Carlquist, 1975b, 1976, 1977b, 1978).

Imperforate tracheary elements in Pittosporaceae are not markedly gelatinous in appearance of walls when compared to those in other families. The long slitlike pits in imperforate tracheary elements in Pittosporaceae, however, may represent some splitting as sections are dehydrated and wall materials shrink compared with the living condition.

**Axial Parenchyma.**—The basic parenchyma type in Pittosporaceae, as noted by Metcalfe and Chalk (1950), is scanty paratracheal. A few cells are adjacent to vessels or vessel groups, as seen in transection. Parenchyma is very scanty in the following species: *Billardiera bicolor*, *Pittosporum bicolor*, *P. bracteolatum*, *P. deplanchei* (Figures 15 and 16), *P. eugenioides*, and *P. pancheri*. Strands of axial parenchyma mostly range from four to seven cells.

In addition to paratracheal parenchyma, a few diffuse axial parenchyma strands were observed in *Pittosporum glabrum*, *P. haematomallum*, and *P. hosmeri* (Figure 71). In addition to these three species, in which non-crystal-bearing diffuse parenchyma strands were observed, other Pittosporaceae were observed to have diffuse
axial parenchyma strands in which crystals were characteristically present. These strands are sometimes subdivided into numerous small cuboidal cells, each bearing a crystal, as in *P. lifuense* (FIGURE 29) or *P. gomonenense* (FIGURES 37 and 38). Alternatively, crystal-bearing axial parenchyma cells may be large and fewer per strand, as in *P. erioloma* (FIGURE 52). Crystal-bearing diffuse axial parenchyma strands were observed in *Bursaria incana*, *B. spinosa*, *Citriobacus lancifolia*, *Pittosporum acuminatum*, *P. bicolor*, *P. cornifolium*, *P. eugenioides*, *P. floribundum*, *P. gayanum*, *P. haematomallum*, *P. mouanum*, *P. pancheri*, and *P. undulatum*. In the material of *P. undulatum* studied, the rhomboidal crystals were full of minute internal fractures, appearing nearly opaque.

**Ray Parenchyma.—**Rays in Pittosporaceae as seen in tangential section can be described as narrow, two to three cells wide when multiseriate (FIGURES 2, 12, 16, 26, 34, 46, 50, 70, and 72) or more than three cells wide (FIGURES 4, 6, 10, 20, 40, 48, 54, 58, 62, 66, 80, and 82). Examination of these tangential sections shows that uniseriate rays are scarcer than multiseriate rays throughout the family. Not surprisingly, uniseriate rays are most abundant in woods with narrow multiseriate rays a few cells wide. Such rays resemble uniseriate rays more closely and might be expected to coexist with uniseriate rays (e.g., FIGURES 12, 16, 26, 34). Uniseriate rays can be found in all woods of Pittosporaceae, however.

Narrow multiseriate rays are apparently correlated with the habit of New Caledonian and Hawaiian species, shrubs with numerous slender branches from near the base, the branches tipped by leaf rosettes. The narrow rays may correlate with the great strength of these polelike stems. The New Zealand species, which are freely branched shrubs, mostly have wider rays (FIGURES 40, 46, 48). This is also true of well-branched tree and shrub species of other areas, such as *Pittosporum phyllareoides* (FIGURE 54), *P. pentandrum* (FIGURE 58), *P. tobira* (FIGURE 62), *P. rhytidocarpum* (FIGURE 66), *P. mannii* var. *mannii* (FIGURE 80), and *P. mannii* var. *rupicola* (FIGURE 82). Differences among species within the small genus *Bursaria* can be seen in tangential sections (FIGURES 2, 4, 6). Shorter, wider rays tend to occur in the shrubbiest species, *B. spinosa*.

Ray histology in Pittosporaceae is rather uniform and can be expressed simply. The majority of cells in multiseriate rays are procumbent, often several times as long as wide (FIGURES 27, 31, 52). The wider the ray, the more numerous the procumbent cells and the more radially elongate they are. Most multiseriate rays do not have uniseriate wings more than one or two cells high. These wing cells, however, are upright or square as seen in radial section. Uniseriate rays are equivalent to the wing cells of the multiseriate rays, composed of upright and square cells. Occasionally a few upright or square cells may be found sheathing the body of a multiseriate ray. The rays thus correspond, I believe, to the type Kribs (1935) called Heterogeneous Type IIA, although Metcalfe and Chalk (1950) interpret these rays as Heterogeneous IIB or Homogeneous I.

*Marianthus procumbens* (FIGURE 13) is exceptional in its ray histology. Its rays have only a few procumbent cells; square and erect cells are abundant. *Marianthus procumbens* is a shrub of very limited xylem accumulation. Therefore, it may represent an instance of paedomorphosis (Carlquist, 1962), a phenomenon in which erectness predominates in ray cells.

Erect cells in wings of multiseriate rays of Pittosporaceae may occasionally be
PHYLOGENETIC RELATIONSHIPS

Within the family Pittosporaceae, woods offer few clues to interrelationships of the genera. The discovery of notably primitive wood structure in *Pittosporum paniense* suggests that we ought to entertain New Caledonian *Pittospora* in our search for primitive characteristics within the family. Schodde (1972) has a hypothetical origin for the genus *Pittosporum* midway between Australia, Africa, and India. During evolution in Australia, *Pittosporum* is held by him to have yielded the Australian genera as offshoots—an idea rather like that of Diels and Pritzel (1904)—and continued into New Guinea, from which central area all the Pacific and Malesian *Pittospora* are thought to be derived.

Whatever the interrelationships among the genera of the family, wood anatomy does not offer any features which correlate with generic distinctions. The patterns shown here could rather be described as variations on a basic plan, variations related to habit and ecology as described above. Features other than wood, such as the ones stressed by Schodde (e.g., fruit type, trichome type, mode of anther attachment, nature of stamen tips, degree of corolla connation, and inflorescence position and structure), are more likely to provide criteria for recognition of the various genera and of the subgenera within *Pittosporum*. Flavonoids may also be useful in recognition of genera and subgenera in the family (Jay, 1969).

With respect to hypotheses about the relationships of Pittosporaceae to other families, we can probably neglect some earlier views, such as the polygaloid affinity suggested by de Candolle (1824) and Bentham and Hooker (1862), the rutoid affinity claimed by Richard (1828) and Schnizlein (1843–1870), and the celastroid relationship advanced by Endlicher (1840) and Eichler (1878). None of these views has received support in recent times.

Baillon (1865, 1871) was probably the first to place Pittosporaceae in what could be called a rosoid alliance, relating it to such families as Saxifragaceae. I am using the term “rosoid” in order to avoid endorsing particular and rather narrow concepts of Rosales. The idea of rosoid affinity for Pittosporaceae has been followed by a large number of authors. Pax (1891) and Pritzel (1930) represent the adherence by *Die natürlichen Pflanzenfamilien* to this view; Wettstein (1935) concurred.


The concept of Pittosporales is not radically different from the way other authors treat rosoid groups. Takhtajan (1969) ranks Pittosporaceae in Saxifragales, along with Roridaulaceae, Byblidaceae, and Bruniaeae. Cronquist (1968) enters Pittosporaceae into a Rosales in which he includes such families as Bruniaeae, Byblidaceae, Cunoniaceae, Davidsoniacaeae, Eucryphiaceae, and Hydrangeaceae.

Against this almost uniform viewpoint of modern angiosperm phylogenists, one must place the claims of those who find an aralioid or umbellalean affinity for Pittosporaceae. One can trace this latter viewpoint to van Tieghem (1884), whose numerous studies on secretory canals in plants were undoubtedly persuasive to him. Pittosporaceae would be the only rosoid family with secretory canals. Probably these
secretory canals tend to contain the classes of compounds found in secretory canals in other families, judging from the chemical data of Hegnauer (1969, 1971) and Jay (1969). Prior to this accumulation of chemical data, Schürhoff (1929) had supported an umbellalean placement for Pittosporaceae. He noted that ovules of Pittosporaceae agree more with those of Umbellales in being unitegmic, in contrast to the bitegmic ovules in the rosoid families. Number of integuments is a feature very much subject to parallel evolution within angiosperms, however, and one might guess that other features would be of greater significance in assessing relationships. Hegnauer (1969) also claims affinity between Pittosporaceae and Rutaceae, a family which also has secretory canals and secretory cavities. Occurrence of secretory canals may be an anatomical manifestation of accumulation of particular classes of compounds, such as terpenoids, as in Asteraceae, and parallel evolution of secretory canals and the compounds they contain must be considered a distinct possibility. None of the adherents of the aralioid affinity hypothesis claim that floral morphology of umbellalean families is strongly suggestive of relationship to Pittosporaceae.

Thus, in the phylogenetic placement of Pittosporaceae, we have a classical instance in which those who have studied numerous features of floral morphology and other aspects of gross morphology find themselves in opposition to those whose opinions tend to favor evidence from plant chemistry. Does wood anatomy lend any support to either the rosoid or the umbellalean viewpoint? Umbellales are variously construed, and so I shall compare Pittosporaceae only with Araliaceae, which perhaps include Apiaceae as well (Thorne, 1968, 1976). These families have vessel element morphology and ray types similar to conditions found in Pittosporaceae, but the match is no closer than between Pittosporaceae and the rosoid families. Such similarities in all probability are due more to likenesses in evolutionary level than to genuine relationship and must not be used as indicators of relationship. Scalariform perforation plates are known for a scattering of aralioid genera (Metcalf and Chalk, 1950) and are common in rosoid families; *Pittosporum paniense* with its scalariform perforation plates demonstrates that the primitive xylem characteristics found in either of the two major alliances is also represented in Pittosporaceae.

Araliaceae and Apiaceae have secretory canals in rays, but Pittosporaceae do not (Metcalf and Chalk, 1950); likewise those authors report only paratracheal axial parenchyma from Araliaceae and Apiaceae; presence of diffuse axial parenchyma, often bearing chambered crystals, characterizes a number of Pittosporaceae, as mentioned above. No crystals have been reported from axial parenchyma of Araliaceae or Apiaceae, but axial parenchyma with chambered crystals has been reported for an assortment of rosoid or pittosporalean families such as Balanopaceae (Carlquist, 1980a), Grubbiaceae (Carlquist, 1977b), and Bruniaceae (Carlquist, 1978). These families also have crystals in subdivided erect ray cells in ray wings, as seen in Pittosporaceae, but no such ray wing crystals have been reported for Araliaceae or Apiaceae. Rhomboidal crystals have been reported from non-subdivided erect ray cells and from procumbent cells of the multiseriate ray body for *Panax* and three other genera of Araliaceae (Chattaway, 1956). There are rhomboidal crystals in the body of multiseriate rays in Balanopaceae (Carlquist, 1980a), Geissolomataceae (Carlquist, 1975b), Grubbiaceae (Carlquist, 1977b), and Bruniaceae (Carlquist, 1978). Additional rosoid families could be cited, but the similarity of modes of crystal occurrence between Pittosporaceae and rosoid families is evident. In this regard, one should not omit
PHYLOGENETIC RELATIONSHIPS

Within the family Pittosporaceae, woods offer few clues to interrelationships of the genera. The discovery of notably primitive wood structure in *Pittosporum paniense* suggests that we ought to entertain New Caledonian *Pittosporum* in our search for primitive characteristics within the family. Schodde (1972) has a hypothetical origin for the genus *Pittosporum* midway between Australia, Africa, and India. During evolution in Australia, *Pittosporum* is held by him to have yielded the Australian genera as offshoots—an idea rather like that of Diels and Pritzel (1904)—and continued into New Guinea, from which central area all the Pacific and Malesian *Pittosporum* are thought to be derived.

Whatever the interrelationships among the genera of the family, wood anatomy does not offer any features which correlate with generic distinctions. The patterns shown here could rather be described as variations on a basic plan, variations related to habit and ecology as described above. Features other than wood, such as the ones stressed by Schodde (e.g., fruit type, trichome type, mode of anther attachment, nature of stamen tips, degree of corolla connation, and inflorescence position and structure), are more likely to provide criteria for recognition of the various genera and of the subgenera within *Pittosporum*. Flavonoids may also be useful in recognition of genera and subgenera in the family (Jay, 1969).

With respect to hypotheses about the relationships of Pittosporaceae to other families, we can probably neglect some earlier views, such as the polygaloid affinity suggested by de Candolle (1824) and Bentham and Hooker (1862), the rutoid affinity claimed by Richard (1828) and Schnizlein (1843–1870), and the celastroid relationship advanced by Endlicher (1840) and Eichler (1878). None of these views has received support in recent times.

Baillon (1865, 1871) was probably the first to place Pittosporaceae in what could be called a rosoid alliance, relating it to such families as Saxifragaceae. I am using the term “rosoid” in order to avoid endorsing particular and rather narrow concepts of Rosales. The idea of rosoid affinity for Pittosporaceae has been followed by a large number of authors. Pax (1891) and Pritzel (1930) represent the adherence by *Die natürlichen Pflanzenfamilien* to this view; Wettstein (1935) concurred.


The concept of Pittosporales is not radically different from the way other authors treat rosoid groups. Takhtajan (1969) ranks Pittosporaceae in Saxifragales, along with Roridulaceae, Byblidaceae, and Bruniaecae. Cronquist (1968) enters Pittosporaceae into a Rosales in which he includes such families as Bruniaecae, Byblidaceae, Cunoniaceae, Davidsoniaceae, Eucryphiaceae, and Hydrangeaceae.

Against this almost uniform viewpoint of modern angiosperm phylogenists, one must place the claims of those who find an aralioid or umbellalean affinity for Pittosporaceae. One can trace this latter viewpoint to van Tieghem (1884), whose numerous studies on secretory canals in plants were undoubtedly persuasive to him. Pittosporaceae would be the only rosoid family with secretory canals. Probably these
secretory canals tend to contain the classes of compounds found in secretory canals in other families, judging from the chemical data of Hegnauer (1969, 1971) and Jay (1969). Prior to this accumulation of chemical data, Schürhoff (1929) had supported an umbellalean placement for Pittosporaceae. He noted that ovules of Pittosporaceae agree more with those of Umbellales in being unitegmic, in contrast to the bitegmic ovules in the rosoid families. Number of integuments is a feature very much subject to parallel evolution within angiosperms, however, and one might guess that other features would be of greater significance in assessing relationships. Hegnauer (1969) also claims affinity between Pittosporaceae and Rutaceae, a family which also has secretory canals and secretory cavities. Occurrence of secretory canals may be an anatomical manifestation of accumulation of particular classes of compounds, such as terpenoids, as in Asteraceae, and parallel evolution of secretory canals and the compounds they contain must be considered a distinct possibility. None of the adherents of the aralioid affinity hypothesis claim that floral morphology of umbellalean families is strongly suggestive of relationship to Pittosporaceae.

Thus, in the phylogenetic placement of Pittosporaceae, we have a classical instance in which those who have studied numerous features of floral morphology and other aspects of gross morphology find themselves in opposition to those whose opinions tend to favor evidence from plant chemistry. Does wood anatomy lend any support to either the rosoid or the umbellalean viewpoint? Umbellales are variously construed, and so I shall compare Pittosporaceae only with Araliaceae, which perhaps include Apiaceae as well (Thorne, 1968, 1976). These families have vessel element morphology and ray types similar to conditions found in Pittosporaceae, but the match is no closer than between Pittosporaceae and the rosoid families. Such similarities in all probability are due more to likenesses in evolutionary level than to genuine relationship and must not be used as indicators of relationship. Scalariform perforation plates are known for a scattering of aralioid genera (Metcalf and Chalk, 1950) and are common in rosoid families; *Pittosporum paniense* with its scalariform perforation plates demonstrates that the primitive xylem characteristics found in either of the two major alliances is also represented in Pittosporaceae.

Araliaceae and Apiaceae have secretory canals in rays, but Pittosporaceae do not (Metcalf and Chalk, 1950); likewise those authors report only paratracheal axial parenchyma from Araliaceae and Apiaceae; presence of diffuse axial parenchyma, often bearing chambered crystals, characterizes a number of Pittosporaceae, as mentioned above. No crystals have been reported from axial parenchyma of Araliaceae or Apiaceae, but axial parenchyma with chambered crystals has been reported for an assortment of rosoid or pittosporalean families such as Balanopaceae (Carlquist, 1980a), Grubbiaceae (Carlquist, 1977b), and Bruniaceae (Carlquist, 1978). These families also have crystals in subdivided erect ray cells in ray wings, as seen in Pittosporaceae, but no such ray wing crystals have been reported for Araliaceae or Apiaceae. Rhomboidal crystals have been reported from non-subdivided erect ray cells and from procumbent cells of the multiseriate ray body for *Panax* and three other genera of Araliaceae (Chattaway, 1956). There are rhomboidal crystals in the body of multiseriate rays in Balanopaceae (Carlquist, 1980a), Geissolomataceae (Carlquist, 1975b), Grubbiaceae (Carlquist, 1977b), and Bruniaceae (Carlquist, 1978). Additional rosoid families could be cited, but the similarity of modes of crystal occurrence between Pittosporaceae and rosoid families is evident. In this regard, one should not omit...
Figures 1–4. Wood sections of *Bursaria*. 1 & 2. *B. incana* (CQTW). 1. Transection, showing numerous vessels, clustered variously, and pronounced growth rings. 2. Tangential section; rays are narrow, short. 3 & 4. *B. tenutifolia* (CQTW). 3. Transection; vessels are sparse, mostly solitary. 4. Tangential section; rays are tall, wide. Scale for all shown above 1 (finest divisions = 10 μm).
FIGURES 5-8. Wood sections of Bursaria spinosa (FPaw-8152). 5. Transection, showing moderate grouping of vessels. 6. Tangential section; rays are wide, short. 7. Tip of ray from tangential section; crystals present in two of the ray cells. 8. Vessel from tangential section, showing helical thickenings. Scale for 5 & 6 above 1; scale for 7 & 8 above 7 (divisions = 10 μm).
FIGURES 13-16. Wood sections of Marianthus, Sollya, and Pittosporum. 13. Marianthus procumbens (Carlquist 5532). Radial section, showing that most ray cells are erect, few procumbent or square. 14. Sollya heterophylla (Carlquist 5733). Transection; vessels range from very wide to very narrow, depending on position in growth ring. 15 & 16. Pittosporum deplanchei (Carlquist 15615). 15. Transection; fibers thick-walled. 16. Tangential section; rays uniseriate to triseriate. Scale for 13 above 13 (divisions = 10 μm); scale for 14-16 above 1.
FIGURES 21–24. *Pitiosporum paniense* (Carlquist 15578). Details of vessels from radial sections. 21. Perforation plate with about 11 bars; bars tenuous, several forked. 22. Perforation plate with wide bars; alternate intervacular pitting below. 23. One of two perforation plates at tip of vessel element; about eight bars (below), several forked. 24. Intervacular pitting, showing transition between scalariform, opposite, and alternate types. Scale for all above 7.
FIGURES 29-32. Wood sections of New Caledonian species of Pittosporum. 29 & 30. *P. lifuense* (Guillaumin 7577). 29. Strand of chambered crystalliferous cells from radial section. 30. Small styloids of phloem parenchyma from radial section of bark. 31 & 32. *P. haematomallum* (Carlquist 5282). 31. Radial section, showing subdivided and non-subdivided crystal-bearing sclereids from radial section; crystal-bearing sclereids in ray. 32. Four crystal-bearing sclereid ray cells from radial section; crystals are encapsulated in thick secondary walls. Scale for 29, 30, & 32 above 7; scale for 31 above 13.
FIGURES 39–44. Wood sections of *Pittosporum tenuifolium* (SFCw-R657-16). 39. Transection, showing tendency of vessels to occur in radial chains. 40. Tangential section; note wide, short rays. 41–43. Crystals in rays from tangential sections. 41. Crystal from margin of ray. 42. Crystal viewed from hexagonal face. 43. Side view of rhomboidal crystal, tip cell of ray. 44. Helical thickenings on vessel from radial section. Scale for 39 & 40 above 1; scale for 41–44 above 7.
FIGURES 45-48. Wood sections of New Zealand species of Pittosporum. 45-47. P. turneri (WZw, s.n.).
45. Transection; note large numbers of narrow vessels. 46. Tangential section; rays rather narrow, short. 47.
Vessel from tangential section, showing helical sculpturing. 48. P. eugenioiides (FPAw-33660), tangential
section; rays wide; tall, large cells contain crystals. Scale for 45, 46, & 48 above 1; scale for 47 above 7.
Figures 49–52. Wood sections of New Zealand and Lord Howe Island species of *Pittosporum*. 49–51. *P. divaricatum* (Alan Marks, s.n.). 49. Transection; vessels are narrow and grade into vascular tracheids. 50. Tangential section; rays are tall but narrow, uniseriates abundant. 51. Vessels with helical thickenings from radial section. 52. *P. erioloma* (SFCw-R638-1f). Radial section to show crystals in ray wing (center) and enlarged crystal-bearing cells of an axial parenchyma strand (right). Scale for 49 & 50 above 1; scale for 51 above 7; scale for 52 above 13.
FIGURES 53–56. Wood sections of *Pittosporum phyllareoides* (Carlquist 5135). 53. Transection, showing narrow diameter of most vessels. 54. Tangential section, showing large numbers of vessels (pale areas). 55. Tangential section; crystals abundant in wings of rays. 56. Large crystal encapsulated by sclereid wall which contains smaller crystals, from radial section. Scale for 53 & 54 above 1; scale for 55 above 13; scale for 56 above 7.
Figures 57–60. Wood sections of *Pittosporum pentandrum* (FPAw-610). 57. Transection; vessels are notably large. 58. Tangential section; rays are wide, tall, corresponding to arboreal habit of this species. 59. Subdivided crystal-bearing cells from ray wing of radial section. 60. Septate fibers from radial section; vestigial borders on pits (above). Scale for 57 & 58 above 1; scale for 59 & 60 above 7.
FIGURES 61–64. Pittosporum tobira (cult. Claremont, coll. Carlquist, s.n.). 61. Transection; growth ring activity and diagonal banding of vessels evident. 62. Tangential section; large group of vessels in right third of photograph. 63. Vessels from radial section, showing helical sculpture. 64. Portion of ray from radial section; crystalliferous cells are scattered variously in ray. Scale for 61 & 62 above 1; scale for 63 & 64 above 7.
FIGURES 65–68. Wood sections of Pittosporum rhytidocarpum and P. undulatum. 65–67. *P. rhytidocarpum* (USw-4582). 65. Transection, showing wide, mostly solitary vessels. 66. Tangential section; vessels bulk large in proportion to fibers. 67. Fiber-tracheids from radial section; vestigial borders evident on pits, center. 68. *P. undulatum* (cult. Claremont, coll. Carlquist s.n.). Ray cells from radial section; air-filled cell, above, demonstrates bordered nature of pits; portion of crystal, below, reveals the numerous pervasive fractures crystals in this wood have. Scale for 65 & 66 above 1; scale for 67 & 68 above 7.
Figures 73-78. Wood sections of Hawaiian and African species of *Pittosporum*. 73. *P. gayanum* (Stern & Carlquist 1239). Transection, showing narrowness of vessels. 74-76. *P. napaliense* (Stern & Carlquist 1344). 74. Transection; vessels wider. 75 & 76. Crystals encapsulated as sclereids in ray cells from radial sections. 75. A single crystal in a cell otherwise entirely composed of cell wall. 76. Large crystal contained in a wall, smaller crystals in outer parts of cell. 77 & 78. *P. viridiflorum* (Carlquist 4998). 77. Transection, showing various types of vessel grouping. 78. Transection of stem; druse from pith cell. Scale for 73, 74, & 77 above 1; scale for 75, 76, & 78 above 7.
Hamamelidaceae (Carlquist, 1980a). Modes of crystal occurrence are not the most important characters for phyletic analysis, but they do have the advantage of being unrelated to level of evolutionary advancement, which produces parallel evolution of anatomical features (e.g., simple perforation plates evolving from scalariform perforation plates). Wood anatomy of Pittosporaceae yields characters which tend to indicate relationship with rosoid families somewhat more than with umbellalean families, but not overwhelmingly so. Other characteristics will doubtless be more significant. For example, trichomes ought to be a very basic type of evidence. The illustrations of Schodde (1972) and Haas (1977) for trichomes of Pittosporaceae show types more reminiscent of rosoid families than of umbellalean families, if one can judge from the figures and descriptions of Metcalfe and Chalk (1950) for families of both groups.

LITERATURE CITED


CRONQUIST, A. 1968. The Evolution and Classification of Flowering Plants.


   and Chemistry of the Umbelliferae.
   817—827.
   547—557.
MCCULLIVRAY, D. J. 1975. Billardiera Sm. and Rhizidosporum F. Muell. (Pittosporaceae) in New South
   Wales. Telopecta 1: 55—57.
   106—114.
   2. 18a: 265—286.
SCHODDE, R. 1967. Contributions to Papuanese botany. III. Three new species of Pittosporum (Pittosporaceae)
SCHÜRHOFF, P. N. 1929. Über die systematische Stellung der Pittosporaceae. Beitr. Biol. Pflanzen 17:
   72—86.
   2 vols.
STEINIS, C. G. G. J. VAN, and M. M. J. VAN BALGOOV. 1966. Pacific plant areas. 2. Blumea Suppl. 5:
   1—312.
   383—385.
WEBER, I. E. 1936. The woods of sclerophyllous and desert shrubs and desert plants of California. Amer. J.
   Bot. 23: 181—188.
OTHER PUBLICATIONS OF THE GARDEN

THE BULLETIN. A non-technical quarterly dealing with news of the Garden as well as topics of general botanical or horticultural interest. Sent free to members of the Garden.

MEMOIR 1. List and Summary of the Flowering Plants in the Hawaiian Islands. Harold St. John. 519 pp. 1973. A list of all native and introduced seed plants in Hawaii, including indications of which species are endemic or indigenous, their ranges, and origins of introduced species. The remaining copies have been damaged in a flood and prices vary from $5.00 to $13.00 according to condition.


HAWAII: A NATURAL HISTORY, SECOND EDITION. Sherwin Carlquist. xii + 484 pp. 924 photographs, including 53 in color, and many line drawings. 1980. A reprint of the 1970 book on Hawaiian plants and animals, emphasizing biological principles, with new updating material and a supplementary bibliography prepared by the author. $19.95.


COASTAL FLOWERS OF THE TROPICAL PACIFIC. W. Arthur Whistler. 84 pp., with 80 color photographs and map. 1980. Descriptions of the common and widespread coastal species of Polynesia, with comments on their scientific and vernacular names and habitats. $4.95.

LIMU: AN ETHNOBOTANICAL STUDY OF SOME HAWAIIAN SEAWEEDS. Isabella Abbott & E. H. Williamson. 21 pp., 14 figs. An illustrated guide to the commonly used seaweeds, discussing their identification, distribution, common names, methods of preparation, and uses by various ethnic groups living in Hawaii. $1.00.

BOTANICAL GUIDE NUMBER 1: THE AWAAWAPUHI TRAIL, KOKEE, KAUAI. Derral Herbst. A guide to conspicuous and interesting plants along one of the hiking trails in Kauai's Kokee area. $1.00.

Orders may be placed by writing the PUBLICATIONS SECRETARY.

PUBLICATIONS OF NA LIMA KOKUA

(The Helping Hands of the Pacific Tropical Botanical Garden)

BREADFRUIT (ULU): USES AND RECIPES. The first of a series on the edible plants of the Hawaiian Islands; a discussion of the ethnomobotany of the breadfruit and many recipes. $2.00.

TARO (KALO): USES AND RECIPES. The second in the series on the edible plants of the Hawaiian Islands; a discussion of the ethnomobotany of taro and many recipes. $2.00.

COCONUT (NIU): USES AND RECIPES. The third in the series on the edible plants of the Hawaiian Islands; a discussion of the ethnomobotany of the coconut and many recipes. $2.00.

SINCLAIR PLATES ON NOTEPAPER. One dozen sheets of notepaper, with envelopes, three each of IEIE, HAU, OHIA LEHUA, and NONI. $3.25 per package.

Orders may be placed by writing:

Na Lima Kokua
Pacific Tropical Botanical Garden
P.O. Box 340
Lawai, Kauai, Hawaii 96765
THE PACIFIC TROPICAL BOTANICAL GARDEN

was chartered by Act of Congress on August 19, 1964, to form a non-profit corporation with these purposes:

(a) to establish, develop, operate, and maintain for the benefit of the people of the United States an educational and scientific center in the form of a tropical botanical garden or gardens, together with such facilities as libraries, herbaria, laboratories, and museums which are appropriate and necessary for encouraging and conducting research in basic and applied tropical botany;

(b) to foster and encourage fundamental research with respect to tropical plant life and to encourage research and study of the uses of tropical flora in agriculture, forestry, horticulture, medicine, and other sciences;

(c) to disseminate through publications and other media the knowledge acquired at the gardens relative to basic and applied tropical botany;

(d) to collect and cultivate tropical flora of every nature and origin and to preserve for the people of the United States species of tropical plant life threatened with extinction;

(e) to provide a beneficial facility which will contribute to the education, instruction, and recreation of the people of the United States.

Mateo Lettunich
President

Michael J. Shea
General Counsel

William L. Theobald
Director

The Garden is guided by a distinguished Board of Trustees and an International Scientific Advisory Committee. Membership is open to all and is available in several categories of permanent and annual types. As a member you support the Pacific Tropical Botanical Garden's developing programs in botany and horticulture. Members have special visiting privileges and are entitled to discounts on certain Garden publications. For detailed information write to:

The Membership Chairman
Pacific Tropical Botanical Garden
1270 Avenue of the Americas
New York, N.Y. 10020