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### THE SECONDARY XYLEM OF HAWAIIAN TREES

BY

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IN A SOMEWHAT DIFFERENT FORM "THE SECONDARY XYLEM OF HAWAIIAN TREES" WAS SUBMITTED TO THE GRADUATE FACULTY OF YALE UNIVERSITY IN 1918 AS PART FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY.

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# The Secondary Xylem of Hawaiian Trees

BY FOREST BUFFEN HARKNESS BROWN<sup>1</sup>

## INTRODUCTION

On account of isolation in the Pacific, Hawaii has afforded exceptional opportunity for the origin and development of an endemic flora, the elements of which appear to have been contributed at different geologic periods from widely different sources. As early as 1888, a general knowledge of the flora was made available by the publication of Hillebrand's "Flora of the Hawaiian Islands" (9).

But while the floral characters were thus made known by Hillebrand and by later writers, the anatomy of the woody plants has remained to a large extent unknown. There has consequently been insufficient data by which Hawaiian woods could be classified or identified with certainty. Late in the year 1914 the Yale Forest School received from R. S. Hosmer a collection of 71 Hawaiian indigenous woods. At the suggestion of Professor Record, a morphological study of the woods of this collection was undertaken by the writer in the fall of 1916. Stained sections and macerations of each of the samples were made, and 400 slides prepared, including one complete collection for the Osborn Botanical Laboratory. New methods of technique have been elaborated; a new classification and terminology relating to vascular tissues devised, and a key has been worked out to aid in the identification of unknown Hawaiian woods.

The writer expresses indebtedness to Professor Record for many kind suggestions and criticisms in directing the work; to Professor Alexander W. Evans for criticism in the treatment of many of the difficult anatomical problems involved, and for the loan of publications; to Dr. George E. Nichols and Dr. H. N. Whitford for suggestions in the treatment of ecological problems; to Dr. G.

<sup>1</sup> While this paper was being printed, Mr. Brown was absent in the Marquesas as a member of the Bayard Dominick Expedition. The editor has assumed responsibility for minor revision and for proof reading.

R. Wieland and Professor Charles Schuchert for their interest and aid in the treatment of the paleobotanical and geological phases of the problem.

#### PHYSICAL FEATURES AND CLIMATE OF HAWAII

Hawaii embraces a group of islands in the central Pacific Ocean in a nearly linear northeast-to-southwest series between  $18^{\circ} 55'$  and  $22^{\circ} 15'$  north latitude and between  $154^{\circ} 54'$  and  $160^{\circ} 30'$  west longitude. No other group of oceanic islands is so isolated. The distance from Hawaii to the nearest high islands is more than 1,800 miles, and 2,000 miles of water separate the islands from California, the nearest continental land. Another insular factor is the prevailing direction of the North Pacific Drift Current, which in this region flows from northeast to southwest nearly at right angles to the axis of the group and hence courses between the several islands in such a manner as not readily to transport drift material from one island to the next. However, drift material may be transported directly from the shores of Canada and north-west United States, or, indirectly, by the combined effects of the southwest winds and the equatorial ocean currents, from other portions of the American continent.

According to the latest statistics of the United States Geological Survey there are nine islands in the group with an aggregate area of 6,406 square miles, an estimate which does not include the thousands of islets in the Hawaiian Bird Reservation. The island of Hawaii, with an area of over 63 per cent of that of the group, is slightly smaller than the State of Connecticut. In order of position west from Greenwich the inhabited islands are Hawaii, Maui, Molokai, Lanai, Oahu, Kauai, Niihau, and Midway.

The islands are dissected volcanoes with altitudes of nearly 14,000 feet, reaching above the snow line, and have therefore a highly varied mountain climate not possessed, to the same degree, by any other of the Pacific islands.

Associated with the mountainous topography, extreme variations in precipitation and humidity occur within a few miles. The northeast trade winds, which blow almost continuously, are cooled in their upward course over the mountain and precipitate a large

part of their moisture on the northeast (windward) side of the islands. The corresponding leeward side receives, in consequence, a less amount of rain. For example, the windward side of Kauai receives, in places, as much as 500 inches annual precipitation, and hence a bog flora is developed. On the leeward side of this island, less than 21 inches of rainfall was recorded for the same period; here the relative humidity is less, and the vegetation correspondingly xerophytic.

Rainfall increases with elevation from the coast to about 4,000 or 5,000 feet altitude, and decreases from this point upward. Summits of 10,000–14,000 feet receive very little rainfall. In the cloud belt, 2,000–8,000 feet, the annual rainfall is seldom less than 200 inches, giving a rainy zone in which the native forest reaches its best development.

The distribution of rainfall throughout the year may be nearly uniform, as in the belts of incessant rain of the bog areas, or may show a seasonal variation, corresponding to a more or less pronounced rainy (winter) season and a correspondingly dry (summer) season. In some portions, as on the coastal plain of Honolulu, such seasonal variations in precipitation are well marked and probably correlated with the formation of growth-rings in woody stems. In other portions, as on Mount Tantalus, Oahu (2,018 feet), the precipitation is greater and more evenly distributed throughout the year, and is apparently without seasonal variation sufficient to cause the formation of structural growth-rings.

The relative humidity is low in comparison with other Pacific islands, being about 75 per cent at Honolulu. It is less on the leeward side than on the windward side. In the cloud belt it is high and may reach a nearly continuous saturation, as in the bog areas. On the high summits above the cloud belts, the air is clear, the insolation intense, and the relative humidity about 50 per cent.

The mean annual temperature of Hawaii is about 70° F., and there is a fall of about 3° F. for each 1,000 feet of elevation. The estimated mean annual temperature of the zone in which the best forest growth occurs, 4,000–6,000 feet elevation, is therefore between 63° F. and 57° F. On the high summits snow falls in winter, and the night temperature drops below freezing throughout

the year. While variations of more than 30° F. may occur between night and day temperatures, marked seasonal variation in temperature is lacking. The mean winter temperature may be only 5° lower than the mean summer temperature, a difference probably too small to exercise any appreciable influence on plant growth.

The light intensity is greatly reduced by the presence of clouds, fog, misty precipitation, or rain, and it is probably because of the low light intensity thus caused that the slow growth and low stature of the Hawaiian trees are chiefly due. (See p. 218.)

Edaphic conditions independent of topography are apparently more uniform than any other environmental conditions. The soil throughout Hawaii is mainly derived from the decomposition of basaltic rock; it is claylike and generally pervious to water. Coral sand is formed at the beach, and dunes of coral sand are formed in places. Physico-chemical factors are therefore comparatively constant, except in the narrow littoral zones where calcium carbonate originating from coral is present, together with sodium chloride and other material from the ocean. It is also possible that sea salts are carried inland by the winds to moderately high levels.

## FLORISTIC COMPOSITION AND AFFINITIES

### ENDEMISM

The wide range of conditions prevailing more or less over each island, together with the extreme isolation of the group, has been favorable for the development of a varied flora richer in endemic species (9, p. xv) than that of any other land. Numerous groups composed of closely related (endemic) species are present, the lineal descendants, in all probability, of a single ancestral immigrant. But the groups are only distantly related, and constitute a heterogeneous whole. Probably the factor which is responsible for the heterogeneity of the groups is the number of sources and climates from which the flora has been derived. Hillebrand (9, p. xvii) recorded a total of 705 species of angiosperms, of which 574, or 81 per cent, are endemic. Guppy (6, p. 232) later places the number of endemic species at 546, and the indigenous at 686, or 80 per cent endemic. Of the 216 species of indigenous trees recorded by Rock (18), 93 per cent are endemic.

Wallace, observing the high endemism in the fauna and flora of Hawaii, assumed a great antiquity both for the age of the flora and for the age of the islands. We find the words: "These facts undoubtedly indicate an immense antiquity for this group of islands, or the vicinity of some very ancient land (now submerged) from which some portion of their peculiar fauna might be derived" (23, p. 326). Hillebrand (9, p. xviii), believed the difference in endemism in the islands might be related to the progressive age of the Hawaiian islands in order from east to west. Sinnott and Bailey (20, pp. 574-575) remark: "Such a high degree of endemism seems clearly to imply great antiquity." But Guppy (6, p. 248) says: "This great preponderance of peculiar [endemic] species and genera in Hawaii is not to be connected with the relative antiquity of the group, but with its degree of isolation." Guppy uses the term ancient in this connection in the same sense that the endemic forms of Hawaii are relatively older than those which are nonendemic; or, in other words, the endemic element indicates, primarily, what forms came first and have therefore been longest on the Islands. His meaning is clear, where, speaking of endemic genera (6, p. 261) he says: ". . . on one point there can be but little danger of going astray, namely, in imputing to them a high antiquity in the floral history of Hawaii."

The evidence gathered in the microscopic examination of Hawaiian woods, especially in the size of the vessels, likewise points to a great antiquity. The vessels of all the species belonging to the endemic series are of exceptionally small size (average of 71 species,  $0.13\ \mu$  in diameter), rarely exceeding  $0.15\ \text{mm.}$  in diameter, or less than one-third that often exceeded by vessels in such temperate continental types as *Quercus rubra*. The vessels of many continental tropical or subtropical woods, such as *Eucalyptus*, often exceed this size. Introduced species, such as *Terminalia catappa*, have comparatively large vessels; and even the species of evidently recent geological acquisition, such as *Rhus semi-alata* var. *sandwicensis*, have likewise large vessels. It would therefore seem as if smallness in the size of vessels has been the result of a slow evolution in response to a generally humid climate in which transpiration is relatively slow.

Furthermore, Hillebrand has shown that there are no gymnosperms of any kind upon the islands and observes (9, p. xxx): "Absence of gymnosperms militates for the view that the islands were formed subsequent to the age in which these were universally distributed." Since the green cones of all species examined by the writer sink in water, and since the seed is ill adapted to resist the effect of sea water, it is more probable that these plants are not adapted for dispersal over long stretches of ocean.

When the age and affinities of the species and genera are considered, the flora of Hawaii is found to consist of at least two main groups, very distinct from one another. The first and evidently the most ancient group, consisting of endemic or near endemic genera with well-differentiated species, and comprising 322 species or nearly one-half of the total indigenous flora, seems to be entirely an American derivative. The second and next in point of age, consisting of species belonging to nonendemic genera, is partly American, but mainly Malayan or Australasian. The third and last, the most recent group, consisting of nonendemic genera, is predominantly Malaysian or Australasian.

#### THE AMERICAN ELEMENT

The first group, representing the American component, is plainly the most ancient, since it consists of endemic genera with well-differentiated species. It is characterized by Compositae and Lobelioideae, which alone are represented by 109 species, nearly all of which are woody. There are no other plant families with so many representatives. Of these two, the Compositae stand first. All of the endemic genera of this family typified by *Dubautia* and *Raillardia*, show American affinities centering largely about Central America. One genus, *Hesperomannia*, is of particular interest, for it shows a Brazilian affinity. Concerning the Lobelioideae, all of which are woody, Drake del Castillo (6, p. 254) is quoted: "These plants connect Hawaii with America just as the Goodeniaceae link the same group [Hawaii] with Australia. This is what we might have expected, since the center of the order is in America principally in the Mexican and Andine regions." The main endemic, or near endemic, genera of trees belonging to this



group, and contemporaneous with the Compositae, are *Dubautia*, *Raillardia*, *Hesperomannia*, *Clermontia*, *Cyanea*, *Platydesma*, *Nothocestrum*, and *Charpentiera*. *Nothocestrum* (Solanaceae), with its four endemic arboreal species, is of particular interest, for it is believed (18, p. 417) to be most closely related to the Brazilian genus *Athenaea*, a genus with 14 species peculiar to Brazil. The evidence is supported by the fact that the center of distribution of the Solanaceae is in Central and South America. We have thus a second instance in which Brazilian affinities are plainly indicated.

The next group, with 103 species, evidently represents a slightly later stage in the floral history of the islands and is made up of near endemic genera. Both American and Old World affinities are indicated, but the Old World affinities are doubtful. As with the first series, American affinities are mainly if not wholly represented. This group seemingly represents a transition stage between the first and last groups. The main genera of trees are *Pelea*, *Broussassia*, *Cheirodendron*, *Triplasandra*, *Pterotropia*, *Gouldia*, *Bobea*, *Straussia*, *Labordea*, and *Notrichium*.

In summary, the highly endemic element thus described, or the most characteristic portion of the Hawaiian flora, indicates, in all probability, the portion which was first to arrive on the Islands. It was derived largely from the South and Central American region, particularly from at or near the isthmian portion, though to some extent the Brazilian and Andine portions of South America, and possibly North America, are indicated. In the latter part of the period, as shown in the second group, Austro-Malayan plants begin to come in. It is of interest to note that while no trees of high commercial importance belong to this period, more than 91 per cent of the species (9, p. 574) are more or less woody. All are interior plants and many occur at high levels.

#### THE INDO-MALAYAN ELEMENT

The somewhat larger remaining portion of the Hawaiian flora, comprising approximately three-fifths of the whole, is evidently of comparatively recent origin, as indicated by the fact that though the species are largely endemic, the genera to which they belong

are represented by some species which occur outside the group, or the genera are nonendemic. In contrast to the earlier element, which was seen to be an American derivative, this latter element is largely Indo-Malayan or Australasian in its affinities, but in all probability these plants are of American origin. A somewhat larger portion of this element is composed of herbaceous species, but the commercially important timber trees all arrived in this period. A few of the trees, as *Sophora*, *Myoporum*, and *Cyathodes*, occur at high elevations, but the majority, such as *Pittosporum*, *Sapindus*, *Reynoldsia*, *Gardenia*, *Psychotria*, *Phyllanthus*, *Elaeocarpus*, *Dodonea*, *Metrosideros*, *Alphitonia*, *Pisonia*, and *Acacia*, are more characteristic of the lower levels.

#### AGENCIES OF DISPERSAL

The double affinity—American and Indo-Malayan—indicated in the flora of Hawaii is perplexing and presents a problem which, up to the present, seems not to have been solved, though the possibilities of agencies of dispersal, such as winds, birds, and ocean currents, have been considered in detail.

Wallace considers that winds may have played an important part in the transfer of seeds—an idea supported by the known distances to which small particles like volcanic dust have been carried by the winds. But a large number of the seeds of the early Hawaiian flora, such as the berries of the *Lobelioideae*, seem unsuited to be transported long distances by this means. Furthermore, the winds, because of their prevailing direction, would, if effective, seem likely to bring seeds from near the Canadian portion of the North American continent—a section scarcely represented in the Hawaiian flora.

Wallace (23, p. 325) mentions two local elevations in the ocean bed between San Francisco and Hawaii which may mark the past location of two small islands which served as a "stepping stone" from the American continent. The main difficulties of such an assumption lie in the fact that it is hard to conceive of any agencies that would be likely to transfer life from such places as Mexico, Central America, and especially Brazil, to such a station as would be demanded by the floral affinities. Even granting such

a possibility, additional difficulties are encountered in explaining how such forms would then reach Hawaii to the exclusion of others.

Pilsbry (16, p. 431) cannot escape the conviction of the past existence of a land connection to the continent, to account for the presence of certain families of snails in Hawaii and other Pacific islands. The fact that the contour of the Pacific Ocean bed discloses only a series of mid-oceanic ridges running northwest-southeast—in just the opposite direction from that of the adjacent continents, Asia and Australia, and that between those ridges occur great ocean depths precludes any possibility of there ever having been such a land connection.

Guppy (7, p. 250) disagrees with Wallace with respect to the effectiveness of air currents in seed transportation. He observes: "I am not inclined to think that, except as regards the spores of Cryptogams, winds have done very much for Hawaii." He emphasizes the probable agency of birds and indicates the very numerous means by which seeds may become fastened to their plumage or feet, in addition to passing unharmed through the digestive tract.

Among the difficulties occurs the fact that, as in the case of the winds, such agencies fail to account for the development of numerous endemic forms, and it becomes necessary to make a second assumption, as is done by Guppy (6, p. 263), where he explains that the means which enabled such agencies to be effective in the transport of seeds to the islands were suppressed upon arrival. Thus seeds which possessed hooks or barbs at time of transportation gave rise to species with barbless seeds; similarly, thick-coated seeds, which would pass unharmed through the digestive tract, gave rise to thin-coated seeds; and so on. The almost visionary character of such reasoning merely demonstrates the greatness of the difficulty which naturalists, from Wallace's time to the present, have encountered in explaining the sequence of the eastern and western affinities of the Hawaiian fauna and flora.

Such birds as the plover, which occur also on the coast of North America, and the tropic bird *Phaëthon* have been mentioned in connection with the dispersal of species (18, p. xxx). But it is difficult to understand how such agencies could be very efficient in the dispersal of seeds over long distances, since such

birds prey upon fish and other animal food, as do practically all sea-going birds. Birds that make long flights arrive in a lean, fatigued condition, the digestive tract empty. Also, seed would need to be fastened with exceptional firmness to resist the long action of wind, and probably of rain and water, over the long stretch of ocean, not to mention the care which birds exercise in cleaning their plumage.

The probability of bird agency, then, in such long-distance transportation of seeds as from the American continent to the Hawaiian islands would seem to be slight, if not negligible.

The efficiency of ocean currents in the transportation of seeds has been variously estimated, both from experiment and from observed data (6, p. 66). The rate has been determined by bottles set adrift in a given current. Five miles a day seems a conservative estimate, though an average rate of as high as 40 miles a day for a distance of 1,000 miles was obtained in the main equatorial current off the Amazon estuary, in the direction of Trinidad. We shall see that this marked drifting toward Trinidad has an especial value in the explanation to be offered later on.

Guppy (6, p. 92) found that of 16 common cosmopolitan beach plants all had buoyant seeds, and all possessed structural specializations by means of which they could be transported in the equatorial current from west Africa to Brazil in a sound condition. Some seeds, as *Thespesia populnea*, can float a year in sea water without loss of germinative capacity. Many varieties seem adapted for long-distance transport, and if carried by such natural rafts as floating logs would, especially if kept reasonably dry, be likely to retain their germinating power for very long periods. Becquerel (1) found 20 specifically different kinds of seed which germinated 28 to 87 years from time of collecting. It is interesting to note, in this connection (5, p. 8), that 14 years after the destruction of all life on the volcanic island of Krakatau, 53 phanerogams had reached the island, from which it was estimated that 60 per cent had arrived by ocean currents, 32 per cent by wind agency, and only 4 per cent by fruit-eating animals or by man. From such data, ocean currents, as compared with other agencies, would

appear to be by far the most efficient agency in the dispersal of the seed-bearing plants.

The possibilities of birds, winds, ocean currents, "stepping stones," and land connections have been considered without success so far as arriving at any consistent solution of the problems involved in the origin of the Hawaiian forests. None of these agencies explains an early dispersal of plant life from the American continent to Hawaii, nor why such migration should practically cease, to be replaced by the later dispersal of life from Australo-Asiatic sources.

Ocean currents have been considered as, on the whole, the most probable agency, but the existing ocean streams which come in contact with the American continent afford no opportunity for species from the central and southern portion of the continent, especially Brazil, to be brought to Hawaii. Furthermore the fact that the westward dispersal of American plants was completed in some past geological epoch is obvious and also that an explanation calls for an understanding of past rather than of present conditions. The American elements in the Hawaiian flora could be accounted for on the assumption that at some previous time westward-moving currents had been brought in contact with isthmian and South American floras.

It was therefore gratifying to find geological evidence on which to base such an hypothesis. Professor Schuchert (19) has shown that in late Eocene and throughout Oligocene time both the Isthmus of Panama, including most of Central America, and the Isthmus of Tehuantepec were beneath the sea. The Caribbean Sea then united the Atlantic and Pacific oceans. Some time after the Oligocene, probably in late Miocene time, this portion of the continent emerged, closing both openings then and apparently forever since.

Such conditions furnish the data anticipated as necessary for the solution of the problems relating to the origin of the Hawaiian flora.

It is easy to see that the rapidly flowing Atlantic equatorial current, passing over the wide open Central America, would have carried drift into the Pacific in a wide, fan-shaped path toward

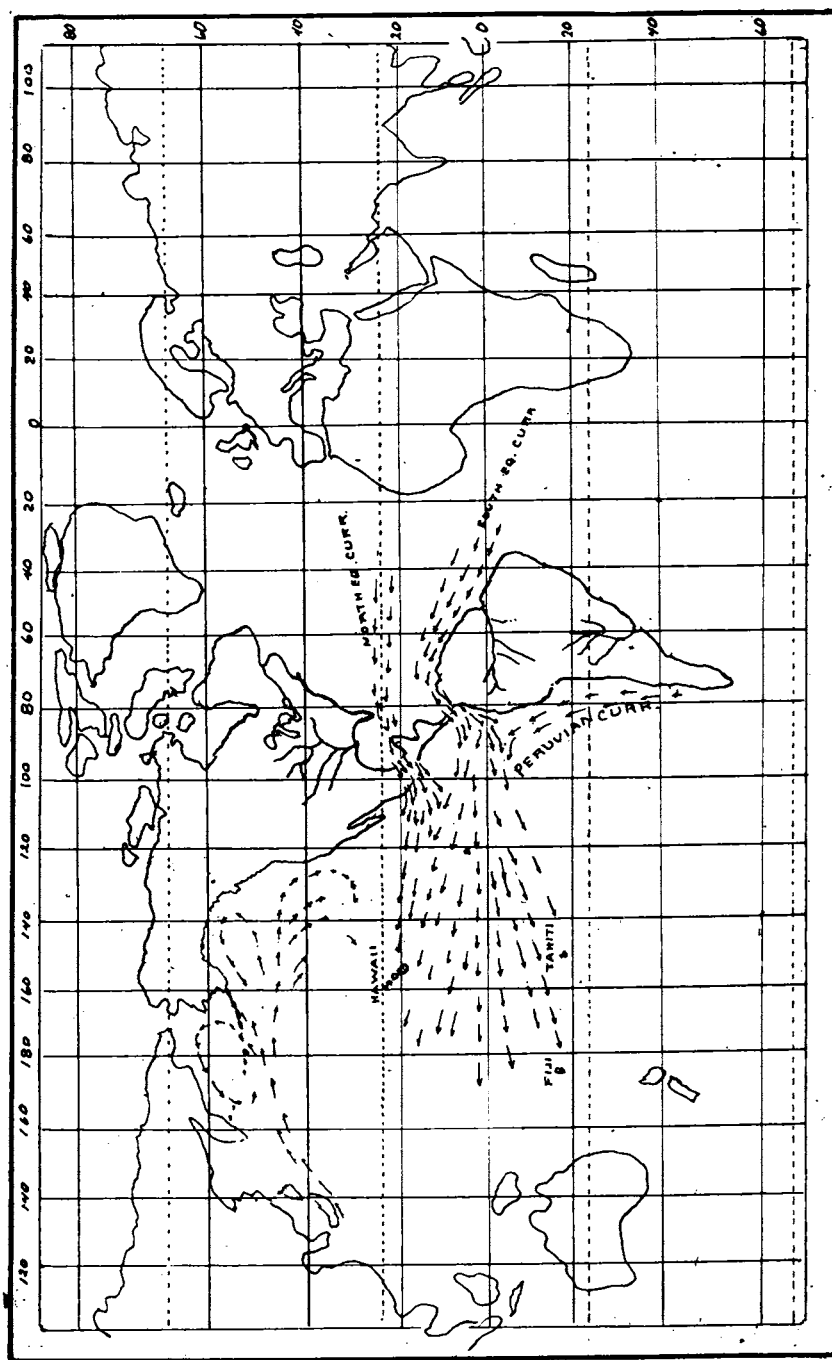


FIGURE 1. Chart showing probable floods and changed oceanic currents of late Eocene and early Oligocene times.

Hawaii and other Pacific islands. It is likely that the Pacific currents were so changed, possibly somewhat in the manner shown in figure 1, as to facilitate a direct transfer of material by ocean currents. The Amazonian drainage, flowing directly into the equatorial current, would contribute Brazilian drift. Assuming now that Hawaii had emerged in Middle Tertiary time—an assumption quite in keeping with the volcanic origin and high protuberance of the islands—it is difficult to conceive how such land would escape being colonized by American plants. Probably the coconut came in this period. Furthermore, it is plain to see why plant dispersal should have ceased with the permanent closing of both openings in the Oligocene. It is also apparent why in the following period, at the time of emergence of the smaller islands of the west Pacific, plant dispersal should have proceeded to the westward, the nearness of small islands affording a more direct path for animal agencies in that direction than could be found to the eastward. Probably birds were then the active agents, since the direction of both air and ocean currents would now seem comparatively unfavorable.

If 1,500,000 years be the least length of time of the Eogenic, then about 750,000 years may have passed during subsidence, and twice as long since then during the emergence of Central America. It is likely that the Central American lowlands were first flooded, during subsidence. With continued subsidence, the zone of the Lobelioideae would be reached possibly at the time the waters commenced to flow over the peninsula. The Lobelioideae, then, would be the first element to arrive on the Islands. This may explain the peculiar ancient appearance noted by Rock (18, p. 489) and others in the members of this tribe. The composites, occurring at higher levels, would follow the Lobelioideae. The two elements being the first to arrive upon the islands, or the most ancient in the floral history, the species have become most modified of all. They are hence represented by endemic genera, of which there are 158 species.

It is particularly interesting to note that at the first stage when plants begin to arrive from the west, the drupe appears for the first time in Hawaii. In this transition group there are 19 species

whose fruits are small drupes. All evidence strongly suggests the agency of birds as a leading factor in the dispersal of plants from the Old World. With the emergence of the Isthmus in late Miocene time, the Caribbean current would cease and so the drifting of seeds or seed-bearing material from the American continents. Hence but few American elements are present.

The final group, which is more recent as indicated by the absence of endemic genera, as well as the comparatively slight differentiation of its species, may be termed the post-emergence group. It followed the closing of the openings at the Isthmus, and has come largely from Indo-Malaysian sources. In all probability, the first two groups, particularly the first, arrived in comparatively short time. The third or more recent group probably made its appearance gradually, in keeping with the known slowness of animal agencies (7, p. 8), particularly over long distances of the ocean, and probably has been more or less continuous from the date of the emergence of the islands of the west Pacific up to the present time.

In the first group, it is probable that some forms arrived which are not endemic. The coconut palm has been placed in this group. It seems well substantiated that the coconut palm (*Cocos nucifera*) must have originated at or near the isthmian portion of the continent. Hillebrand (9, p. 452) quotes Martius, who places the original home of the coconut in the western border of the Isthmus of Panama. More recently, Cook (2, pp. 338-339) suggests the interior valleys and plateaus of the Andes in northwestern South America, since all other species of the genus *Cocos* are natives of this region.

But both Hillebrand (9, p. xvi) and Cook (2) suggest the agency of primitive man in its introduction. Cook asserts that the short-lived quality of the coconut seed (p. 326) and the inability of this palm to endure shade (p. 299) would make it impossible for it to establish itself on any coast, and states (p. 296) that the "coconut palm is not known to exist except as a cultivated plant on any tropical seacoast . . . (p. 297). We should find on some tropical coast a place where the palms thrive and multiply, where we find old palms surrounded by flourishing young ones, growing



spontaneously, without aid of man, but no such instance has been reported." Finally he adds (p. 349): "The theory that it has been disseminated by ocean currents is gratuitous, unproved, and improbable."

Unfortunately, each of the above statements which underlie Cook's whole hypothesis, and which seem insufficiently substantiated, is contradicted. Guppy (6, p. 435) personally observed the germination and development of the coconut palm from drift seeds on the Fiji coasts. Furthermore on the volcanic island of Krakatau (5, p. 30) the coconut appeared thirteen years after the destruction of all life on the island, on the shore, in the strand forest, and some distance inland. The plants of the interior forest were in full fruit, and seedlings, some a meter in height, were growing from the nuts which had fallen from the trees to the ground, so that a renewal of the forest was thus amply provided for. Thus Cook's statements seem to be without sufficient foundation.

Given the presence of the coconut in condition and climate where single trees produce as many as 200 seeds, within reach of the swift inundating currents of the Tertiary floods, the chances are highly probable that coconut fruits would be carried uninjured even as far as Hawaii. The great variation conceded for the coconut palm (2, p. 322), of which there are numerous varieties, would itself argue for a corresponding variation in seed vitality. Since available data and investigations are at present in disagreement upon this point (3, p. 923; 15, p. 325), the necessity for further investigation is apparent. Such experimental work should be extended sufficiently to include all the varieties, together with sufficient material of each to consider, as far possible, the numerous possibilities before such data can be regarded as conclusive. From present data, it may be stated as probable that, with such conditions as have been indicated for the Eogenic, the coconut was disseminated over the Pacific even as far as Hawaii.

Another plant which may have been established upon the islands during the period of submergence is *Batis maritima*, a monotypic species which, outside the Islands, is only recorded on the West Indies, the west coast of Mexico, and Lower California.

The evidence pointing to the altered condition of the oceanic streams is not confined to plants. Pilsbry (16, pp. 429-433) mentions the greatly specialized but primitive groups of land snails inhabiting the forests of Hawaii and other high islands in Polynesia. The westward extension of this fauna stops at the Fiji Islands. On the continents such groups were prevalent before the Eocene, but have now been almost entirely supplanted by the modern families of snails. At the same time, the modern families (*Helicidae*) are absent from the islands. Pilsbry remarks (p. 431): "If Pacific faunas were derived . . . from waifs drifted thither on 'natural rafts' or carried by birds from the continent, such migration must have stopped as an effective factor . . . before Tertiary times, for all dominant Tertiary snails of the continents are absent, as, with our present knowledge, they appear to be." He concludes that some land connection between the Pacific and the continent must have existed in the past in spite of the fact that it is "heterodox to doubt the absolute permanence of oceanic basins."

It is obvious that the same agency which transported the seeds of the early Hawaiian flora could have at an earlier date carried the land snails that inhabited the forests of that period. The Central American area was open in Lower Cretaceous-Jurassic times, and may account for an early transfer of snail fauna, though it is not apparent why the more modern families were not brought over in the Eocene. It is possible either that by further exploration the more modern groups of snails may yet be found, or that more complete evidence may enable one to determine more definitely the age of the floral elements. There seems no reason why the two lines of evidence may not be brought into agreement. Such data would seem to have particular bearing in suggesting the existence of drifting material, or "natural rafts," upon which seeds as well as snails would have been transported. Of added interest is a group of small land snails adapted to the conditions of and prevalent in the insular coconut groves, hiding under leaves and wood, to which they stick fast in dry weather. There are 800 species of them in the Hawaiian islands. Yet in spite of the fact that they "seem particularly adapted to flotsam,

. . . even they fail on the more outlying islands." Such facts would seem to relate the action of the Tertiary flood directly to the continental coconut forests.

In summary, the differences in endemism noted in the different elements of the Hawaiian forests are apparently related to the relative antiquity of such elements. The most ancient as well as characteristic component seems to have arrived in the Middle Tertiary, or even in earliest Cretaceous time, largely by way of the isthmian portions of the American continent, by agency of the trans-isthmian ocean currents prevailing at that period. Brazilian and Andine elements, contributed by the Atlantic equatorial and the Peruvian currents, respectively, arrived at the same time. Subsequently, commencing with the closing of the two gaps through the Isthmus, and the emergence of the islands in the west Pacific, plant dispersal through the agency either of birds or of oceanic currents, or both, began and came to predominate from the west—mainly from Australo- and Indo-Malaysian sources. The commercially important timber trees arrived during this last period.

An exceptionally large proportion of the Hawaiian plants, particularly those belonging to the early group, are woody. This may, at least in part, be the result of generally favorable conditions for forest growth, together with the absence of such destructive agencies as browsing reptiles and other wood-chewing animals. Another view has recently been advanced, namely, that the Hawaiian vegetation may be a relic of past conditions in which woody plants were universally more common than now (20, pp. 547-600).

## MATERIALS AND TECHNIQUE

### PREPARATION OF MATERIAL

By reason of the wide range of variation in hardness, and in mineral or resin-like contents of the different Hawaiian woods, it has been necessary to adopt special methods in the preparation of tissues for microscopic study.

Thomson's modification of the Jung-thoma sliding microtome with a Walb blade, 170 mm. in length and 35 mm. wide was used in sectioning. The knife was so sharpened as to give a

wedge-shaped edge, of which the two planes were inclined at an angle of 20 degrees to each other. Perfect axial alignment of the cutting edge was obtained, then the blade so inclined downward as to give an angle of 4 degrees between the section surface and the lower plane of the knife wedge. The knife carriage was so revolved as to give an angle of 7 degrees to the direction of movement, in order to secure the thinnest sections. Carefully prepared material could then be cut to a thinness of  $2\frac{1}{2}$  microns.

The wood was cut in blocks with a radial surface of 8 mm. vertical height, 2 cm. radial length, and 8 mm. of tangential thickness. Air was abstracted as far as possible from the cell-lumina by alternate boiling and cooling, together with the use of an Eimer and Amend aspirator, No. 3250.

? / The blocks were then placed in a paraffine cup and covered with strong hydrofluoric acid for a period varying from three weeks to six months, the time being determined by removing blocks at intervals of three weeks and testing with a sharp scalpel until they were sufficiently soft to cut well. No injury is done the tissues by remaining a long time in the acid, and strong acid always gives best results. The blocks were then washed in running water for four days to remove all acid, then covered with glycerine until wanted for sectioning. Cross sections were cut 0.01 to 0.015 mm. in thickness; radial sections, 0.008 to 0.02 mm.; the tangential, 0.007 to 0.008 mm. When cutting the blade was wet with 70 per cent alcohol. The sections were removed with a fine brush and transferred to water.

#### STAINING

After washing in at least three changes of water to remove glycerine, the sections were covered with 2.5 per cent solution of iron alum for five to twelve hours, then washed in running water for five minutes, then covered with 5 per cent aqueous solution of haematoxylin for twelve hours, then washed in water for three minutes, then covered with iron alum solution until the sections became light gray, then washed in running water for three hours, then stained in one-half alcoholic and one-half aqueous solution of safranin for two hours, then washed in 96 per cent alcohol, dehydrated, covered with xylol, then mounted in damar.

## INDEX OF REFRACTION OF MOUNTING MEDIA

Stained sections were found satisfactory for most of the work, but some of the minute details were obscured in staining—a process which depends for clearness mainly upon color contrasts. Minute pits, such as occur in some of the membrane-walls, are often not differentiated by color. It was found that if such tissues were left unstained and mounted in some clear medium whose index of refraction differed as much as possible from that of the membrane wall, the greatest minuteness of detail was obtained. The following media are arranged in order of their refractive properties:

(1) Water .....	index of refraction, 1.33
(2) Styra <sup>x</sup> .....	“ “ “ 1.38
(3) Glycerine .....	“ “ “ 1.46-1.47
(4) Damar, balsam .....	“ “ “ 1.52
(5) Balsam of Tolu .....	“ “ “ 1.628
(6) Mono-bromide of naphthol-naphtalene alpha mono-bromated .....	“ “ “ 1.65
(7) Tolu dissolved in naphtalene alpha mono-bromated .....	“ “ “ 1.7 ?
(8) Quinidine (melts above temperature of water) .....	“ “ “ 1.8 ?

Unstained sections of woody tissues mounted in glycerine and cemented with Brunswick black were found more satisfactory for many purposes than stained sections, particularly in observing the pitting of fibers and vessels.

## MACERATION

Many of the tropical woods contain resin-like, gumlike, or other substances in the ray-cells, vessels, and other elements, by reason of which details of pitting and other features are obscured. Macerations were found satisfactory in treating such woods, and the following method was adopted in their preparation. The pieces found most satisfactory were cut to expose a radial length of 2 cm., an axial length of 1 cm., and a thickness of 2 mm. These were first boiled in water for an hour, then allowed to stand and

cool. Alternate cooling and boiling periods were continued for at least five changes, then as much potassium chlorate was added as could be taken upon a small knife blade, then the pieces of wood were covered with 50 per cent nitric acid and heated to boiling. A water bath capable of receiving twenty test tubes was found especially convenient. After the pieces whitened and commenced to fray, cool water was added, causing the macerated material to settle, then changed to clear water and allowed to heat again to remove the acid. The material was then transferred to a watch glass and teased apart by a small-sized artist's bristle brush. The water was then removed by a pipette, changed several times, and the maceration covered with 96 per cent alcohol and allowed to stand thirty minutes, or until all air had been removed from the cell-lumina. The alcohol was then removed, the material covered with a 2 per cent solution of Bismarck brown in a 70 per cent alcohol, and allowed to stand for 12 to 24 hours. After washing for a short time in alcohol to remove excess stain, the macerated material was mounted in glycerine and cemented with Brunswick black. Such preparations were found to be of especial value in determining the details of vascular anatomy.

#### DESCRIPTIVE CLASSIFICATION OF PITS AND PERFORATIONS

Many of the terms applied to the pits of plant-cells, and in current use, are often confused or inaccurately or loosely applied. For example, the term "pit" has been defined as a structure peculiar to a single cell. An isolated tracheid, accordingly, is described as having pits. Consistently, the bordered structures communicating between tracheids should each be considered as made up of two pits, one belonging to each tracheid. In such connections terminology is seldom employed with the discrimination essential to clearness, and confusion has arisen. For example, the term "semi-bordered" or "half-bordered" is applied to the intercommunicating structures between vascular elements and parenchyma, where the pit-canal in the vascular element is bordered, while on the opposite side of the closing membrane the canal is open. Such terms are confusing if the double nature of such pits is accepted.

The restriction of the term "pit" to the intercommunicating structure between the two cells might seem justified from the fact that the closing membrane has, in an increasingly large number of wood specimens been shown to be perforate. Strands of protoplasm (21, p. 686), or "protoplasmic bridges," pass through such membranes, except, possibly, in gliding cells from one cell to another. Liquids, in passing through such structures, must enter at one orifice and pass out at the other. Thus the two orifices are functionally different. The action of one orifice is dependent upon the presence of the other, and ceases to function as soon as one is separated from the other; the two are thus a physiological whole. The so-called pits of isolated fibers, tracheids, vessels, and other elements, as in a maceration, are therefore the separated portions of pits for which the term "pit markings" is here employed.

But other pits, such as sensory pits and ray pits communicating with intercellular spaces, are peculiar to a single cell. A distinction must therefore be made between pits peculiar to a single cell and such pits as are common to more than one cell. Accordingly, the following classification of pits and perforations has been devised and used in the accompanying descriptions:

#### PITS

A pit is a modified portion of a cell-wall by means of which, or through which a cell is in communication with the exterior, or with an intercellular space, or with other cells. It is distinguished from a perforation by the presence of a closing membrane, which, however, may have, or possibly always has, minute perforations. They are of two main kinds: uniportal and biportal.

Uniportal pits have a single orifice. Such pits are peculiar to a single cell, i.e., are cell-pits, and are structures by means of which a cell is in communication with the exterior or with an intercellular space, but not with another cell. Examples are sensory pits, ray-pits communicating with intercellular spaces, and pits communicating with resin canals or secretory cavities.

Biportal pits have two orifices. Such pits communicate between cells—hence in a sense are tissue pits, and belong to three different classes, based upon the shape of the pit canals and orifices: (1) Simple pits, in which neither side is bordered—pits between

parenchyma cells are usually of this kind, (2) half-bordered or semi-bordered, and (3) bordered.

The half-bordered or semi-bordered pits, bordered upon one side only, are of four different kinds:

(a) Annular, in which the orifice of the bordered side, the closing membrane, and the orifice of the unbordered side, are approximately circular in outline. Pits between vessels and adjacent ray- or wood-parenchyma cells in *Platydesma campanulatum* are typical examples:

(b) Piceiform, in which the orifice on the bordered side is lenticular, while the closing membrane is circular, or nearly so, in outline. Pits between ray-parenchyma cells and adjacent tracheids of *Picea* and many of the nut-pines are typical.

(c) Long piceiform (piceiform pits with extended slits), in which the bordered aperture possesses a slitlike orifice extending beyond the closing membrane.

(d) Scalariform, in which both the orifice and the closing membrane are linear and parallel.

Bordered pits are those in which borders are formed on both sides of the closing membrane. Four main types are recognizable, based on the shape of the orifices and closing membrane.

(a) Annular, in which the orifices and closing membrane are circular in outline. Pits in the early-wood tracheids of *Pinus strobus* are of this kind.

(b) Taxiform, in which the orifices are lenticular, oblique, and crossed, while the closing membrane is circular, or nearly so, in outline. Pits in the early-wood tracheids of *Taxus* are mainly of this kind.

(c) Long taxiform, which resemble taxiform pits except that each orifice is extended beyond the closing membrane to form crossed slitlike orifices. Pits in the late-wood tracheids of *Taxus* are of this kind.

(d) Scalariform, in which the orifices and closing membranes are linear and parallel. Pits of this kind are present in the vessels of many of the Magnoliaceae.



## PERFORATIONS

Perforations are openings between cells and may be derived from pits by the dissolution of the closing membranes. Three main types may be distinguished:

(1) Sclariform perforations, in which parallel bars occur, as in the vessels of *Magnolia* and other primitive forms. Some of the bars may be branched, but not to an extent to destroy the parallel arrangement.

(2) Reticulate perforations, in which the bars are so branched that the parallel effect is destroyed. Perforations of this kind may be formed in the vessels of *Panax* or *Didymopanax*.

(3) Simple perforations, or porous perforations of Jeffrey (10, p. 99), in which a single large opening is present, as in the vessels of *Dubautia* and other specialized angiosperms.

Vessel-segments were found to terminate in three main ways:

(1) A segment may extend and continue the central cavity or lumen beyond the perforation into a tapering tracheid-like end, which may be inserted between adjacent tracheids or vessels or other elements with which intercommunicating pits are formed after the manner of a tracheid-end. Such projections have been described as tracheid-like. (These may be seen in *Straussia*.)

(2) A solid tonguelike projection may extend beyond the perforation, overlapping the next adjoining segment. Tonguelike projections are apparently derived from tracheid-like projections, and differ from the tracheid-like ends in not possessing a lumen and hence in having lost their physiological function. Such projections have been described as tongue-like.

(3) The segment may terminate abruptly at the plane of perforation, in which the termination is described as truncate.

## MONOCOTYLEDONEAE

## Order PANDANALES

## Family PANDANACEAE

The Pandanaceae are confined to the Tropics of the Old World, especially in the Malay region.

**Pandanus tectorius** Sol. HALA, PUHALA, LAUHALA, OR SCREW PINE. Material, lxv:32:1464.

*Pandanus odoratissimus* L.

Pandanus is a small littoral or lowland tree 20 feet high, abundant on the windward side of the islands of Hawaii, from sea level to 1,000 feet: distributed from Hawaii to Arabia. The leaves were woven into mats. The wood is hard, fibrous, brittle, light yellow, with dark fibro-vascular bundles. Growth is endogenous. No secondary xylem is formed.

## CROSS SECTION

*Gross.*—The fibro-vascular bundles are broadly crescent-shaped in outline; they become more numerous and composed in large part of sclerenchyma fibers toward the outer part of the stem.

*Minute.*—Two large vessels,  $0.12 \pm$  mm. in diameter, are found in each bundle. The walls are thin,  $0.002 \pm$  mm., and the lumina open. The sclerenchyma fibers of each bundle are  $0.009 \pm$  mm. in diameter, and exhibit marked concentric layers. Outside the bundles occur large sclerenchyma cells,  $0.09 \pm$  mm. in diameter, and nearly isodiametric, rarely elongated or branched. The ground tissue is composed of the rather thick-walled, finely pitted, nearly isodiametric cells  $0.015 \pm$  mm. in diameter.

## LONGITUDINAL SECTION

*Gross.*—The bundles are dark brown, fibrous, extremely hard and strong. The wood is hard, brittle, and difficult to cut or split.

*Minute* (maceration).—The vessels are composed of long segments, with scalariform perforations. The sclerenchyma fibers are  $2 \pm$  mm. in length.

## Order LILIIFLORAE

## Family LILIACEAE

The Liliaceae comprise about 2,450 species of general distribution. Only 5 genera with 8 species occur in Hawaii.

**Dracaena aurea** Mann. HALAPEFE. Material, vii:2.

This species is endemic to Hawaii and occurs throughout the group in dry situations at elevation of 1,000-2,000 feet. It reaches a height of 35 feet and a D. B. H. of 3 feet. In *Dracaena*, the growth is at first endogenous. After the stem reaches a certain diameter, usually a fraction of an inch, a cambium is formed and true secondary xylem is produced, composed of slightly thickened wood-parenchyma cells in which bundles of tracheids occur, each bundle of which contains one or two small central strands of phloem nearly enclosed by the tracheids. The secondary vesselless wood thus formed is light yellow in color, soft, of fine even texture, and without heartwood or growth-rings.

#### CROSS SECTION

*Gross.*—The tracheid bundles are broadly elliptical in outline with obtuse rounded ends; they are  $0.5\pm$  mm. in diameter, slightly darker in color than the surrounding tissue, numerous, and evenly distributed.

*Minute.*—There are no rays or growth rings. The fibro-tracheids are polygonal in outline,  $0.06\pm$  mm. in diameter, thick walled ( $0.012\pm$  mm.) and with rounded, often circular lumina. Bordered pits are present in all adjacent walls, and half-bordered pits communicate with adjacent parenchyma. The central phloem strand is not invariably completely surrounded by the tracheids. Generally a narrow strand of thin-walled cells joins the enclosed central phloems with the surrounding parenchyma. The parenchyma cells composing the tissue in which the tracheid bundles lie are generally four-sided, thin-walled,  $0.002\pm$  mm. in thickness, and possess numerous sub circular or elliptical, irregular pits  $0.004\pm$  mm. in diameter.

#### LONGITUDINAL SECTION

*Gross.*—The tangential and radial sections are very similar, the main difference consisting in the fact that the bundles appear slightly wider in the radial section. The wood is soft, easily cut, very fine and even in texture, and has little variation in color. The luster is dull. Under a lens, the parenchyma cells appear in seriation, especially on the radial surface.

*Minute.*—The tracheids bear circular bordered pits on their lateral walls,  $0.012$  mm. in diameter. The orifices are lenticular or slitlike, and generally vertical. At the overlapping tracheid ends, many perfect scalariform pits are present. The parenchyma cells are  $0.18\pm$  mm. in axial length, nearly four-sided, and in horizontal seriation, especially in the radial aspect.

#### MACERATION

The tracheids are  $5\pm$  mm. in length, and taper from near the middle to obtuse ends. The walls are thickest in the central portion of the

tracheid, and become gradually thinner toward each end. Circular pit markings with slitlike or lenticular orifices prevail in the walls except at the ends where scalariform pits are commonly present. No perforations were found.

#### DISTINGUISHING CHARACTERISTICS

The secondary wood is without vessels or rays, is whitish-yellow, soft, easily cut, of very fine even texture, and finely mottled on the cross section surface. The tangential and radial surfaces are nearly alike, and fine transverse lines are visible under a lens, especially on the radial surface. The tracheids are thick-walled and arranged in bundles with one or more central strands of phloem.

## DICOTYLEDONEAE

## Order URTICALES

## Family MORACEAE

The Moraceae are mainly trees or shrubs with latex, occurring largely in warm climates. The fig, mulberry, and breadfruit belong to this family. The wood is characterized by vessels of varying diameter, simple perforations, and bordered or simple pits. The rays are several cells broad. The wood-prosenchyma bears simple pits and may be septate.

**Artocarpus incisa** L. ULU, BREADFRUIT. Material, xl:31:1431.

The genus consists of about 40 species distributed from Ceylon to China. *Artocarpus incisa* is indigenous to the Sunda Islands and was introduced to other Pacific islands by primitive man. It does not produce seed. The tree reaches a height of 60 feet and a D. B. H. of 2 feet. The wood is light, soft, diffuse porous, with a broad zone of yellow sapwood and with a reddish-brown heartwood in large trees; without structural growth-rings; pith large, 0.5+ inch.

## CROSS SECTION

*Gross.*—The pores are visible without lens, mainly isolated, and without tyloses or other contents. The rays are much smaller than the pores, barely visible without lens.

*Minute.*—The vessels are large, sometimes over 0.3 mm. in diameter, most of them isolated and circular in outline, but some compactly grouped 2-3+ together; the walls are very thin (0.002 mm.). The rays are 1-3+ cells wide, thin-walled, and composed of radially elongated cells; the walls are minutely pitted. The wood-prosenchyma cells are in regular radial rows, are of large diameter, rounded in outline, and thin-walled, with large open lumina. The wood-parenchyma is mainly paratracheal, with lateral extensions from the radial walls of the vessels. The cell walls are thin and the diameter of the cells nearly the same as that of the fibers.

## RADIAL SECTION

*Gross.*—The surface has a silky luster. The rays and vessels are slightly dark colored and visible without a lens.

*Minute.*—The vessels are composed of short segments. The walls bear rather large, usually semibordered pits, with open lenticular or elliptical outlines. The pits in communication with the ray cells are often very narrowly semibordered and may be nearly simple. The rays are composed

mostly of radially elongated cells, but some axially elongated marginal cells are present. The pits communicating with prosenchyma are minute. Some communicating with vessels are rather large, semibordered, or nearly simple. Those communicating between ray cells are intermediate in size, sub-circular in outline, and not distinct. The prosenchyma cells bear indistinct slitlike simple pits, and here and there thin filmlike transverse membranes. The wood-parenchyma cells are long ( $0.15 \pm$  mm.) and of large diameter ( $0.04 \pm$  mm.).

#### TANGENTIAL SECTION

*Gross.*—The vessels are plainly visible without lens, and rather dark colored. The rays are small and visible with lens.

*Minute.*—The rays are narrowly elliptical in outline, rather obtusely pointed, 1-3 cells wide, and 1-25+ cells high. The cells are rather uniform in size and nearly circular in outline. Axially elongated cells are present in uniseriate rays and are sometimes seen at the margins of the wider rays.

#### MACERATION

The wood-prosenchyma is composed of thin-walled fibers, mostly cylindrical in the central portion, with long tapering ends. Pits are present in the cylindrical portion, but rather indistinct. The vessel segments are short, with transverse or only slightly oblique ends. The perforations are simple. The pit markings are generally lenticular, but somewhat variable in size and shape.

#### DISTINGUISHING CHARACTERS

Breadfruit wood is light, soft, of even texture, and without evident growth-rings or heartwood; the sapwood is yellow and the heartwood deep reddish-brown. The vessels are visible without lens, and are without tyloses or other contents, diffuse, mainly isolated; segments short with large simple perforations. The pits are rather large and mainly semibordered, but nearly simple pits occur. The rays are 1-3+ cells wide, visible in cross section with lens, and imperfectly heterogeneous. The fibers are arranged in radial rows, are of large diameter, thin-walled, with large open lumina. The wood-parenchyma is rather abundant, paratracheal, with extensions from the radial sides of the vessels.

#### Family URTICACEAE

The family comprises 500 species of plants mainly tropical, distributed over both Hemispheres. There are 41 genera, 9 of which occur in Hawaii. Two of these, *Neraudia* and *Touchardia*, are endemic. Two genera, *Pipturus* and *Urera*, have arborescent species.

**Pipturus gaudichaudianus** Wedd. MAMAKI OR MAMAKE.

*Pipturus albidus* G.

Material, cix:63:1482.

*Pipturus* is a shrub or small tree, in mesophytic habitats, at elevations of 1,500-4,000 feet. This species occurs also in Tahiti. A strong fiber is furnished by the bark, from which the Hawaiians made their tapa cloth. The wood is reddish-brown, soft, with a zone of sapwood in which the color gradually becomes lighter in shade or white. There are no distinct growth-rings.

## CROSS SECTION

*Gross.*—The pores are small, visible with lens, diffuse, isolated or in small groups. The rays are light brown, as a rule, slightly smaller than the vessels, and visible without a lens.

*Minute.*—The vessels are angular in outline, isolated or grouped 2-6+ together, mostly radially. The size is rather uniform,  $0.09 \pm$  mm. in diameter. The lumina contain tyloses. The walls are very thin,  $0.002 \pm$  mm. The rays are 1-4+ cells wide, and are composed of moderately elongated cells, with numerous rather small pits. The walls are thin. The cell cavities contain globules of resinlike material. The prosenchyma cells are large,  $0.04 \pm$  mm. in diameter, polygonal, thin-walled ( $0.004 \pm$  mm.), with large open rounded lumina, and are arranged in radial rows. Pits are fairly abundant in the radial walls. Wood-parenchyma is paratracheal; sparingly developed.

## RADIAL SECTION

*Gross.*—Rays and vessels are visible without lens, but not prominent. The luster is dull; the wood straight-grained, of fine and even texture, and easily cut.

*Minute.*—The vessels contain tyloses. The walls in mutual contact bear crowded hexagonal pits ( $0.12 \pm$  mm. in diameter). The walls in contact with rays bear large elliptical or irregular semibordered or simple pits. The segments are  $0.24 \pm$  mm. in length and bear circular perforations in the end-walls, many of which are of about one-half the diameter of the vessel. The rays are composed partly of cells moderately elongated radially. The marginal row or rows of cells may be greatly elongated axially. The uniseriate rows consist mainly of axially elongated cells. The cell cavities contain globules of resinlike material which partly obscure the numerous rather small pits in the walls. Large elliptical or irregular semibordered or simple pits are formed in contact with vessels. The prosenchyma cells bear numerous short slitlike simple pits in their radial walls; septae are present.

## TANGENTIAL SECTION

*Gross.*—The tangential surface is of fine, even texture. The vessels are visible with lens, but the rays are fine and indistinct even under magnification.

*Minute*.—The rays are narrowly elliptical, acutely or acuminate pointed, 1-3+ cells wide, and 1-30+ cells high. The cells are mainly sub-circular or broadly elliptical in outline, or elongated at the margins and in the uniseriate rays. The prosenchyma cells bear few pits in the tangential walls.

#### MACERATION

The fibers are short and of large diameter, cylindrical or prismatic in the central portion. The ends taper for about one-third the length of the fiber, and bear few pits. Forked ends are frequent.

#### DISTINGUISHING CHARACTERS

The wood is dull reddish-brown in color, becoming gradually lighter in shade in the sapwood, is soft, easily cut, of fine, even texture, and without growth-rings. The vessels are small, visible with lens, filled with tyloses, and bear in the end-wall a simple circular perforation often less than one-half the diameter of the vessel. The pits are bordered in the common walls, semibordered or simple in contact with rays. The rays are 1-3 cells wide and 1-30+ cells high, visible without a lens, heterogeneous. Wood-parenchyma is sparingly developed. The fibers are short, of large diameter, thin-walled, and arranged in radial rows.

### Order SANTALALES

#### Family SANTALACEAE

The Santalaceae consist of 250 species of herbs, shrubs, or trees distributed mainly in temperate continental climates or in tropical Polynesian or Australasian islands. Trees of the genus *Santalum* possess haustoria in connection with their roots by which they may become parasitic upon the roots of other trees. The wood is characterized by even texture, vessels with simple perforations, narrow rays, and fibers with bordered pits.

***Santalum freycinetianum*** Gaud. ILIAHI, SANDALWOOD. Material. c:—:1479.

Sandalwood is a medium-sized tree, reaching on the heights of Mauna Loa a height of 50 feet and a D. B. H. of 2 feet. It is variable, and has a number of distinct varieties. It was formerly common on all the islands of Hawaii, but the forests have been largely destroyed as sandalwood was one of the most valuable of Hawaiian woods. It thrives in dry regions, at elevations of 2,000-5,000 feet. The wood is whitish gray, of firm even texture, and medium hardness.

#### CROSS SECTION

*Gross*.—The pores are small, visible with lens, and isolated. The rays are smaller than the pores, visible with lens. Concentric rings are indicated by variation in color.



*Minute.*—The vessels are subcircular in outline, very uniform in diameter ( $0.07 \pm$  mm.), isolated, and thin-walled. The lumina are free from contents.

The rays are 1-2 cells wide, with brown resinlike contents. The prosenchyma cells are small, rather thick-walled, polygonal in outline with rounded lumina, and in no definite arrangement. Large bordered pits are present in all walls. The wood-parenchyma cells are larger than the fibers, diffuse, and contain resinlike globules or crystals of calcium oxalate. Some of the cells are very thick-walled ( $0.012 \pm$  mm.); the most are thin-walled.

#### RADIAL SECTION

*Gross.*—The surface is a dull, uniform whitish-yellow. Under a lens, beads of reddish resinlike material are visible, and to a less extent in the wood-parenchyma. The wood is cross-grained.

*Minute.*—The vessels bear circular, vertically arranged, bordered pits, with short lenticular orifices, or semibordered pits in contact with ray-cells. The perforations are simple and of nearly the same diameter as the vessel.

The rays are imperfectly heterogeneous, with radially elongated cells in all but the marginal row, in which the cells are comparatively higher and shorter. The radial walls bear mostly circular semibordered pits. The prosenchyma cells bear conspicuous circular-bordered pits with crossed lenticular orifices, and of the same diameter as the vessel pits. The wood-parenchyma cells are slightly elongated and contain resinlike globules. Other cells are short and contain crystals. Part of the short parenchyma cells are very thick-walled.

#### TANGENTIAL SECTION

*Gross.*—The rays are small and indistinct under a lens. The vessels are straight, free from contents.

*Minute.*—The rays are mainly 2 cells wide and as much as 20 cells high, or more. The fibers bear numerous large circular-bordered pits on the tangential walls.

#### MACERATION

The prosenchyma consists of rather thick-walled, crooked fibrotracheids of medium length, and small diameter, with circular-bordered pits throughout their length.

#### DISTINGUISHING CHARACTERS

The wood is dull whitish-yellow, of medium hardness, and cross-grained. The vessels are diffuse, without contents, small, circular, isolated; perforations simple; pits circular, in vertical rows. The rays are mostly 2 cells wide, up to 20 cells high, and imperfectly heterogeneous. The fibrotracheids bear conspicuous bordered pits, are medium thick-walled, and of small diameter. Wood-parenchyma is diffuse. Short, crystal-containing cells are present, and short, very thick-walled strands occur.

**Santalum ellipticum** Gaud. Material, xcix:x22:1478.

The structure and other characters are the same as the material used for *S. Freycinetianum*, except that the thick-walled, short wood-parenchyma are much less abundant.

**Santalum pyrarium** A. Gray. ILIAHI, SANDALWOOD. Material, xcvi:42:1476.

This is a tree that attains as much as 40 feet in height, endemic to Kauai. It grows at elevations of 3,000-4,000 feet, in dry leeward (or sometimes wet) situations. The wood is yellowish-brown, rather hard, becoming gradually light yellow in the sapwood. Growth-rings are present.

#### CROSS SECTION

*Gross.*—The vessels are small, visible with lens, isolated. The rays are visible with a lens, much smaller than the vessels. A reddish globular substance may be distinguished in the rays and in some of the vessels. The heartwood is impermeable to alcohol; sapwood permeable.

*Minute.*—The vessels are isolated, nearly circular in outline, nearly uniform in size,  $0.06 \pm$  mm. in diameter, thin-walled, and communicate with the surrounding prosenchyma by medium-sized bordered pits. There are no tyloses, but some of the lumina contain a yellowish or reddish resinlike substance, especially in the heartwood.

The rays are 1-2+ cells wide, thin-walled, and contain a resinlike substance. The pits are minute, and circular or lenticular in outline. The prosenchyma cells are polygonal in outline, rather small,  $0.02 \pm$  mm. in diameter, medium thick-walled ( $0.004 \pm$  mm.), and with rounded lumina often filled with resinlike material. Large bordered pits are present in all walls. Wood-parenchyma cells are few, diffuse, thin-walled, and contain resinlike material. Some of them contain large crystals.

#### RADIAL SECTION

*Gross.*—The surface has a waxy luster, and is of fine even texture. The rays are visible without lens, reddish in color, but not prominent. Few are more than 0.5 mm. in height. Under a lens, reddish cell contents are visible, and the vessels in the heartwood are visible with their lumina filled with bright reddish resinlike material.

*Minute.*—Cells, especially in the heartwood, contain a resinlike material in the cell cavities, which is colorless, yellowish, or deep reddish-brown. Many of the cells are in the form of wide or narrow bars. The vessels have large simple perforations, and not numerous circular-bordered pits with crossed lenticular orifices in vertical rows. The cells of the rays are mostly elongated radially, except the marginal cells, which are higher and shorter. The pits, which are small and circular or elliptical, are for the

most part obscured by the cell contents. But few crystal-bearing or thick-walled wood-parenchyma cells occur.

#### TANGENTIAL SECTION

*Gross.*—The rays are barely visible with a lens. The vessels, with their reddish contents, are visible in good light without lens, appearing as fine striations.

*Minute.*—The rays are 1-20+ cells high and 1-2+ cells broad. The cells are subcircular in outline, except at the margin, where in many specimens there is a cell elongated and obtusely pointed.

#### MACERATION

The prosenchyma is composed of thick-walled, usually crooked or bent, fibro-tracheids of medium length, small diameter, and pitted throughout. The vessel-segments are cylindrical and  $0.4 \pm$  mm. in length. The pit markings vary from lenticular to elliptical or circular in outline, and, except for those formed in contact with rays, are arranged in vertical rows.

#### DISTINGUISHING CHARACTERS

The wood is of medium hardness, color light brown, becoming gradually lighter in shade in the sapwood. Growth-rings are present. The vessels are diffuse, isolated, visible with lens, with resinlike contents, simple perforations and circular-bordered pits in vertical rows. The rays are 1-2 cells wide and 1-20+ cells high, imperfectly heterogeneous. Wood-parenchyma is diffuse, not abundant. The prosenchyma cells are of medium length, small diameter, and pitted throughout. It is distinguished from *S. freycinetianum* by the more abundant resinlike material in the cells, and the imperfect occurrence either of short crystal-parenchyma or of thick-walled wood-parenchyma.

#### Order CHENOPODIALES

#### Family AMARANTACEAE

The Amarantaceae include 40 genera with 655 species of general distribution. In Hawaii only five genera are represented, two of which, *Charpentiera* and *Nototrichium*, are endemic. The wood is characterized by vessels with simple perforations and prosenchyma with simple pits. Anomaly in the structure of the stem is recorded for many of the genera.

***Charpentiera obovata*** Gaud. PAPAPALA. Material, xiv:75:1420.

The tree grows 15 to 35 feet high, with a maximum diameter of 30 inches. It occurs in both rainy and dry forests, but especially in the dry, at elevations up to 4,000 feet. The wood is soft, fibrous, extremely light, grayish-yellow, with a very narrow zone of light-

colored sapwood. The seasoned wood is traversed by numerous fine longitudinal cavities. It is used for torches.

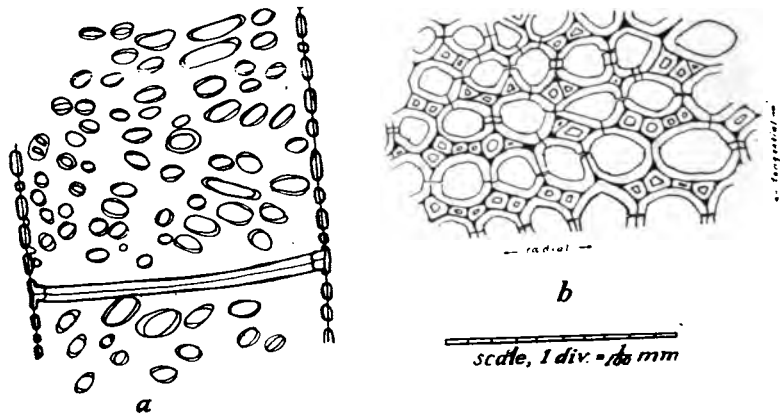


FIGURE 2. Sections of *Charpentiera obovata* wood: **a**, trachéa, showing perforation and semibordered pits varying to simple, formed in contact with parenchyma; **b**, cross section, showing arrangement of fibers.

#### CROSS SECTION

*Gross.*—The wood is traversed by numerous fine longitudinal cavities, zonately arranged and giving the appearance of growth-rings, though true growth-rings are absent. The rays are whitish, barely visible without lens. The pores are single or grouped compactly  $3\pm$  together, visible with lens.

*Minute.*—The vessels are scattered singly or grouped compactly  $3\pm$  together; where single, subcircular in outline; those in groups, variously compressed or flattened; average diameter, 0.15 mm.; walls very thin, 0.003 mm. thick; cavities without tyloses or other contents. Rays straight, broad as the vessels, composed of short thin-walled cells. Wood prosenchyma (fig. 2, **b**) composed of fibro-tracheids with wide lumina and presenting, by reason of their shape and serried arrangement, a regular pattern of radial rows of large open subcircular cavities alternating with rows of small cavities which correspond to the attenuate unpitted fiber points (fig. 3). The fiber point sections are of twice the number of the large cavities with pitted walls and are crowded between them at the angles or between their radial but not tangential walls. Wood-parenchyma occurs (1) in broad tangential bands; (2) surrounding the vessels and compressed. The cell walls are thin.

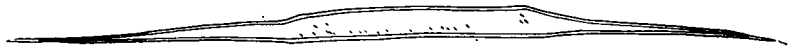


FIGURE 3. Drawing showing macerated fiber of *Charpentiera obovata* wood.

## RADIAL SECTION

*Gross.*—The rays are visible without lens and up to 3 mm. in height; vessels, visible under lens, light-colored.

*Minute.*—The elements are in serried arrangement. The vessel segments are short, cylindric, 0.24 mm. long, unconstricted, with simple perforations. Pits between vessels are bordered, or simple, or narrowly half-bordered between vessel and parenchyma. The bordered pits are subcircular, elliptical or crowded hexagonal, with large elliptical pit mouths. The simple and semibordered pits are numerous (fig. 2, *a*), large, generally elliptical, but very variable from greatly elongated to subcircular in outline. The wood fibers have numerous pits with oblique lenticular mouths. The rays are composed of nearly isodiametric, thin-walled cells, numerous pitted on all sides in mutual contact, with minute subcircular pits.

## TANGENTIAL SECTION

*Gross.*—The rays are difficult to distinguish, even with lens. The vessels are visible with lens.

*Minute.*—The rays are 1-5+ cells broad and up to 3 mm. in height, and composed of numerous cells, rather variable in size and shape, but not greatly elongated except where in contact with prosenchyma, where the ray cells appear to merge rather gradually into the prosenchyma. The prosenchyma cells are numerous pitted.

## MACERATION

The fibro-tracheids are cylindrical in the central portion and pitted on both radial and tangential sides. The long, attenuate ends are unpitted (fig. 3).

## DISTINGUISHING CHARACTERS

The wood is light yellow, extremely light and soft, and traversed, when seasoned, with numerous fine longitudinal cavities in zonal arrangement. The elements are in serried arrangement. The vessels are diffuse, solitary, or grouped  $3\pm$  together, visible with a lens, with simple perforations, and without tyloses. The rays are as broad as the vessels, homogeneous, up to 2 mm. high and up to 0.15 mm. broad. The cells are irregular in shape and size, but elongated only on the outer surface. The wood prosenchyma is composed of fibro-tracheids pitted in the central portion on all sides, but unpitted over the long attenuate ends. In cross-section they appear in peculiar radial arrangement. The wood-parenchyma is abundant, in broad tangential bands, and also in one or more rows surrounding the vessels.

**Nototrichium sandwichense** Hbd. KULUI. Material, xiii:76:1419.

The kului is a small tree common on all islands, 15 to 20 feet high, in the lower forest zone in very dry regions at 2,000-3,000 feet. The genus is endemic, comprising three species, of which the other two are shrubs. As with *Charpentiera*, this genus is allied to

Brazilian genera. The seasoned wood is rather hard, yellowish, fibrous, chambered by small longitudinal cavities in irregular arrangement (fig. 4, a).

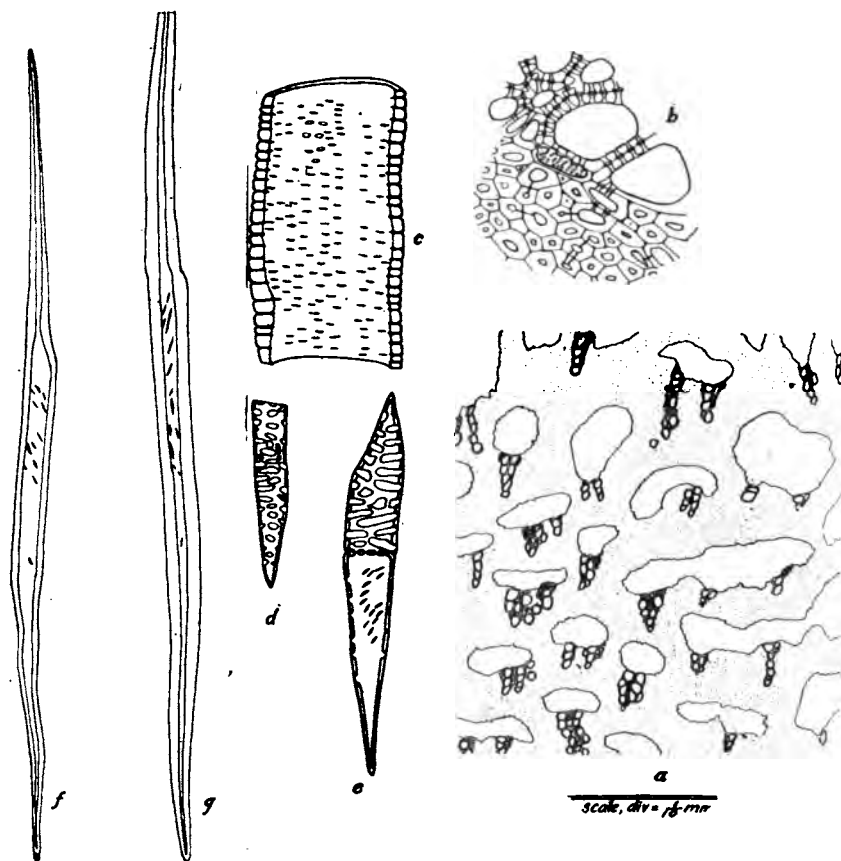


FIGURE 4. Sections of *Nototrichium sandwicense* wood: a, cross section, showing chambered cavities; b, cross section; c, tracheal segment from maceration; d, wood-parenchyma cell from maceration; e, wood-parenchyma strand from maceration; f, and g, typical fibers from maceration.

#### CROSS SECTION

*Gross*.—No growth-rings present. The cavities are uniform in outline, with vessels, visible under a lens, grouped at one side of the cavity. There are no medullary rays. (Cavities result from disintegration of interxylary phloem?)

*Minute*.—The vessels are grouped radially in the axial direction at one side of the cavities, 2-10+ together, or rarely isolated, variously compressed on one or more sides, and 0.015-0.09 mm. in diameter, unevenly thick-walled (0.009+ mm.); or rather thin-walled in the smaller vessels; no tyloses or other contents; pit-canals, very broad and widening, both outward toward the pit membrane and inward to form the long slitlike canal mouth; most tracheids, small in diameter and relatively thin-walled. Rays are absent.

Prosenchyma thick-walled (0.009 mm.), irregularly polygonal in outline, and  $0.027 \pm$  mm. in diameter. Wood-parenchyma incompletely vasicentric, limited in amount, very few containing crystals, thin-walled (fig. 4, b).

#### RADIAL SECTION

*Gross*.—Cavities  $0.3 \pm$  mm. in diameter, numerous, with nearly parallel sides; vessels minute, visible with lens; no rays.

*Minute*.—The vessel-segments are short, 0.16—mm. long, with numerous lenticular or slitlike pits narrowly bordered. Perforations simple, the plane of perforation as a rule transverse with slight inward projections; tracheids of smaller diameter, numerous.

Wood-parenchyma in single vertical strands of 2-4 cells together; the cells  $0.01 \pm$  mm. in length, pitted with numerous, generally elongated, elliptical pits, irregular in outline (figs. 4, D, and E). The terminal cell in a strand tapers to a point.

#### MACERATION

The fibers (figs. 4, f and g) with elongated, sharply pointed, some forked, unpitted ends, the central portion with numerous lenticular or slitlike pit markings on all sides. Tracheal segments are usually cylindrical (fig. 4, c) but often irregular.

#### DISTINGUISHING CHARACTERS

Wood with collateral secondary bundles distributed irregularly in a mass of thick-walled prosenchyma constituting slightly more than one-half of the volume of the stem. The phloem breaks down, leaving *small longitudinal cavities*; *no medullary rays* present. The vessels are minute, visible with lens, clustered at side of phloem (or cavities), without tyloses, and with simple perforations.

#### Family NYCTAGINACEAE

This family comprises about 155 species of herbs, shrubs, or trees in warm climates. In tropical America it is especially well represented. The four-o'clock belongs to this family.

The wood is distinctly different in structure from typical secondary xylem. It is composed of secondary collateral bundles

formed from successive zones of cambium which develop in the pericycle. The bundles thus appear in zonal or irregular order, isolated from one another and surrounded by conjunctive tissue, which may either be prosenchymatous, resembling wood-fibers, or parenchymatous. Thin radial strips of cells resembling medullary rays, may also occur. The secondary bundles consist of xylem and phloem. The xylem is characterized by vessels with simple perforations, prosenchyma with simple pits, and parenchyma. In many wood specimens thin-walled parenchyma—in some unligified—is present with the phloem. In *Pisonia*, the dry wood specimens are chambered longitudinally by cavities  $1 \pm$  mm. in breadth, resulting from the disintegration of thin-walled perishable tissue.

***Pisonia excelsa*** Blume PAPALA KEPAU.

*Pisonia umbellifera* (Forst.) Seem.

Material, xliii:1444 B5.

*Pisonia* is a tree 15 to 30 feet high at elevations of 200-1,600 feet. It is common on the windward wet sides of islands and occurs also in Australia, the Philippines, and Polynesia. The wood is soft and almost herbaceous in character. "Logs of this tree . . . collected for wood specimens, shriveled . . . like stems of banana plants. Trunks a foot in diameter can be felled with one stroke of the axe" (18, p. 145). The dry wood is chambered from the disintegration of the softer tissues to an extent that specimens fall to pieces. The remaining tissue consists of concentric lamellae which readily separate from one another. The wood is yellowish, extremely light, weak, and brittle, and contains a resinlike material which spreads over the surface.

CROSS SECTION

*Gross.*—The sound woody tissue is in perfect zonal arrangement, the lamellae being about 0.4 mm. in thickness and almost unconnected with each other. The vessels are small, visible with a lens, and either isolated or in contact. Rays are not visible with a lens.

*Minute.*—The vessels are mainly isolated and circular in outline. In some specimens two or more vessels are in contact and flattened. The diameter is rather uniform ( $0.09 \pm$  mm.); the walls, very thin (0.002—mm.). The prosenchyma cells are thin-walled, numerous and finely pitted, polygonal in outline, and in regular radial arrangement. Raylike strands are



present, but difficult to distinguish, short celled, as a rule one or two cells wide.

#### RADIAL SECTION

*Gross.*—The vessels are visible with lens. Raylike tissue is difficult to distinguish even with lens. The wood of the lamellae is very soft, easy to cut, and with a silky luster.

*Minute.*—The elements are serried. The vessels are composed of segments of nearly equal length (.02 mm.), with transverse ends. The perforations are simple and large, of nearly the same diameter as the vessel. The pits are  $0.009 \pm$  mm. in diameter, circular, elliptical or linear in outline, mainly semibordered, with transverse lenticular or long slitlike orifices. The lumina often contain a yellow resinlike material. The prosenchyma cells bear very numerous minute circular simple pits. Numerous needlelike raphides are present. Raylike bands of cells are present, commonly not more than three cells high, and composed of thin-walled isodiametric parenchyma.

#### TANGENTIAL SECTION

*Gross.*—The woody lamellae appear of very uniform texture, under a lens, the vessels being the only distinct structural character visible.

*Minute.*—The raylike strands are 1-2 cells wide and 1-3+ cells high.

#### MACERATION

The prosenchyma cells are very short,  $0.7+$  mm. in length, and of comparatively large diameter ( $0.09 \pm$  mm.). The central one-third portion is cylindrical and numerous pitted. The ends taper abruptly into a long and somewhat irregular, or forked, nearly unpitted portion. The walls are thin.

#### DISTINGUISHING CHARACTERS

The dry wood is composed of thin concentric lamellae, nearly loose from one another, light straw-yellow in color, and with a resinlike varnish which covers the surface, and appears in the vessels and other elements. The elements are serried. The vessels are visible with a lens, mostly isolated, very thin-walled, and with simple perforations. Raylike tissue is present in the form of bands 1-3 cells wide and 1-2 cells thick. Such ray-cells are isodiametric. The prosenchyma is very short, of large diameter, and thin-walled.

***Pisonia sandwicensis*** Hbd. AULU. Material, xlv:1445.

This species is endemic. It reaches a height of 60 feet, a diameter of 2 feet, and grows at elevations of about 2,000 feet in dry situations, in association with *Cryptocarya mannii*, *Xylosma*, *Osmanthus*, *Rauwolfia*, and *Scettonia lanaiensis*. The dry wood is grayish-yellow or blue by decay, with chambered spaces imperfectly zonal in arrangement, so that specimens do not readily separate into

thin lamellae. The tissue composing the true xylem is of sufficient hardness nearly to resist impression of the finger nail. The wood is extremely light and brittle, useless for most construction purposes. The surface, on drying, becomes coated with a resinlike varnish.

#### CROSS SECTION

*Gross.*—The vessels are small, visible with a lens, and appear mostly grouped radially or slightly tangentially. The rays are plainly visible with a lens. A reddish-yellow resinlike substance occurs in some of the vessels, and in the chambered cavities and other places.

*Minute.*—The vessels are rather closely grouped, mostly radially, but some extend tangentially, 2-15+ together, very variable in size up to 0.1+ mm. in diameter, with slightly thickened walls, and containing a yellowish resinlike substance, in some cases filling the lumina. The isolated vessels are circular. The grouped vessels are more or less compressed. The prosenchyma-cells are of medium diameter ( $0.024 \pm$  mm.), rounded in outline, slightly thick-walled, and with numerous simple pits on all sides and open lumina. The raylike strands are 1-2+ cells wide and the cells usually elongated radially. The walls are thin, numerous and very finely pitted; the cavities often contain a resinlike material.

#### RADIAL SECTION

*Gross.*—The narrow chambered spaces alternate with the more durable yellow or grayish xylem strands. Raylike bands are visible without lens, low ( $0.3 \pm$  mm.) and, under a lens, many are seen to contain a resinlike substance.

*Minute.*—The elements are indistinctly serried. The vessels bear circular or elliptical pits with mostly transverse lenticular or long slitlike orifices. The perforations are simple, of the same diameter of the vessel-lumen or smaller. The plane of perforation is transverse or slightly oblique. The ray-cells are mostly somewhat radially elongated, thin-walled, and numerous and finely pitted, or slightly coarsely pitted in contact with the vessels.

#### TANGENTIAL SECTION

*Gross.*—The vessels are visible without lens. The raylike strands are small and visible with lens.

*Minute.*—The ray-strands are 1-15+ cells high and 1-2+ cells wide. The cells are rounded in outline, and rather uniform in size.

#### MACERATION

The prosenchyma cells are  $0.7 \pm$  mm. in length. They are of irregular and rather crooked shape, but generally cylindrical in the middle one-third portion, where there are numerous small pit-markings. The ends taper—abruptly in most of the cells—into a long only slightly pitted, or forked, end. The pit-markings of the vessel segments are rather small and of rather uniform size.

## DISTINGUISHING CHARACTERS

The dry wood is yellowish-straw colored, or blued by fungi; chambered but not readily separating into thin lamellae; slightly hard, but extremely light and brittle. A resinlike substance is present in the vessels and other elements. The elements are serried. The vessels are visible in cross section with a lens, as a rule grouped 2-15+ together, variable in size, and with simple perforations. The rays are visible in all planes without lens, 1-15+ cells high and 1-2+ cells wide. The ray-cells are somewhat elongated radially. The prosenchyma cells are of medium length, crooked, cylindrical, and finely pitted in the central portion, and abruptly tapering into a long, slightly pitted point. The parenchyma has probably perished from decay, leaving the cavities.

**Pisonia grandis** R. Br. PAPALA KEPAU.

*Pisonia inermis* Forst.

Material, xliii a:68:1443.

This is a small tree 15-18 feet high, of dry habitat. It occurs in association with *Pelea cinerea*, *Zanthoxylum*, at elevations of 2,000 to 4,000 feet, and occurs rather generally in other Pacific islands. The dry wood is yellow or blackened by fungi, and so chambered that the mass appears composed of coarse and harsh anastomosing fiberlike strands. A resinlike varnish exudes from the tissue and covers the surface. The wood is extremely light and brittle, but holds together, with care. Evidently nearly 50 per cent of the stem is composed of soft tissues which perish on drying, leaving the cavities.

## CROSS SECTION

*Gross*.—The fiberlike sections are  $1\pm$  mm. in diameter, circular or irregular in outline, irregularly arranged, hard to cut, and brittle. The vessels are visible with a lens, and most isolated. Raylike bands are difficult to distinguish even under a lens.

*Minute*.—The vessels are  $0.08\pm$  mm. in diameter, mainly isolated, some adjacent, subcircular in outline, of rather uniform size, slightly thick-walled, with wide pit canals. The lumina of some cells contain a yellow resinlike body. The raylike strands are 1-6+ cells broad, the larger strands largely broken down. The cells are twice the diameter of the prosenchyma cells, nearly isodiametric, thin-walled, and minutely pitted. The prosenchyma cells are rounded polygonal in outline, of medium size, rather thick-walled, irregularly arranged, and with numerous small simple pits in all walls. Wood-parenchyma has largely disintegrated. A few cells are in contact with the vessels.

## RADIAL SECTION

*Gross.*—Under a lens, the elements appear serried. Definite raylike strands are not readily distinguished even under a lens. The fiberlike strands appear to be coarsely anastomose.

*Minute.*—The vessels are composed of short segments of nearly uniform size and shape. The perforations are large and simple, and the plane of perforation is nearly transverse. The pits are rather uniform in shape and size (0.006 in diameter), mostly subcircular in outline, with transverse lenticular orifices. Such pits are largely of the typical semi-bordered type, and arranged in vertical rows. Raylike tissue is thin-walled and isodiametric; in the dry material the large masses are broken down, leaving longitudinal cavities.

## TANGENTIAL SECTION

*Gross.*—The fiberlike strands anastomose with mostly small meshlike spaces. The raylike strands appear to merge into the wider perishable parenchyma areas.

*Minute.*—The tangential section shows only a vague appearance of any typical rays.

## MACERATION

The prosenchyma cells attain a length of 0.9+ mm. The walls are rather thick, and the cells taper from a cylindrical or prismatic central pitted portion rather gradually into a sharp-pointed, nearly unpitted end. Many variations in size and shape are present.

## DISTINGUISHING CHARACTERS

The dry wood is generally yellow, and composed of coarse, harsh, anastomosing, fiberlike strands. A resinlike body is present in the elements, and covers the dry surface. The wood is extremely light and brittle. The elements are serried. The vessels are composed of short segments, uniformly pitted, with moderately thick walls and simple perforations. Typical rays are absent; but small irregular radial strands of parenchyma occur in addition to thicker masses which are largely broken down. The prosenchyma is composed of rather thick-walled, irregular fibers of rather short lengths and medium diameter, and pitted in the central cylindrical portion. A few wood-parenchyma cells are in contact with the vessels.

Order RANALES  
Family LAURACEAE

The Lauraceae are a family of aromatic shrubs, lianes, and trees, rarely herbs, composed of 39 genera and 950 species, of general distribution in tropical or subtropical climates. A single arborescent species, *Cryptocarya mannii*, occurs in Hawaii. The leaves are commonly leathery and, with the single exception of

sassafras, are entire and evergreen, persisting for several years. The laurel, *Laurus nobilis*, the camphor tree, *Cinnamomum camphora*, the cinnamon tree, *Cinnamomum zeylanicum*, and the American nutmeg, *Cryptocarya moschata*, belong in this family; the true nutmeg, *Myristica fragrans*, is a close relative.

The Lauraceae, with the exception of Cassytha, have a number of uniform characters in the structure of the secondary wood. The vessels are of medium size and of rather uniform diameter throughout the same annual ring. "Sassafras alone is distinguished by the fact that the vessels of the springwood have very wide lumina" (17). Both scalariform and simple perforations occur. "The number of bars in the scalariform perforations is small, the largest number observed being seventeen (*Cryptocarya wightiana*)". The vessel-pits in contact with the ray show transitions from semi-bordered to simple. Spiral markings occur in *Tetranthera* and *Camphora*. The rays are 1-3+ cells wide, and the ray-cells vary in height. Wood-parenchyma may or may not be abundant. Tangential lines of wood-parenchyma occur in *Cryptocarya* and a few other genera. The wood-prosenchyma may be thin or thick walled, and gelatinous layers occur in some genera. The pits of the wood-prosenchyma are simple and septations occur in sassafras and some other genera.

***Cryptocarya mannii*** Hbd. HOLIO. Material, xxxiii:37:1440 (38 new).

The genus consists of about 40 species of wide distribution in warmer climates, 10 of which are American. *Cryptocarya mannii* is endemic to Hawaii, occurring in dry habitats, exposed to light, in Kauai and Oahu at elevations of 3,000-4,000 feet. The tree attains a height of 20-40 feet and a D. B. H. of 12 inches. Only a limited use is made of the wood. The wood is rather soft, light yellow in color or with dark streaks, rather straight-grained, fine and even textured; no distinct heartwood.

#### CROSS SECTION

*Gross.*—The vessels are barely visible in good light without lens, and mainly isolated. The rays are visible with lens, light-colored, and much smaller than the pores; no distinct growth-rings.

*Minute.*—Growth-rings are defined by slight compression and thickening of the walls of the prosenchyma, together with the presence of wood-parenchyma.

The vessels are of medium size ( $0.12 \pm$  mm.) and fairly uniform throughout the growth-ring. Many are isolated and nearly circular in outline. Others are grouped 2-3, rarely 3-9+, together radially, or in twos tangentially. The walls are thin ( $0.002$  mm.). The lumina are empty except for a few tyloses. The rays are 1-4+ cells wide and consist of elongated cells where more than one cell wide. The cavities are slightly resinous. The walls are numerous pitted with rather small subcircular pits  $0.003 \pm$  mm. in diameter. The prosenchyma consists of moderately thick-walled fibers with simple pits in the radial walls. The outline of the cell is angular; the lumen, fairly large. The walls of the fibers are  $0.003 \pm$  mm. thick. Early-wood cells have thinner walls than late-wood cells. Wood-parenchyma cells are of nearly the same dimensions as the prosenchyma, but the lumina are generally larger. The prosenchyma is distributed irregularly in narrow tangential lines about two cells wide. Paratracheal parenchyma is present, but not abundant.

#### RADIAL SECTION

*Gross.*—The rays are seldom over 1 mm. high, color reddish, and visible without lens. The vessels appear as fine brownish lines, and there are dark streaks in many sections.

*Minute.*—The vessels are composed of short segments with nearly transverse ends. The perforations are simple or scalariform near the primary xylem; the radial walls bear a few large circular perforations and large circular—on some radial walls crowded—bordered pits 0.01 mm. in diameter, with lenticular orifices, or, in contact with wood-parenchyma, very narrowly semi-bordered or even simple pits. In contact with the rays, larger, as a rule elongated, simple, or very narrowly semibordered pits are formed. Scalariform pits occur near the primary xylem.

The rays are heterogeneous and usually less than 1 mm. wide. The marginal cells are  $0.04 \pm$  mm. in radial diameter, and  $0.07 \pm$  mm. in height. The remaining cells are  $0.15 \pm$  mm. long radially and  $0.02 \pm$  mm. in height. The radial walls bear numerous circular pits  $0.003 \pm$  mm. in diameter, or, in contact with vessels, large, generally elongated pits  $0.015 \pm$  mm. in diameter. Prosenchyma cells are nonseptate. The radial walls bear numerous large simple pits with oblique widely lenticular orifices, many of which have rhombic outlines. The wood-prosenchyma cells are elongated, slightly resinous, and numerous pitted.

#### TANGENTIAL SECTION

*Gross.*—The vessels are reddish and visible without a lens. The rays are fine and barely visible without lens.

*Minute.*—The rays are  $3 \pm$  cells wide and generally less than 30 cells high. The marginal cells are commonly more or less elongated and either obtusely or acutely pointed. The remaining cells are rather uniform in size and subcircular or slightly elliptical in outline.

## MACERATION

The vessel segments are short, cylindrical, with or without projection at the transverse or slightly oblique end. Pits are of more than one size. Tracheids are frequent.

The prosenchyma consists of libriform fibers  $1-1.5\pm$  mm. in length. The radial walls bear many simple pits except towards the end, and many numerous long oblique crossed slits in the inner wall, which traverse the entire side.

## DISTINGUISHING CHARACTERS

The wood is rather soft, light yellow, of fine texture, diffuse porous, and without distinct heartwood. The vessels are barely visible in cross section without lens, diffuse, either solitary or in small groups. The vessels are without tyloses; the perforations are simple; the walls bear pits of distinctly more than one size. The rays are heterogeneous,  $4\pm$  cells wide, and commonly less than 30 cells high, with very large generally elongated narrowly semibordered or simple pits in contact with the vessels. The prosenchyma consists of libriform fibers, with simple pits on the radial walls. Long oblique crossed checks occur on many of the inner walls. The wood-parenchyma occurs in narrow tangential bands wide apart; also, in contact with the vessels, but few surrounding them.

## Family PITTOSPORACEAE

This family comprises 9 genera, of which 8 are endemic to Australia. The 70 species of the genus *Pittosporum* are of general distribution in the Tropics of the Old World. The wood is characterized by vessels with simple perforations, bordered or semi-bordered pits, and some spiral thickenings. The rays are 1-6 cells wide. The wood-parenchyma is sparingly developed. The fibers may possess septae and bordered or simple pits. There is little wood-parenchyma.

***Pittosporum glomeratum*** Hbd. HOWA. Material, lxvii:57:1469.

This is a small tree which closely resembles *P. glabrum*. It is found at the eastern end of Oahu. The wood is rather hard, of fine even texture, yellowish-white in color, without heartwood or macroscopic growth-rings.

## CROSS SECTION

*Gross.*—The vessels are very small, visible with lens, diffuse, solitary or in small groups of 2-3+. The rays are whitish, barely visible without lens, and as large or larger than the pores.

*Minute.*—The vessels are subcircular in outline, small ( $0.05 \pm$  mm.) in diameter, isolated or in very small groups. The walls are thin ( $0.003$  mm.) and the lumina free from contents.

The rays are 1-3 cells wide and composed of cells not greatly elongated. The walls are thin ( $0.002$  mm.) and bear numerous minute subcircular pits  $0.003$  mm. in diameter. The wood-parenchyma fibers are rounded, polygonal in outline, and arranged in radial rows. The walls are thick,  $0.006 \pm$  mm. in diameter, and with pits mostly in the radial walls. The lumina are rather small.

The wood-parenchyma is limited to a few cells in contact with the vessels.

#### RADIAL SECTION

*Gross.*—The wood is straight-grained. The rays are whitish, mostly less than  $0.6$  mm. in height, and fairly visible without lens. The surface has a silky luster.

*Minute.*—The vessels have simple perforations through some end-walls—as a rule somewhat oblique—which project into the vessel cavity, the perforate opening being about one-half the diameter of the vessel. The pits are small,  $0.07 \pm$  mm. in diameter, subcircular, with lenticular orifices. Vessel pits communicating with the rays are of nearly the same diameter as those between vessels.

The uniseriate rays are composed of cells axially elongated; the multi-seriate rays, of radially elongated cells, except for axially elongated cells which occur as a rule at the margins. The pits are minute, subcircular or lenticular in outline. The prosenchyma bears narrowly bordered pits with slitlike orifices.

#### TANGENTIAL SECTION

*Gross.*—There is little variation in color or structure visible without a lens. Under the lens, the vessels and rays are visible but not prominent.

*Minute.*—The rays are narrowly lanceolate in outline and acutely pointed, 1-35 cells high, and 1-3+ cells wide. The marginal cells as a rule are axially elongated; and likewise all the cells of the few uniseriate rays. In other cases, the cells are subcircular or slightly angular in outline, and rather uniform in size. The prosenchyma bears but few pits in the tangential walls.

#### MACERATION

The vessel-segments are rather long, the ends generally somewhat obliquely inclined and with a perforation of about one-half the diameter of the trachea. Lateral perforations occur. A tongue-like projection is generally present from one or both ends. The pit markings are small, with lenticular orifices. Large simple pit markings are absent. The prosenchyma consists of rather thick-walled, straight, libriform fibers, with pit markings extending to near the point.

#### DISTINGUISHING CHARACTERS

The wood is rather hard, whitish, diffuse porous, without growth-rings or heartwood. The vessels are not visible without lens, isolated or grouped



2-3+ together, and possess simple perforations through somewhat oblique end-walls. The pits are small, bordered or semibordered, and with lenticular orifices. The rays are 1-3+ cells wide, 1-35+ cells high, and imperfectly heterogeneous. The wood-prosenchyma consists of rather thick-walled libriform fibers. The wood-parenchyma is limited to a few cells in contact with the vessels.

**Pittosporum hosmeri** Rock. AAWA HUA KUKUI.

Material, lxx:72:1466.

This tree is endemic to Hawaii, growing 18-25 feet high, in dry situations, at elevations of 4,000-5,000 feet.

The wood is light yellow in color, rather soft, of fine and even texture, straight-grained, and without true macroscopic growth-rings, although there is a pronounced zonal variation in color.

#### CROSS SECTION

*Gross.*—The vessels are small, visible with a lens, diffuse, mostly grouped in radial rows 2-6 together. The rays are light-colored, visible without lens, and larger than the pores.

*Minute.*—The vessels are mostly grouped 2-6+ together in radial rows, rather variable in size up to  $0.09+$  mm. in diameter, with lumina free from tyloses, resin, or other contents, and walls of medium thinness ( $0.003\pm$  mm.).

The rays are 1-6+ cells broad, as a rule with radially elongated cells free from resin or other contents, and with numerous, subcircular pits of medium size,  $0.004\pm$  mm. in diameter. The wood-prosenchyma cells are rounded, polygonal in outline, and irregular in size and arrangement. The walls are of medium thickness, and bear pits on radial and tangential sides. The lumina are large and open. The wood-parenchyma is not abundant, and mostly in contact with vessels.

#### RADIAL SECTION

*Gross.*—The rays are light-colored, as a rule less than 0.7 mm. in height and not conspicuous. The vessels are light-colored, visible under a lens.

*Minute.*—The vessels have simple perforations. The segments are of medium length and constricted abruptly inward at the plane of perforation, which in some segments is more or less oblique. The pits are subcircular, with lenticular orifices; many of those in communication with rays or parenchyma cells are larger and elliptical in outline with narrow half-borders.

The wood-prosenchyma bears bordered pits of medium size with lenticular or slitlike, vertical, or obliquely inclined orifices.

The wood-parenchyma is paratracheal in distribution. The pits are rather large, circular, or elliptical in outline, and  $0.006\pm$  in diameter. Many of the pits are clustered three or more together. The cells are  $0.15\pm$  mm. in length.

## TANGENTIAL SECTION

*Gross.*—The structural characters are indistinct without lens. The rays are narrowly elliptical or linear, not conspicuous even under the lens.

*Minute.*—The rays are linear lanceolate in outline and acutely pointed, 1-6 cells broad and from 1-30 cells high. The cells are nearly elliptical in outline or slightly angular, and as a rule only slightly elongated, except at the margin where an elongated, pointed cell may be present.

The prosenchyma bears but few pits in the tangential walls.

## MACERATION

The vessel-segments are of medium length, and many bear an overlapping tip from one or both ends. Most of the end-walls are more or less oblique and bear a single circular perforation of about one-half the inner diameter of the trachea. The pit markings are variable, as a rule, with lenticular, or long narrow slitlike apertures; the ray- or parenchyma-pit markings possess larger, more open irregularly elliptical, apertures.

The fibers are of medium length ( $1\pm$  mm.), taper from near the middle, and are pitted to near the points. The walls are of medium thickness and the lumina large and open.

## DISTINGUISHING CHARACTERS

The wood is light yellow in color, rather soft, of very fine and even texture, without heartwood or well-defined growth-rings. The vessels are without tyloses or other contents and possess simple perforations. The pits are variable, from lenticular to slitlike or elliptical. The rays are 1-6 cells wide and up to 30 cells high, homogeneous or heterogeneous in composition. The wood fibers are of medium length, with large lumina, and fairly distinct bordered pits. The wood-parenchyma is limited to a few cells mostly in contact with the vessels.

***Pittosporum kauaiense*** Hbd. HOAWA. Material, lxviii:49:1469.

This species is endemic to Kauai at elevations of 2,000-4,000 feet and is one of the largest of the genus, reaching a height of 40 feet and D. B. H. of 10 inches. The wood is grayish-yellow streaked with brown, and somewhat hard. It is fine and even textured, without distinct heartwood or growth-rings.

## CROSS SECTION

*Gross.*—The vessels are very small, visible with lens, diffuse and mainly in radial groups of 2-8+. The rays are whitish, and barely visible without a lens.

*Minute.*—The vessels are mainly in radial groups of 2-8+ and variable in size, but very few more than 0.07 mm. in diameter. The cavities are free from tyloses or other contents, and the walls are rather thin ( $0.002\pm$  mm. in thickness).

The rays are multiseriate, the walls thin and with numerous small, subcircular pits,  $0.003 \pm$  mm. in diameter. The wood-prosenchyma cells are polygonal in outline, irregularly arranged, medium thick-walled ( $0.004 \pm$  mm.), and possess large open lumina. Pits are fairly abundant in the radial walls. The wood-parenchyma consists of a few cells in contact with the vessels, or diffuse among the prosenchyma.

#### RADIAL SECTION

*Gross.*—Very few rays are more than 0.7 mm. in height, but are plainly visible without lens. The texture is fine and even, but the grain is more or less irregular.

The vessels have simple, circular or elliptical perforations of about one-half the diameter of the vessel, and the end-walls are more or less oblique. The bordered pits communicating with vessels are of fair size ( $0.007$  mm.), subcircular in outline, with transverse lenticular orifices; those communicating with the rays and parenchyma are larger, more open, and narrowly semibordered. The vessel-segments are serried.

The prosenchyma fibers are intercrossed, irregularly curved, and abundantly pitted on the radial walls with circular-bordered pits with lenticular orifices.

#### TANGENTIAL SECTION

*Gross.*—The rays and vessels are visible with lens; but not prominent.

*Minute.*—The rays are 1-10+ cells broad and 1-50+ cells high, elliptical in outline, and acutely pointed. The cells are very variable in size, from  $0.009$  mm. to  $0.03$  mm. in diameter, or elongated at the margin of the ray and in the few uniseriate rays. The prosenchyma bears comparatively few pits in the tangential walls.

#### MACERATION

The vessel-segments are of medium length ( $0.7 \pm$  mm.); the end-walls as a rule are oblique and perforated by a circular or elliptical opening of about one-half the diameter of the vessel. A tongue-like projection is usually present at one or both ends. The prosenchyma fibers taper from near the middle and are  $1 \pm$  mm. in length.

#### DISTINGUISHING CHARACTERS

The wood is grayish-yellow, streaked with brown, not very hard, without distinct heartwood or growth-rings. The vessels are visible with lens, are without tyloses or other contents, and have simple perforations through oblique end-walls. The rays are imperfectly heterogeneous, 1-10+ cells broad, and 1-50+ cells high; some of the cells are very low. The prosenchyma fibers are of medium length, medium thick-walled, and pitted especially on the radial surface. The wood-parenchyma is sparingly developed and diffuse.

## Family LEGUMINOSAE

## Sub-Family MIMOSOIDEAE

The Mimosoideae, entirely absent from Europe, are trees or shrubs (erect or climbing) with bipinnate leaves. The sensitive plant (*Mimosa pudica*), *Haematoxylon*, *Copaifera*, and *Gleditschia* belong to this subfamily. An important gum is yielded by *Acacia senegal*, as a result of the disintegration of the parenchyma. The wood is characterized by vessels with simple perforations, bordered or half-bordered pits; tracheids are absent. The medullary rays are narrow, 1-5 cells broad, and composed of low cells which are elongated radially. In some species of *Acacia* and *Inga*, the rays are arranged in tierlike order. Mucilage fibers occur. Septations, sometimes associated with starch storage, occur in case of fibers of *Acacia* and a few other genera. Secretory canals (17) are present in some genera.

**Acacia koa** Gray. KOA or KOA KA. Material, iv:40.

*Acacia koa* is endemic to Hawaii and one of the most valuable of Hawaiian trees, growing to a height of 80+ feet, and a D. B. H. of 6 feet. It grows in the rain forest, but occurs also in dry districts. It occurs throughout the Territory, at elevations from 600 to 5,000 feet, in a wide range of conditions. It grows at low levels, in association with *Pandanus odoratissimus*; or, at higher elevations (in middle forest zone), with *Myoporum sandwicense*, *Suttonia*, *Metrosideros*, and *Sophora chrysophylla*. The wood is dark brown, with narrow zones of black or blackish-brown, and light-colored, sometimes yellowish-white, sapwood. It is rather soft, fine and even textured, resinous, and with indistinct growth-rings. The wood is used for cabinet work, particularly for the construction of the ukulele.

## CROSS SECTION

*Gross*.—The vessels are diffuse, single or in small compact groups, barely visible without lens. The rays are very narrow, smaller than the pores, reddish brown, visible under a lens.

*Minute*.—The vessels are either isolated or grouped compactly 2-5+ together. When isolated, nearly circular in outline, and comparatively uniform in size ( $0.2\pm$  mm. in diameter). Those in groups are greatly compressed and vary greatly in size. The walls are thin, and the cavities free

from tyloses, but many are filled with a brownish substance which reacts slightly to resin tests. The rays are 1-2+ cells wide, and resinous. The prosenchyma cells are rounded, polygonal in outline,  $0.03 \pm$  mm. in diameter, and rather irregularly arranged. The walls are thin,  $0.004 \pm$  mm. in thickness, and the lumina large, many filled with blackish-brown resinous matter. Some of the growth-rings are faintly indicated by compressions of the cells. Pits are simple and present in both radial and tangential walls.

#### RADIAL SECTION

*Gross.*—The rays are visible without lens, most less than 0.5 mm. in height, and as a rule resinous. The vessels are straight, many resinous.

*Minute.*—The vessels bear numerous subcircular pits with short, lenticular orifices. The segments are short; the perforations simple; and the plane of perforation as a rule nearly transverse.

The rays are composed of low, greatly elongated cells,  $0.2 \pm$  mm. in length and  $0.015 \pm$  mm. in height. The walls are pitted on all sides with minute, subcircular pits. Many of the cell-cavities are filled with resinous matter. The prosenchyma fibers bear small, oblique, slitlike pits. The wood-parenchyma cells are paratracheal,  $0.15 \pm$  mm. in length, rather irregularly shaped, and usually minutely pitted. Many coarse elliptical pits occur.

#### TANGENTIAL SECTION

*Gross.*—The rays are very narrow, and visible only with a lens; many are dark in color.

*Minute.*—The rays are homogeneous, 1-2, generally 1 cell wide. The cells are comparatively uniform in size and shape, and rounded elliptical in outline.

#### MACERATION

The vessel-segments bear numerous pit markings uniform in size. The ends are transverse as a rule, and many bear a short projecting overlapping tip. The fibers are of medium length ( $1.4 \pm$  mm.) and taper from near the middle. The sides bear small, slitlike, obliquely inclined, pits.

#### DISTINGUISHING CHARACTERS

The wood is dark brown, resinous, with zones of black, and with white or light-colored sapwood. The vessels are barely visible without lens, isolated or arranged 2-5+ together in compact groups. The perforations are simple; the segments, short; the cavities without tyloses but many filled with resinous material. The rays are homogeneous, 1-2+ cells, generally 1 cell wide, and up to 30+ cells high. The prosenchyma fibers are nonseptate, medium thin-walled, and with large lumina. The wood-parenchyma is paratracheal.

Black koa is distinguished by the broader rays (usually 2 cells wide) and by the great abundance of resinous material in rays, vessels, fibers, and wood-parenchyma. A drop of alcohol, placed on a dry block of ordinary koa cross-surface, immediately penetrates the vessels; on black koa, it remains for several seconds on the surface.

**Acacia koaia** Hbd. KOAIA or KOA OHA. Material, ii:8:1412.

The koaia is a small tree, 20-25 feet high, on the dry leeward sides of Molokai, Maui, and Hawaii, and is endemic to these islands.

The wood is dull reddish-brown in color with a narrow zone of light-colored sapwood, very hard, fine and even textured, and without macroscopic growth-rings, though an irregular zonal variation of color is present. The wood was formerly used for spears and similar purposes requiring hardness.

#### CROSS SECTION

*Gross.*—The vessels are visible with lens, diffuse, isolated, or in small groups. The rays are very fine, yellowish-brown, visible only by lens, much smaller than the pores.

*Minute.*—Growth-rings are clearly defined by compression of the elements as well as by terminal parenchyma. The vessels are isolated and subcircular in outline or grouped compactly 2-6+ together either in a radial direction or, to some extent, tangentially. The diameter is fairly uniform for the isolated vessel (seldom found over 0.2 mm.); for the grouped vessels, smaller diameters are common. The cavities are filled with resinous material, but tyloses are not present. The walls are thick,  $0.009 \pm$  mm. The rays are 1-3 cells wide and tend to bend around the vessels. The cell-cavities contain a dark globular material and some also contain large crystals of calcium oxalate. The pits are minute and subcircular. The wood-prosenchyma is composed of libriform, thick-walled fibers, with sharply polygonal outlines and small lumina. The pits are small, uncommon, in the radial as well as the tangential walls. The pectin lamella is seldom thickened at the angles. The wood-parenchyma is mainly paratracheal in distribution, but terminal and diffuse cells are present. Crystal-containing cells are frequently seen.

#### RADIAL SECTION

*Gross.*—The radial surface has a waxy luster. The rays are not conspicuous. The vessels are visible with a lens and in heartwood are filled with a blackish substance.

*Minute.*—The vessels, as a rule filled with dark material, bear numerous pits 0.006 mm. in diameter with lenticular orifices. Those communicating with the rays are of the same size as those between vessels. The perforations are simple, and the plane of perforation is generally not greatly inclined. The segments are short, but variable in size and shape. The rays are homogeneous, and composed of low cells radially elongated. The pits are minute,  $0.002 \pm$  mm. in diameter, and subcircular or lenticular in outline.

The wood-parenchyma cells vary from less than 0.06 mm. in length to 0.15+ mm. The shorter cells are in contact with the vessels. Chambered crystal-parenchyma strands are numerous and diffusely distributed. The pits are minute, and circular or lenticular.

## TANGENTIAL SECTION

*Gross.*—The vessels appear under a lens as dark lines, the rays are small and indistinct even under a lens.

*Minute.*—The rays are very small, 1-3 cells wide and up to 15 cells high. They are somewhat variable in size and shape, but not elongated. The walls are slightly thickened (0.003 mm.) and the cavities filled with brownish globular contents. Large solitary crystals of calcium oxalate occur in some of the cells.

## MACERATION

The wood-parenchyma cells in contact with the vessels bear coarse elliptical pit markings; but the pits in the vessel walls are uniformly small, and more or less grouped. The prosenchyma is composed of short libriform fibers 0.9 mm. in length, which taper from near the middle to sharp points. The walls are thick and bear small slitlike pits.

## DISTINGUISHING CHARACTERS

The wood is hard and of fine and uniform texture, dark brown in color, with a narrow zone of light-colored sapwood. The vessels are invisible without lens, thick-walled, short segmented, and with simple perforations and pits of uniform size. Contents are dark. The rays are homogeneous, 1-3 cells wide and 1-15 cells high, and minutely pitted.

The prosenchyma fibers are libriform, short, and thick-walled. The wood-parenchyma is mainly paratracheal in distribution, but terminal and diffuse strands occur. Chambered crystal-strands are among the wood fibers and other elements. Microscopic growth-rings are present.

## Subfamily CAESALPINIOIDEAE

Trees or shrubs with pinnate or bipinnate leaves, and reduced flowers. The wood is characterized by vessels of varied diameter, with simple perforations. Spirally thickened tracheids and small vessels are present in some genera. The rays are mostly narrow, 1-8 cells broad, and homogeneous. The wood-parenchyma is abundant and much of it in form of tangential bands. Crystal-parenchyma occurs in some genera. The wood-prosenchyma has simple pits, and many mucilaginous layers and septa are present.

***Mezoneurum kauaiense*** (Mann.) Hbd. UHII.

Material, ix:10:1510.

There are 11 species in all belonging to this genus; these are distributed in the Tropics of the Eastern Hemisphere. *Mezoneurum kauaiense* alone is endemic to Hawaii. This tree reaches a height of 30 feet and a D. B. H. of over 12 inches, and occurs on

the leeward side of the islands. On the island of Hawaii it is associated with *Erythrina monosperma*, *Colubrina oppositifolia*, and *Maba sandwicensis*. The wood is extremely hard, fine and even textured, and has a specific gravity greater than 1. The seasoned wood is dark blackish brown with a very narrow zone of white sapwood, and was formerly used for spears and other purposes requiring exceptionally heavy or hard material.

#### CROSS SECTION

*Gross*.—Growth-rings are visible without lens. The vessels are diffuse, visible with lens, single or grouped 2-6+ radially. The rays are yellowish, very narrow, visible only by lens.

*Minute*.—Growth-rings are defined by compressions of the elements. The vessels, when isolated, are subcircular in outline, and rather variable in diameter up to 0.2+ mm. The walls are rather thick ( $0.009 \pm$  mm.) and the cavities filled with a gumlike substance. The rays are 1-2 cells wide and the cells filled with gumlike material.

Wood-prosenchyma is composed of very thick-walled fibers with very small lumina. The walls bear pits on all sides. Mucilage-reacting fibers are very common, the interior layers of which stain heavily with haematoxylin.

Wood-parenchyma is paratracheal, with tangential extensions from the tracheae. Crystal-parenchyma cells are present. Some of the wood-parenchyma cell-walls are greatly thickened.

#### RADIAL SECTION

*Gross*.—The surface has a high silky luster. The rays and other elements are visible under a lens. The wood is cross-grained.

*Minute*.—The vessels are composed of short segments with simple perforations and nearly transverse at the plane of perforation. The pits, generally obscured with gumlike material, are as a rule circular or subcircular in outline, small (0.006 mm. in diameter) and with lenticular, commonly transverse, orifices.

The rays are homogeneous. The cells are  $0.07 \pm$  mm. in length and  $0.02 \pm$  in height. The walls are fully 0.003 mm. in thickness, and some are thickened to resemble stone-cells. The pits are minute, subcircular, and rather abundant. Large crystals of calcium oxalate occur in large numbers in the cell cavities. Wood-prosenchyma fibers are somewhat intercrossed; mucilage-reacting fibers are numerous. Wood-parenchyma cells bear minute lenticular pits in the walls, and some cells are thickened to resemble stone-cells. Chambered crystal-strands are numerous.

#### TANGENTIAL SECTION

*Gross*.—Structural characters are visible only with a lens.

*Minute*.—The rays are 1-2 cells wide and up to 15+ cells high; the cells rather uniform in size and rounded in outline. Crystals occur in many of the cavities, and some of the cells are very thick-walled.



## MACERATION

The fibers are libriform, somewhat waxy, and taper from near the middle to sharp points. Pits with oblique slitlike orifices are on all walls and are fairly abundant. The inner layers of the mucilage fibers stain deeply and shrink away from the outer layers.

## DISTINGUISHING CHARACTERS

The wood has a specific gravity greater than 1, is very hard, and blackish brown with a narrow zone of white sapwood. Growth-rings are present. The vessels are diffuse, visible with a lens, the perforations simple, the cavities filled with gum(?) and are without tyloses. The rays are homogeneous, 1-2 cells wide and up to 45+ cells high, and crystal-bearing cells are present. The fibers are libriform, short, and mucilage fibers are abundant. Wood-parenchyma paratracheal and metatracheal; chambered crystal-strands are present and some cells are thick-walled and resemble stone-cells.

## Subfamily PAPILIONATAE

Herbs, shrubs, or trees with zygomorphic flowers and usually pinnate leaves (trifoliate in *Erythrina*). The vessels are very variable in diameter (0.03-6 mm.) and arrangement. The perforations are simple and the pits either bordered or semibordered, very few simple. Tracheids are widely distributed in the family, and spiral thickenings may occur. The rays are from 1-3, rarely 30, cells wide, and some are arranged in tierlike seriation. In part of the genera, including *Erythrina* and *Sophora*, the rays are composed of cells of similar height; in the remaining genera, the rays are composed of cells of both high and low form. The wood-prosenchyma bears simple pits and may have inner mucilage-reacting layers. *Sophora* and a few other genera possess septate and starch-storing prosenchyma fibers. In many specimens the wood-parenchyma is abundant, mostly in the form of tangential bands, which include the vessels. Chambered crystal-parenchyma is abundant.

***Sophora chrysophylla*** Seem. MAMANI. Material, v:30:1415.

The genus *Sophora* consists of more than 25 species of trees or shrubs of general distribution in the warm climates. *S. chrysophylla* is the only species in Hawaii and is endemic. It reaches a height of 20-40 feet and a D. B. H. of over 2 feet, and is of common occurrence from sea level to 10,000 feet elevations.

The wood is deep walnut-brown in color with blackish zones. The sapwood is slightly lighter in color and narrow. It is very hard, heavy, fine, and nearly uniform in texture, and fairly straight-grained. It is durable in the ground and is widely used for fence posts.

#### CROSS SECTION

*Gross.*—Growth-rings are indistinctly described by lines of wood-parenchyma. Groups of vessels surrounded by wood-parenchyma are visible without lens. The vessels are small, visible only with lens. The rays are of about the same size as the vessels, reddish-brown, and visible with a lens.

*Minute.*—The vessels are grouped irregularly together, circular in outline, or more or less flattened by contact, fairly uniform in diameter ( $0.09 \pm$  mm.), rather thick-walled ( $0.006 \pm$  mm.) and filled with a brownish-yellow gumlike body which does not stain with alcannin but is colored by safranin. The small vessels are numerous, and associated with tracheids and wood-parenchyma. The rays are polyseriate and about as wide as the vessels; the cells are rather thick-walled ( $0.003 \pm$  mm.), elongated radially, minutely pitted with circular pits  $0.002 \pm$  mm. in diameter, and filled with gum, and some with rhombic crystals.

The wood-prosenchyma is composed of libriform fibers irregular in arrangement, very thick-walled and with very small lumina filled with resin or gumlike matter. Many of the fibers show one or more concentric mucilage-reacting layers.

Wood-parenchyma is abundant, associated with the vessels, and extends in indefinite tangential bands  $5 \pm$  cells wide. The walls are rather thick ( $0.003 \pm$  mm.). The cavities are filled with gumlike matter and rhombic mineral crystals are present. The tangential diameter ( $0.03 \pm$  mm.) exceeds that of the fibers. The radial diameter is usually only half that of the tangential.

#### RADIAL SECTION

*Gross.*—The elements are filled with a gumlike material which is visible under a lens by reflected light and deep garnet-red in color. The rays are low, usually not much more than 1 mm. in height, slightly light-colored and not very distinct without lens. Alternating bands of prosenchyma fibers are visible under lens.

*Minute.*—The elements are serried. The vessels are minutely pitted. The pit orifices are narrowly lenticular or slitlike; many are elongated beyond the usually indistinct borders, some having a spirallike effect. The segments are short,  $0.18 \pm$  mm., and the plane of perforation nearly transverse. The perforations are simple, circular, and terminal, and some are lateral in position. Many small tracheids occur in the wood-parenchyma zones together with small vessels.

The rays are composed of elongated cells, most of those at or near the margins being somewhat shorter. The walls are slightly thickened ( $0.003$  mm.) and with numerous small circular pits  $0.003 \pm$  mm. in diam-

eter, or varying to lenticular in contact with vessels. The cavities contain a deep-colored gumlike body which is yellowish-brown by transmitted light, and a few large crystals of calcium oxalate. Mycelium is often present even in presence of the gum. The thick-walled libriform fibers are intercrossed, the lumina are filled with deep-staining gum. The wood-parenchyma cells are  $0.19 \pm$  mm. in length and  $0.02 \pm$  mm. in diameter and commonly in storied arrangement. The pits are small and numerous. Chambered crystal-parenchyma containing  $8 \pm$  crystals in a strand are common and mostly in the wood-parenchyma bands.

#### TANGENTIAL SECTION

*Gross.*—The irregular alternation of prosenchyma and wood-parenchyma is visible without lens. Under a lens, the cavities of the vessels filled with garnet-red gumlike material are plainly visible; also, the narrow elliptical rays.

*Minute.*—The rays are narrowly elliptical in outline and acutely pointed at the margins, generally less than 50 cells high, and from 1-7+ cells in breadth. The cells are circular or broadly elliptical in outline and rather uniform in size.

#### MACERATION

The vessel segments are cylindrical, short, and the plane of perforations transverse or nearly so. The pit markings are small. The pit orifices vary from nearly circular to transverse or oblique, slitlike in outline. The libriform fibers are  $1. \pm$  mm. in length, and alternate from near the middle, thick-walled, and brittle after maceration. Tracheids  $0.2 \pm$  mm. in length are common.

#### DISTINGUISHING CHARACTERS

The dry wood is very hard and heavy with a specific gravity greater than 1, deep walnut-brown in color, with a narrow zone of slightly lighter colored sapwood. The elements are filled with deep reddish-brown gumlike material. Wood-parenchyma occurs in tangential lines with the appearance of indistinct growth-rings. The vessels are visible with lens, grouped irregularly together, thick-walled, without tyloses, but filled with gum, short segmented, and with simple perforations. The rays are 1-7+ cells broad and up to 50+ cells high, and homogeneous. The prosenchyma is composed of thick-walled libriform fibers with small simple pits. The wood-parenchyma is in broad tangential lines with large and small vessels, and tracheids. Crystal-parenchyma is rather abundant.

**Erythrina monosperma** Gaud. WILIWILI. Material, xxvi:36:1513.

The 30 species belonging to this genus are distributed widely in the Tropics and subtropics. The single species, *E. monosperma*, is indigenous in the Hawaiian islands. It also occurs in other islands in the Pacific Ocean. The seeds are buoyant, not readily harmed by sea water, and are transported in the ocean currents

with seeds of other cosmopolitan beach plants. *Erythrina monosperma* attains a height of 20-30 feet, and a D. B. H. of 4 feet. The tree is deciduous, losing its leaves in late summer or early fall, and grows in the lowlands up to 1,500 feet in association with *Myoporum sandwicense*, *Reynoldsia sandwicensis*, and *Nototrichium sandwicense*. The wood is the lightest found in the islands, soft, and yellow or bluish-yellow in color. Growth-rings can not be distinguished without microscope. The wood was formerly used for canoes.

#### CROSS SECTION

*Gross.*—The vessels are smaller than the rays, visible without lens, isolated, or in small groups. The cavities are without tyloses. Some of the rays are nearly 0.5 mm. broad, and light-colored. The wood is composed largely of pithlike tissue surrounding the vessels, and narrow tangential lines of prosenchyma without vessels. The pores are barely visible without lens.

*Minute.*—Growth-rings are defined by slight compressions of parenchyma cells. Vessels either isolated and circular in outline or, less commonly, in compact groups of 2-3+. The diameter is rather uniform ( $0.24 \pm$  mm.), the walls are very thin ( $0.002$ —mm.), and the lumina free from tyloses. The rays are multiseriate, composed mainly of elongated cells; the pits are circular or broadly elliptical in outline, scattered, and very variable in size, and from  $0.001$  to  $0.015+$  mm. in diameter. Those of largest diameter are in radial rows and communicate with intercellular spaces. The prosenchyma forms narrow tangential bands 1-7+ cells wide and is seldom if ever found in contact with vessels. The elements are rounded polygonal in outline, variable in size, attaining diameters of  $0.03+$  mm.; the walls are of medium thickness ( $0.004 \pm$  mm.) with simple pits on all sides. The large diameters tend to occur in radial series, in alternation with  $3 \pm$  irregular rows of cells of smaller outline, which are crowded tangentially between the cells of large outline. The wood-parenchyma zones are two to three times as wide as the prosenchyma zones. The cells are hexagonal, very thin-walled ( $0.001$  mm.) and  $0.06 \pm$  mm. in diameter. Several rows of compressed cells define the growth-rings. The paratracheal cells are compressed for a distance of two or more rows from the vessels.

#### RADIAL SECTION

*Gross.*—The rays are 1-2 mm. broad, yellow, and conspicuous. Fine parallel bands of prosenchyma alternate with comparatively wide zones of wood-parenchyma. The vessels are reddish-yellow. Under a lens, the elements appear in radial seriation.

*Minute.*—The vessel segments are short and uniform in length ( $0.2 \pm$  mm.) and in seriation with the parenchyma and prosenchyma. The perforations are simple and the plane of perforation is transverse. The sides have medium-sized bordered pits ( $0.01 \pm$  mm. in diameter) with len-

ticular, transverse or oblique orifices. The pits are arranged in imperfect transverse or oblique rows in such a way that frequently several orifices are found tending to fuse in linear series. Most of the rays are less than 2 mm. in height, and composed of thin-walled, radially elongated cells  $0.03\pm$  mm. high, and  $0.15\pm$  mm. long. The pits are circular or broadly elliptical in outline and vary from 0.001 mm. to 0.03 mm. in diameter. The prosenchyma cells are in seriation with the other elements. The walls bear numerous long oblique crossed slits, and rather small simple pits. The wood-parenchyma cells are  $0.2\pm$  mm. in length and  $0.03\pm$  mm. in diameter. The walls are pitted with small elliptical pits. Chambered crystal-parenchyma occurs near or in the prosenchyma bands, often forming long continuous rows next to the prosenchyma. The crystals are commonly rather perfect tetrahedrons. The paratracheal 1-3+ rows of cells are compressed and commonly one-half or less of the average length.

#### TANGENTIAL SECTION

*Gross.*—The rays are dark yellow, irregularly elliptical in outline and acutely pointed, broader than the vessels, and generally less than 2 mm. in height. The vessels are yellow, and slightly darker in color than the rays. Under a lens light-yellow irregular lines of prosenchyma may be distinguished from the rays.

*Minute.*—The rays are irregularly elliptical in outline, generally less than 2 mm. high and less than 0.45 mm. wide. The cells are rather uniform in size ( $0.03\pm$  mm.) and subcircular in outline. The walls are minutely pitted. Large pits communicate with the intercellular spaces, and many are greatly elongated in the radial direction ( $0.06+$  mm.). The prosenchyma bears numerous rather small, simple or very narrowly bordered pits generally with oblique lenticular orifices. A few long oblique slits are present.

#### MACERATION

The vessel segments are very short with transverse ends, and pits of nearly uniform size. The prosenchyma fibers attain a length of 2+ mm., are cylindrical in the central portion, then abruptly attenuate into very long, rather irregular ends.

#### DISTINGUISHING CHARACTERS

The wood is very light and soft, yellow or bluish in color and with growth-rings visible only by microscope. The elements are serried. The vessels are visible without lens, isolated or in small compact groups, without tyloses, and composed of short segments of uniform length. The perforations are simple and the pits are of uniform size. The rays are homogeneous, broader than the vessels, and generally less than 2 mm. high. The prosenchyma forms narrow bands  $5\pm$  cells wide. The walls are of medium thickness and pitted on radial as well as tangential sides. The fibers are characterized by a short cylindrical central portion with long abruptly tapering ends.

## Order GERANIALES

## Family RUTACEAE

The family comprises 900 species of trees, shrubs, or, rarely, herbs of general distribution in tropical or temperate climates. The genus *Zanthoxylum*, common in the Tropics, is not found in Polynesia except in Hawaii.

The wood is characterized by vessels with simple, or, rarely, scalariform perforations, and bordered, semibordered, or, uncommonly, simple pits. Spiral thickenings occur in certain species. Wood-parenchyma is present and sometimes is found abundantly. Chambered crystal-parenchyma is present in a few genera. The wood-prosenchyma bears simple or narrowly bordered pits. Secretory cavities occur in this family (16).

***Zanthoxylum oahuense*** Hbd. AE or HEAE. Material, xcv:x30:1489 and xciv:58:1483.

A small tree of the rain forest of Oahu, to which it is endemic. Like other Hawaiian *Xanthoxyla* the stem is without prickles.

The wood is light yellow in color, of fine even texture, rather soft, cross-grained, and without true growth-rings, but with prominent narrow zones of wood-parenchyma.

## CROSS SECTION

*Gross*.—The vessels are small, visible with lens, not numerous, and mostly isolated. The lumina are open, readily permeable to alcohol. The rays are barely visible without lens, of nearly the same diameter as the vessels. Tangential zones of wood-parenchyma are plainly visible without lens.

*Minute*.—Generally the vessels are not more than 0.14 mm. in diameter, mostly isolated and subcircular in outline, but a few grouped two or more radially or, rarely, tangentially. When grouped tangentially there are lateral perforations in some vessels. The walls are thin and the lumina without contents. The vessels are largely in contact with prosenchyma. The rays are 1-4+ cells wide and composed of radially elongated thin-walled, rather coarsely pitted cells. The wood-prosenchyma cells are irregularly rounded polygonal in outline, rather thin-walled, irregularly arranged, many contain an inner mucilage-reacting layer which stains lightly with either haematoxylin or safranin, and separates from the primary wall upon sectioning. Wood-parenchyma cells are thin-walled, of nearly twice the diameter of the prosenchyma cells, and disposed mainly in straight tangential bands  $3\pm$  cells wide. Some of the cells are in contact with the vessels.

## RADIAL SECTION

*Gross.*—The rays are low, generally not more than 0.6 mm. high, but plainly visible without a lens. The vertical bands of wood-parenchyma appear as fine striations at right angles to the rays.

*Minute.*—The vessels are composed of medium short segments with transverse or slightly oblique end-walls. The terminal perforations are simple, circular in outline, and generally smaller than the interior diameter of the vessel. Lateral perforations of nearly the same size and shape occur. For the most part the pits are circular or broadly elliptical in outline, bordered or semibordered, and with lenticular or long slitlike orifices. The rays are homogeneous, thin-walled, and bear subcircular pits rather uniform in size and  $0.004 \pm$  mm. in diameter. Marginal cells in contact with vessels occur in which the ray aperture of the semibordered pit is large and elliptical in outline. The vessel apertures of such pits are either lenticular or slitlike. Each of the wood-prosenchyma cells bears commonly about one vertical row of simple slitlike pits along the radial wall. The wood-parenchyma cells are of large diameter, and  $0.12 \pm$  mm. in length. The pits are rather small and many are closely grouped. No crystal-parenchyma was found.

## TANGENTIAL SECTION

*Gross.*—The rays are barely visible without lens. The wood-parenchyma is prominent, appearing in broad, wavelike lines.

*Minute.*—The rays are elliptical in outline and obtusely pointed, 1-4+ cells broad and 1-20+ cells high. The cells are rounded polygonal in outline, nearly isodiametric, and rather uniform in size.

## MACERATION

The vessel segments are  $0.07 \pm$  mm. in length. The end-walls are transverse or slightly oblique. The terminal perforation is simple, circular in outline, and generally smaller than the lumen of the vessel. Lateral perforations occur. The pit markings are lenticular or slitlike and variously arranged, or, on some surfaces, almost absent. The prosenchyma is composed of crooked fibers of medium length, tapering from near the middle. The pits are small and rather few.

## DISTINGUISHING CHARACTERS

The wood is light yellow in color, rather soft, of fine and even texture, cross-grained, and without true growth-rings. The vessels are small, visible with a lens, few, mainly isolated, and largely in contact with fibers. The perforations are simple and smaller than the vessel lumen. The rays are homogeneous, 1-4 cells broad and 1-20 cells high. The fibers are rather thin-walled, commonly contain an inner mucilage-reacting layer, are of medium length and irregularly curved. The pits are few, small, and simple. Wood-parenchyma is composed of cells of nearly twice the diameter of the fibers and mainly disposed in numerous tangential bands  $3 \pm$  cells broad.

**Zanthoxylum kauaiense** Gray. A.E. Material, xci:x13:1490.

A small tree, 40 feet high, endemic to Hawaii. It occurs on the dry leeward side of Kauai at elevations of 3,600 to 4,000 feet, in association with "*Zanthoxylum dipetalum*, var.  $\beta$ , *Alphitonia excelsa*, *Cyanea leptostegia*, *Cryptocarya mannii*, *Bobea mannii*, and *Tetraplasandra waimeae*." (18, p. 199.)

The wood is whitish, rather hard, straight-grained, of fine even texture, and with growth-rings. A thin amber-colored varnish covers the dry surfaces. Dark colored vertical streaks occur on some of the wood specimens.

## CROSS SECTION

*Gross.*—The vessels are few, small, visible with a lens, diffuse, isolated or in small groups. The lumina are filled with an amber-colored body and the wood is not readily permeable to alcohol. The rays are smaller than the pores, visible with a lens. Growth-rings are defined by zonal variation in color, terminal parenchyma, and, to some extent, by variations in the number of pores. Some cross sections show blackish tangential zones of tissue

*Minute.*—The vessels occur both isolated and grouped, as a rule radially, 2 to 3+ together, and mainly in contact with prosenchyma. The diameter is somewhat variable, but seldom found more than 0.12 mm. The walls are rather thin (0.003 mm.). The lumina contain a resinlike material which stains with safranin. The rays are 1-2+ cells wide; the cells, thin-walled, with numerous subcircular pits 0.003± mm. in diameter. The prosenchyma cells are polygonal in outline, rather thick-walled, especially in the late-wood, and with rounded lumina. Wood-parenchyma is sparingly developed and mainly terminal. Crystal-cells occur. Some of the tangential areas of abnormal parenchyma are filled with blackish resinlike material.

## RADIAL SECTION

*Gross.*—The rays and vessels are visible without lens and filled with an amber-colored resinlike material, plainly visible with a lens.

*Minute.*—The vessels are composed of long segments with a single circular perforation of about one-half the diameter of the vessel lumen through each end-wall. The pits are 0.005 mm. in diameter, subcircular in outline, with lenticular or slitlike orifices, and vary little in diameter even when in contact with ray-cells. The rays are homogeneous and composed of radially elongated cells with rather small subcircular pits. In contact with vessels the pits are semibordered, numerous, but not large. The prosenchyma cells bear small simple pits with vertical slitlike orifices in their radial walls. Wood-parenchyma is sparingly developed. Strands of short crystal-containing cells occur in some radial sections.



## TANGENTIAL SECTION

*Gross*.—Rays and vessels are plainly visible with a lens and contain a dark, resinlike material.

*Minute*.—The rays are narrowly elliptical in outline, obtusely or acutely pointed, and composed mainly of elliptical cells of nearly uniform height.

## MACERATION

The vessel segments are rather long ( $0.4 \pm$  mm.), with simple perforations smaller than the lumen. The pit markings are small, with lenticular or slitlike orifices and variously arranged, or nearly absent from some surfaces. The prosenchyma is composed of long libriform fibers of relatively small diameter. The walls are more or less thickened and bear a few slitlike pit markings.

## DISTINGUISHING CHARACTERS

The wood is rather hard, yellowish-white, straight-grained, diffuse porous. Macroscopic growth-rings are defined by dark-colored zones of thick-walled fibers. The vessels are visible with a lens, isolated, or in small groups. The perforations are simple and smaller than the vessel lumen. The lumina contain a resinlike material rendering the wood impermeable to alcohol. The rays are 1-2 cells wide, 1-12+ cells high, and homogeneous. Wood-parenchyma is sparingly developed. Some crystal-containing strands occur.

***Zanthoxylum mauianse* Mann.** AE or HEAE.

Material, xciii:84:1494.

A small tree, endemic to Hawaii. There are a number of varieties, inhabiting mainly dry locations. Intermediate forms between *Z. mauianse* and *Z. havaiianse* are mentioned (18, p. 203).

The wood is yellow, non-resinous, rather soft, straight-grained, of fine even texture, and without marked growth-rings.

## CROSS SECTION

*Gross*.—The vessels are visible with a lens, rather numerous, and mainly grouped in radial rows. The lumina are free from contents and readily permeable to alcohol. The rays are visible with lens, and as broad as the vessels.

*Minute*.—The vessels are mainly grouped in radial rows of 2-20+ together. A few vessels are adjacent tangentially and lateral perforations occur. The outline is mainly subcircular, or slightly compressed, and the diameter usually less than 0.09 mm. The rays are 1-7 cells broad, thin-walled, and numerous and rather coarsely pitted. The prosenchyma cells are irregularly polygonal in outline, the walls moderately thickened, and the lumina rounded and open. Wood-parenchyma is sparingly developed and of nearly the same diameter as the prosenchyma cells.

## RADIAL SECTION

*Gross.*—The rays are visible without lens but not prominent, many more than 1 mm. in height.

*Minute.*—The vessels are composed of medium long segments with a circular perforation through each end-wall equal to about one-half the diameter of the vessel lumen. There are also circular or elliptical, lateral perforations. The pits are variable from circular in outline to elliptical or even scalariform. The pit apertures vary from lenticular to slitlike. Pits communicating with the rays are semibordered, mainly elliptical, and the orifices lenticular and rather open.

The rays are composed of two types of cells: (1) with a very low radially elongated outline, and (2) with an axially elongated, and radially short outline. The axially elongated cells occur in the uniseriate rays and at the margins of the wider rays. The walls bear numerous, rather coarse subcircular pits. The wood-prosenchyma cells each bear an irregular vertical row or circular-bordered pits with lenticular or long slitlike orifices. Wood-parenchyma cells are of nearly the same diameter as the fibers, but thin-walled and bear coarse subcircular simple pits which are often found grouped  $6\pm$  together.

## TANGENTIAL SECTION

*Gross.*—The rays, vessels, and other structural variations are visible, but not prominent, with a lens.

*Minute.*—The rays are linear or narrowly elliptical in outline and acutely pointed. The cells are very variable in size. Those in the central portion of the broad rays are mainly elliptical in outline and vary from 0.006 mm. to 0.03+ mm. in height. Those in the uniseriate rays and mainly at the margins of the broader rays are axially elongated. The prosenchyma bears few pits in the tangential walls.

## MACERATION

The vessel segments are long, cylindrical, and bear slitlike or lenticular pit markings which are irregularly distributed but few or none are crowded. The end-walls are generally somewhat oblique, the perforation is circular or broadly elliptical and of about one-half the diameter of the vessel lumen. A tongue-like projection is generally present at each end. The prosenchyma is composed of rather short fibers of small diameter, moderately thickened walls, and long evenly tapering ends. A few tracheids are present.

## DISTINGUISHING CHARACTERS

The wood light yellow, nonresinous, rather soft, straight-grained, and without marked growth-rings. The vessels are visible with lens, grouped in radial rows, with simple perforations, without contents and readily permeable to alcohol. The rays are heterogeneous, 1-7+ cells broad, and 1-70+ cells high. The prosenchyma is composed of moderately thick-walled fibers generally less than 0.9 mm. in length, with bordered pits in the radial walls, and a few tracheids. Wood-parenchyma is sparingly developed.

**Zanthoxylum dipetalum** Mann. KAWAU.

Material, lxxxviii:x16:1491.

*Z. dipetalum* is a small tree, 30 feet high and distinct in floral characters (18) from other Hawaiian species. It is endemic to Oahu, growing on the leeward slopes of Waiolani.

The wood is light yellow in color, rather soft, of fine even texture, straight-grained, diffuse porous, and with growth-rings defined mainly by the thick-walled, deeper colored, late-wood fibers.

## CROSS SECTION

*Gross.*—The vessels are small, visible with lens, and mainly isolated or in groups of twos. An amber-colored substance is present in small quantity in the vessels, though the wood is slowly permeable to alcohol. The rays are light colored, barely visible without lens. Some tangential areas filled with yellowish resinlike material are formed.

*Minute.*—The vessels are circular, elliptical, or slightly compressed in outline, thin-walled, and chiefly in contact with prosenchyma. Lateral perforations are common. The rays are 1-2+ cells wide and consist chiefly of radially elongated, and rather coarsely pitted cells. The prosenchyma cells are polygonal in outline, slightly rounded at the angles, medium thick-walled in late-wood. Growth-rings are distinctly indicated by thick-walled late-wood fibers. Wood-parenchyma is sparingly developed. Crystal-parenchyma cells are present.

## RADIAL SECTION

*Gross.*—The rays are low, reddish-yellow in color, and visible without a lens. A yellowish resinlike material is present, but not abundant in the rays and vessels.

*Minute.*—The vessel segments are long. The perforations are simple circular or elliptical in outline, of about one-half the diameter of the vessel lumen—terminal, many lateral, in position. The pits are subcircular in outline, with short, lenticular orifices, numerous, and uniform in size. The rays are homogeneous, the cells radially elongated, and with numerous small semibordered pits where in contact with vessels. The prosenchyma cells bear circular-bordered pits with lenticular or slitlike orifices. Wood-parenchyma is mainly represented by occasional strands of short crystal-containing cells. Abnormal parenchyma with dark resinlike contents occurs in vertical bands in portions of certain growth-rings.

## TANGENTIAL SECTION

*Gross.*—The rays and vessels are small, visible with lens, are barely distinguishable without.

*Minute.*—The rays are linear in outline and acutely pointed, 1-2+ cells broad and 1-16+ cells high. The cells are of nearly uniform height, elliptical in outline with an acutely pointed marginal cell at either end. There are few pits in the tangential walls of the prosenchyma.

## MACERATION

The fibers are long, comparatively straight, and taper from near the middle. The vessel segments are long, straight, cylindrical, and bear pit markings of uniform size but variously arranged. A tongue-like projection is commonly present at one or both ends.

## DISTINGUISHING CHARACTERS

The wood is whitish-yellow in color with darker shaded growth-ring zones, rather soft, of even texture, and straight-grained. The vessels are visible with lens, diffuse, isolated or in small groups. Simple perforations, both terminal and lateral, are present. The lumina contain a small amount of resinlike material, but are permeable to alcohol. The rays are homogeneous, 1-2 cells wide and 1-16 cells high. The fibers are long, straight, and rather thick-walled in the late-wood. Wood-parenchyma is sparingly developed. Strands of short crystal-cells are common.

**Zanthoxylum dipetalum** Mann. var.  $\beta$  Hbd. Material xc:77:1488.

This variety differs from species in having 3 foliate leaves instead of 5-7 foliate. It is endemic and occurs on one of the leeward slopes of the island of Hawaii.

## CROSS SECTION

*Gross.*—The wood is dull grayish-white, rather soft and brittle. The growth-rings are defined by zones of wood-parenchyma. The vessels are small, visible with lens, and mainly isolated or in groups of twos. The rays are slightly broader than in the species. The vessels and other elements contain comparatively little resinlike material, and the vessels are readily permeable to alcohol.

*Minute.*—In other points, the wood of the variety is distinguished from that of the species in having relatively thick-walled tracheae, short, thin-walled fibers, and wood-parenchyma in zones  $7\pm$  cells wide. The rays are  $3+$  cells wide instead of 2; the ray-cells are shorter and relatively thin-walled.

**Zanthoxylum dipetalum** Mann., var.  $\gamma$  Hbd.

This variety is endemic to Kauai, occurring on the dry leeward slopes. It reaches a height of 30 feet and a D. B. H. of 1 foot. It occurs at elevations of 3,600-4,000 feet, in association with *Bobea mannii*, *Elaeocarpus bifidus*, *Tetraplasandra waimeae*, and other xerophytic species.

The wood resembles that of the species in gross characters, except that it is possibly of a duller luster and harder. Permeability to alcohol is nearly the same. No differences were discovered

in the structural characters sufficient to separate the variety from the species; though, in the material examined, the walls of the tracheae and possibly of the fibers were slightly thicker; also, the fibers of the variety were more curved and intercrossed, and more resinlike material was present in the elements.

***Pelea sandwicensis* Gray.** ALANI. Material, xcvi:44:1492.

*Melicope*

The alani is a small tree endemic to Oahu, growing to a height of 30 feet in the rain forest at elevations of 2,000 to 2,500 feet.

The wood is rather soft, yellowish-white in color, diffuse porous, of fine even texture, without growth-rings, wavy-grained, and tough. It was formerly used by the natives for tapa beaters.

CROSS SECTION

*Gross.*—The vessels are small, visible with lens, mainly isolated or in twos, without tyloses or other contents (or may contain resinlike contents), and readily permeable to alcohol. The rays are visible with a lens, and somewhat smaller than the vessels. Faint tangential lines of wood-parenchyma are visible with a lens.

*Minute.*—The vessels, where isolated, are generally elliptical in outline and uniform in size ( $0.12 \pm$  mm.). A large number are grouped radially in twos, or rarely three or more. Some of the vessels are adjacent tangentially and lateral perforations are present. Those in groups are somewhat variable in size but only slightly compressed. The rays are straight, 1-4+ cells wide and composed mostly of radially elongated cells, with numerous elliptical pits 0.003 mm. in diameter. The fibers are polygonal in outline, irregular in arrangement, medium thin-walled, and with large open lumina. Numerous, medium-sized, bordered pits are present in radial and tangential walls. Wood-parenchyma cells are of nearly the same diameter as the fibers but thin-walled and distributed in tangential lines, one to several cells wide at irregular but mostly distant intervals. The vessels are mostly in contact with wood-parenchyma.

RADIAL SECTION

*Gross.*—The wood is wavy-grained; vessels, rays, and bands of wood-parenchyma are visible with a lens, but not prominent. A few vessels contain an amber-colored resinlike substance. The surface has a silky luster.

*Minute.*—The vessel segments are of irregular length but mostly short and barrel-like in shape. The end-walls are irregularly transverse and oblique; the perforation is circular and generally much smaller than the mean diameter of the vessel lumen. The pits are subcircular in outline with lenticular orifices, either bordered or semibordered, and of nearly

uniform size even in contact with ray-cells. The rays are indistinctly heterogeneous, composed mainly of cells with slight radial elongation or nearly square at the margin of the ray. The walls bear numerous sub-circular pits of variable diameter up to 0.009 mm. In contact with the vessels, the pits are nearly crowded, and of uniform diameter. The wood-parenchyma cells are  $0.12 \pm$  mm. in length and pitted like the ray-cells. The fibers bear prominent narrowly bordered pits with open slitlike orifices.

#### TANGENTIAL SECTION

*Gross.*—The grain is wavy. The rays, parenchyma bands, and vessels are visible with lens but not prominent.

*Minute.*—The rays are narrowly elliptical or linear in outline, and acute, 1-4+ cells wide, and 1-40+ cells high. The cells are mainly elliptical in outline and of somewhat variable size. The marginal cells show a slight axial elongation. The fibers bear numerous pits on the tangential walls.

#### MACERATION

The vessel segments are of variable short length, commonly with bulging central portions. The pit markings are of uniform size but variously grouped. The fibers are of medium length and taper irregularly from near the middle.

#### DISTINGUISHING CHARACTERS

The wood is rather soft, diffuse porous, yellowish-white, and without growth-rings. The vessels are visible with a lens, isolated or in small groups, and composed of short irregular segments with simple perforations. The lumina are mostly empty and readily permeable to alcohol. The rays are heterogeneous, 1-4 cells wide, and 1-40 cells high. Wood-parenchyma occurs in irregular zones and surrounding the vessels. The fibers have slightly thickened walls with narrowly bordered pits.

**Melicope cinerea** A. Gray, var.  $\delta$  Hbd. MANENA.

*Pelca cinerea* (Gray) Hbd.

Material, xcvi:83:1493.

The species is endemic to Hawaii. There are many varieties, mostly of xerophytic habitats. Hillebrand's variety  $\delta$  is from Hawaii, grows at elevations of 2,000 feet, and is small and shrubby.

The wood is straight-grained, of fine even texture, yellowish-white with black streaks, rather soft, and without very distinct growth-rings.

#### CROSS SECTION

*Gross.*—The vessels are small, visible with lens, and mostly grouped 2-8+ radially. The lumina are open and permeable to alcohol. The rays are smaller than the vessels and visible with a lens. Numerous fine

broken tangential lines are distinctly visible with lens or barely visible without.

*Minute.*—The vessels are mostly slightly flattened by radial contact. Tangential groupings and lateral perforations are uncommon. The diameter is fairly constant ( $0.05 \pm$  mm.). The vessels are mostly in contact with wood-parenchyma and fibers. The rays are 1-2+ cells wide, the cells not greatly elongated, the walls minutely pitted. Wood-fibers are polygonal in outline, of small diameter, the walls  $0.006 \pm$  mm. in thickness, and the lumina rather small. A few fibers have an inner layer which stains with safranin. Simple or very narrowly bordered pits are present in the radial and tangential walls. Wood-parenchyma cells are of nearly the same diameter as the fibers but thin-walled and are arranged (a) in terminal zones  $2 \pm$  cells wide, and more or less compressed, defining the growth-rings; (b) in numerous irregular tangential lines one or more cells wide; (c) in contact with the vessels.

#### RADIAL SECTION

*Gross.*—The rays are low, visible but not prominent without a lens. Fine vertical bands of wood-parenchyma are visible with lens.

*Minute.*—The vessels have parallel sides, segments  $0.7 \pm$  mm. in length, and simple circular perforations nearly as large as the vessel lumen. The pits are very small, bordered, or, in contact with ray- or wood-parenchyma, semibordered, and are of uniform size with short, lenticular orifices. The rays are composed of cells with slight radial elongation except at the ray-margins and in the few uniseriate rays, in which the cells are generally nearly square or slightly elongated axially. The walls are thin, bearing numerous minute circular pits, and only in contact with vessels are of slightly large outline. The wood-parenchyma zones are numerous and, for the most part, one cell wide, though some zones are two or more cells wide.

#### TANGENTIAL SECTION

*Gross.*—The wavy growth-ring lines are visible but not prominent. The rays and wood-parenchyma are visible with lens.

*Minute.*—The rays are linear or narrowly elliptical in outline, acutely pointed, 1-2+ cells wide and 1-20+ cells high. The cells are mostly elliptical in outline and uniform in size or slightly elongated vertically at the margin or in the uniseriate rays.

#### MACERATION

The vessel segments are cylindrical, of nearly uniform length and shape, and often with broad projecting tapering ends. The pit markings are small, uniform in size, and with short lenticular or circular orifices. The fibers are  $1.3 \pm$  mm. in length, of small diameter, and taper from near the middle into thin sharp points. The pits are minute and absent near the ends.

#### DISTINGUISHING CHARACTERS

The wood is yellow, rather soft, and straight-grained. The vessels are small, visible with lens, mainly grouped 2-8+ radially, have large simple

perforations and are readily permeable to alcohol. The rays are 1-2 cells wide and 1-20+ cells high. The fibers are rather thick-walled, and bear simple or very narrowly bordered pits. Wood-parenchyma is abundant and occurs in numerous tangential lines, in zones terminating the growth-rings, and in contact with vessels.

**Platydesma campanulatum** Mann. PILO KEA.

Material, lxxxvii:x16:1484.

The genus is endemic to Hawaii. *P. campanulatum* is a small tree, 20 feet high, on the windward side of Oahu and other islands of the group. The species is the type of the genus, and has a number of varieties the floral characters of which have been described by Hillebrand (9) and Rock (18).

The dry wood is soft, dull whitish-yellow in color, or blued by fungi, and is without macroscopic growth-rings.

CROSS SECTION

*Gross.*—The vessels are diffuse, small, visible with lens, not numerous, and mainly grouped in small radial rows. The lumina are open and readily permeable to alcohol. The rays are as broad or broader than the vessels.

*Minute.*—The vessels are grouped 2-5+ radially together or a few isolated. Many vessels are adjacent tangentially, and lateral perforations are present. The diameter is variable but as a rule not more than 0.12 mm. The rays are 1-4+ cells broad and composed of thin-walled cells with numerous minute circular pits. The fibers are medium thin-walled, arranged in regular radial rows, and bear numerous simple pits in the radial walls. Wood-parenchyma cells are of nearly the same diameter as the fibers, but thin-walled, and distributed partly in indistinct narrow tangential lines, and partly around the vessels. Growth-rings are indistinctly indicated by narrow zones of terminal, slightly compressed, wood-parenchyma.

RADIAL SECTION

*Gross.*—The vessels are composed of segments which are  $0.4 \pm$  mm. in length, and generally constricted near the ends. The end-walls are transverse or, more commonly, slightly oblique. The terminal perforations are circular or elliptical in outline and smaller than the vessel lumen. Lateral circular or elliptical perforations are very common. The pits in the common wall between vessels are bordered and of small diameter with short, open, lenticular orifices. The most common pit or the prevailing type communicating with the adjacent ray- or wood-parenchyma cells is the true annular half-bordered pit (see p. ....), which is more variable in size than other types and is sometimes  $0.006+$  mm. in diameter. The rays are imperfectly heterogeneous and generally have radially elongated cells except at the margin of the wide rays or in the uniseriate rays where the cells are nearly square in outline or elongated axially. The pits are numerous, subcircular, and from 0.001 to  $0.006+$  mm. in diameter. The radial walls



of the fibers possess numerous simple or narrowly bordered pits with lenticular or slitlike orifices. The wood-parenchyma cells are long ( $0.2+4$  mm.) with small pits  $0.003\pm$  mm. in diameter.

#### TANGENTIAL SECTION

*Gross.*—The surface is of nearly uniform texture. Structural details are not prominent even under a lens.

*Minute.*—The rays are mostly narrowly elliptical in outline, 1-4 cells wide and 1-40+ cells high. The cells are polygonal in outline and low except in the uniseriate rays or at the ray-margins, where moderately elongated cells occur. The fibers bear few or no pits in the tangential walls.

#### MACERATION

Many vessel segments terminate beyond the perforation in a tracheid-like end as in *Cyathodes* (fig. 9, *a*). The pit markings are variable in size, shape, and arrangement. The fibers are rather long, straight, pitted on the radial surface except at the short tapering ends.

#### DISTINGUISHING CHARACTERS

The wood is soft, dull whitish-yellow in color, and without macroscopic growth-rings. The vessels are small, visible with lens, diffuse, grouped radially 2-5+ together, have simple perforations and open lumina permeable to alcohol. The pits are bordered or annular half-bordered. The rays are 1-4 cells broad and 1-40+ cells high. The fibers have slightly thickened walls with pits in the radial sides. Wood-parenchyma is abundant and in contact with vessels, or in fine broken tangential rows, or in narrow terminal growth-ring zones.

#### Family EUPHORBIACEAE

This family consists of over 200 genera of wide distribution in the temperate and tropical climates. Five genera occur in Hawaii.

The vessels vary in arrangement and size. Both scalariform and simple perforations occur, and the pits may be either small or large in contact with the rays. The common wall between vessels may bear scalariform-bordered pits. The wood-prosenchyma may be thick- or rather thin-walled and mucilaginous fibers may occur. In species with relatively thin-walled fibers, septae are often found. Wood-parenchyma is sparingly developed.

***Aleurites moluccana*** (L.) Willd. KUKUI or CANDLENUT.

Material, xxviii:x6:1511.

There are 3 to 5 species belonging to this genus. *Aleurites moluccana* is one of the largest and most common trees in Hawaii,

and is thought to have been introduced at an early date by the Hawaiians from the Southern Pacific where it is abundant. Outside of the islands of Hawaii it is widely distributed in the warm portions of the Old World, West Indies, and Brazil. It grows at elevations of 2,200 feet under both wet and dry conditions and reaches a height of 80 feet with a diameter of several feet. The nuts yield an oil which was formerly used for burning in stone lamps or in torches. A dye was extracted from the fruit and used in tattooing.

The wood is whitish or dark from the action of fungi, straight-grained, even textured, and without evident growth-rings.

#### CROSS SECTION

*Gross.*—The vessels are without tyloses, scarcely visible without lens, much wider than the rays, diffuse, arranged partly in small radial groups and partly isolated. The rays are fine, visible only with a lens.

*Minute.*—Growth-rings are indicated by partial compression of the prosenchyma. Part of the vessels are partly isolated and circular in outline, and partly grouped, generally in a radial direction, 2-5+ together, and many four sided. The diameter is rather uniform and  $0.15 \pm$  mm. The walls are thin ( $0.004$  mm.). The rays are uniseriate and curve slightly near vessels. The cells are generally not greatly elongated. The prosenchyma is thin-walled ( $0.004 \pm$  mm.), irregularly polygonal in outline, with large lumina. Growth-rings are indicated by zones of tangentially compressed cells. The pits are small with very narrow borders. Wood-parenchyma is rather abundant, paratracheal and metatracheal in distribution. Generally the paratracheal cells are arranged in one row. The metatracheal cells are diffuse.

#### RADIAL SECTION

*Gross.*—The vessels are barely visible without lens. The rays are low, visible without lens; the wood is straight-grained.

*Minute.*—The vessel segments are  $0.5 \pm$  mm. in length, and have simple perforations which are both terminal and lateral in position. The pits are generally large ( $0.015 \pm$  mm.) in diameter, semibordered, elliptical or circular in outline, with open lenticular orifices. The rays are thin-walled, and composed of cells most of which are somewhat elongated axially. A few, generally near the middle portion, are somewhat elongated radially. Some of the cells contain single mineral crystals. The walls in contact with parenchyma have numerous, somewhat clustered, subcircular pits of medium size ( $0.004 \pm$  mm.), or large, elliptical, semibordered pits ( $0.15 \pm$  mm.) where in contact with vessels. The prosenchyma is nonseptate and bears numerous small bordered pits with oblique lenticular orifices exceeding the border. The wood-parenchyma around vessels consists of rather short cells  $0.06 \pm$  mm. in length. The diffuse cells are about twice this length. The

pits are  $0.004 \pm$  mm. in diameter and usually clustered. Some cells contain one or more mineral crystals but short crystal-parenchyma is not present

#### TANGENTIAL SECTION

*Gross.*—The rays are visible with lens. The vessels may be seen in good light without lens.

*Minute.*—The common walls between vessels have large circular bordered pits with transverse open lenticular orifices. The rays are uniseriate for the most part and made up of axially elongated cells. Short portions of the rays may be two cells wide, and these are little if at all elongated.

#### MACERATION

The prosenchyma fibers are of medium length ( $1.7 \pm$  mm.) and taper from near the middle. The pit markings are minute, with oblique slitlike orifices. The ends of the vessel segments are transverse or somewhat oblique, and some are provided with a short tonguelike projection.

#### DISTINGUISHING CHARACTERS

The wood is soft, whitish, diffuse porous, even textured, straight-grained, and without macroscopic growth-rings. The vessels are without tyloses, and have large simple perforations on both terminal and lateral walls. The pits are large, elliptical, and semibordered in contact with parenchyma or of the same size and circular-bordered with lenticular orifices. The rays are 1-2 cells wide, 1-20+ cells high and irregularly homogeneous. The wood-parenchyma is abundant, paratracheal and metatracheal in distribution. A few cells contain one or more crystals. The prosenchyma is rather thin-walled, nonseptate, small pitted, and of medium length, tapering from near the middle.

***Euphorbia rockii*** Forbes. Koko. Material, xxix:36:1513.

There are more than 600 species belonging to this genus, distributed in warm climates. The species, three of which are arborescent, are endemic to Hawaii. *Euphorbia rockii* is endemic to Oahu, and is typical of the rain forest at elevations of 2,000 feet in association with *Pittosporum glomeratum*, *Straussia*, and *Pterotropia gymnocarpa*. It reaches a height of 15-20 feet and a D. B. H. of 8 inches. The wood is soft, resinous, whitish-yellow, streaked with brown or blue-black, even textured, without growth-rings, and rather straight-grained.

#### CROSS SECTION

*Gross.*—The vessels and rays are visible with lens, diffuse, and mostly in radial groups. The rays are narrow and indistinct even under a lens.

*Minute.*—The vessels are rather uniform in size ( $0.09 \pm$  mm.) and

grouped, for the most part, 2-8 radially together. A few are isolated. Many lateral perforations occur in the common radial wall of tangentially adjacent vessels. The vessel cavities are without tyloses; the walls are of medium thickness ( $0.004 \pm$  mm.). The rays are uniseriate, and composed of but slightly elongated cells. The walls bear numerous medium-sized pits  $0.003 \pm$  mm. in diameter. The prosenchyma cells are 4-6 sided, irregular in shape and size, and arranged in indistinct radial rows. The walls are of medium thickness,  $0.004 \pm$  mm., and in some specimens contain one or more inner layers which separate when sectioned. The lumina are open and the walls pitted on all sides. Wood-parenchyma consists of a few cells in contact with the vessels.

#### RADIAL SECTION

*Gross.*—The rays are fine and indistinct without lens. The vessels are visible with lens as fine straight lines. The wood is light whitish-yellow, streaked with brown or blue-gray.

*Minute.*—The vessels generally bear coarse, irregular, circular or broadly elliptical, semibordered pits with open, lenticular orifices. The perforations are simple. The rays are composed for the most part of axially elongated cells with numerous medium-sized pits on the upper, lower, and tangential walls. The radial walls bear coarse elliptical or subcircular semibordered pits in contact with the vessels, or small and comparatively few pits where in contact with prosenchyma. The prosenchyma cells bear numerous bordered pits with vertical or oblique lenticular orifices. The wood-parenchyma is sparingly developed and consists of elongated cells in contact with the vessels. No crystals were observed.

#### TANGENTIAL SECTION

*Gross.*—The vessels are visible under a lens. The rays are fine and indistinct even under a strong lens.

*Minute.*—The common walls between vessels bear rather large sub-circular bordered pits with long lenticular orifices. The rays are uniseriate, 1-10 cells high, homogeneous, and composed, for the most part, of axially elongated cells. The prosenchyma bears bordered pits.

#### MACERATION

The vessel segments commonly show lateral perforations. Many of the ends have projecting tips of varying length and form. The prosenchyma is composed of fibro-tracheids  $1 \pm$  mm. in length, generally with parallel sides and rather short tapering irregular points. Bordered pits occur on all sides except on the tapering ends.

#### DISTINGUISHING CHARACTERS

The dry wood is soft, resinous, whitish-yellow, streaked with brown, even textured, and without growth-rings. The vessels are visible with lens, wider than the rays, without tyloses, have large bordered or semibordered pits with long lenticular orifices, and are grouped, for the most part, in

small radial rows. Perforations are simple and terminal or lateral. The prosenchyma consists of fibro-tracheids of medium length with bordered pits on all sides except at the tapering ends. Wood-parenchyma is sparingly developed and consists of a few elongated cells in contact with the vessels.

### Order SAPINDALES

#### Family ANACARDIACEAE

A family of trees, shrubs, or lianes, of mainly tropical distribution, comprising 58 genera with 420 species. The wood is characterized by narrow medullary rays, 1-4+ cells wide, which may contain resin canals (17). The vessels have simple perforations, except in *Campnosperma*, *Micronychia*, and *Anaphrenium*. Vessels have large bordered pits in contact with vascular elements or large simple or semibordered pits, elliptical in outline, when in contact with ray- or wood-parenchyma. Spiral thickenings occur in the vessels of *Pistachia* and in *Rhus semialata* var. *sandwicensis*.

The family is represented in Hawaii by *Rhus semialata* Murr. var. *sandwicensis* Engl. The variety differs from the species in having the rachis of the leaf not winged and is peculiar to Hawaii. The species occurs in the Himalaya Mountains.

#### ***Rhus semialata* Murr., var. *sandwicensis* Engl.**

This is a tree 15-25 feet high and less than 1 foot D. B. H., occurring on lowlands at elevations of 600-2,000 feet. Wood is yellowish-gray with hard, dark-colored, resinous streaks, with a dull luster, light, fairly soft, but moderately tough, and contains abundant amber-colored resin, plainly visible, especially with a lens, which comes to the outside and covers the cut surface of dried wood. It is used for plows. By reason of its numerous tyloses it is the slowest of all the species investigated to become water-soaked and sink, and its value for special uses requiring imperviousness approaching that of cork is suggested.

#### CROSS SECTION

*Gross.*—The wood is indistinctly ring-porous with large vessels numerous in early-wood, and becoming gradually smaller and fewer in late-wood. They generally occur singly, but may be compactly grouped radially 2-4 or more together. Tyloses are abundant. The medullary rays are scarcely visible without lens.

*Minute.*—The vessels are isolated and subcircular in outline, or grouped compactly, commonly in radial rows, 2-4 or in late-wood 2-8 together, and tangentially flattened. The lumina are large in early-wood, 0.27 mm. in diameter, and diminish gradually to 0.03 mm. in late-wood; the vessel walls are thin, 0.003 mm. in thickness, and the lumina filled with numerous, tightly crowded tyloses. Tracheids appear with small cavities  $0.03 \pm$  mm. in diameter in outer late-wood, grouped radially and tangentially with small vessels 2-10 or more together.

The rays are resinous, 1-4 cells wide, bending slightly around the vessels; both upright and procumbent cells are elongated in early-wood, shortened in late-wood, and contain crystals. The early-wood fibers have thin walls (0.002 mm.), large lumina, and many contain an inner, separating layer which stains but slightly. The late-wood fibers are tangentially compressed, have thicker (0.004 mm.) walls, and are strongly lignified. The wood-parenchyma is vasicentric and 1-2 cells deep.

#### RADIAL SECTION

*Gross.*—The fibers are yellowish-gray with dull luster. The rays appear as fine and blackish lines. The vessels are filled with tyloses and dark-colored material.

*Minute.*—The vessels bear large bordered pits 0.009 mm. in diameter, rounded or hexagonal in outline, when in contact with vascular elements, or large semi-bordered pits, elliptical in outline and 0.015 mm. in diameter when in contact with parenchyma cells. Tyloses are abundant. Spiral thickenings occur in the smaller vessels. Spirally thickened tracheids  $0.03 \pm$  mm. in diameter are present in late-wood. The rays are heterogeneous, resinous in heartwood, and bear numerous pits in upper, lower, and tangential walls. The radial walls form large, elliptical, semibordered pits in contact with vessels. In contact with prosenchyma the pits are few, minute, and not visible except in favorable sections under high-power magnification. The wood-parenchyma cells are thin-walled,  $0.1 \pm$  mm. long and slightly greater in diameter than the fibers. The pits are commonly large and irregularly elliptical (0.015 mm. in diameter) or, less frequently, minute. The prosenchyma fibers contain both thin and thick transverse resin plates often deep blackish-brown in color. The radial walls bear minute pits which may best be observed in thin, unstained sections mounted in alcohol.

#### TANGENTIAL SECTION

*Gross.*—Medullary rays are visible under lens. The light early-wood zones are in marked contrast to the deeper colored late-wood.

*Minute.*—The medullary rays are 1-4 cells wide and  $0.01-0.4+$  mm. or 1-30+ cells high. Radial walls of ray cells are minutely pitted except in contact with vessels. The vessel segments are cylindrical, but plane of perforation is generally inclined.

#### MACERATION

The vessel segments are cylindrical, often project at the ends, and are 0.25-0.75 mm. long with slightly constricted ends. The perforations are

simple. The fibers are long,  $1 \pm$  mm. in length, rather evenly tapering toward either end, and not conspicuously pitted. Tracheids with spirals,  $0.3 \pm$  mm. long,  $0.03 \pm$  mm. in diameter, are numerous.

#### DISTINGUISHING CHARACTERS

The wood is rather soft, grayish-yellow, resinous, and imperfectly ring porous. The vessels are large, have simple perforations, and are filled with tyloses. The rays are 1-4 cells wide and generally less than 0.5 mm. high, heterogeneous, contain crystals, and bear numerous fine simple pits on the upper, lower, and tangential walls, and on radial walls when in contact with vessels. The fibers are minutely pitted, thin-walled, nonseptate, and many resiniferous.

#### Family AQUIFOLIACEAE

This family of woody plants of mainly temperate distribution, comprises 176 species, belonging, for the most part, to the genus *Ilex*. Familiar representatives of North America are species of *Ilex* and *Nemopanthus*.

The secondary wood is characterized by vessels with scalariform perforations and bordered or semibordered pits. Spirals may occur in the vascular elements and some in the prosenchyma. The fibers have bordered pits. The rays are 1-4 or more cells wide.

***Byronia sandwicensis*** Endl. KAWAU or AIEA.

*Ilex sandwicensis* (Endl.) Loes

Material, XIX:24:1424.

This is a small tree, 20-40 feet high, 12 inches or less D. B. H., and one of the most common trees in the rain forest throughout Hawaii. Associated with it are *Perrottetia sandwicensis*, *Cheiropodendron gaudichaudii*, and *Elacocarpus bifidus*.

The wood is light grayish-yellow with a narrow zone of slightly lighter colored sapwood, soft, diffuse porous, without growth-rings, and is used for saddletrees.

#### CROSS SECTION

*Gross*.—The pores are small, barely visible without lens, occurring singly or irregularly grouped 2-4 together without tyloses. The rays are broad, easily visible without lens, as wide as the largest pores or larger, and light-colored.

*Minute*.—The vessels are either isolated and nearly circular in outline or grouped 2-4+ together, radially or irregularly, and moderately compressed; the diameter is variable but rarely exceeds 0.16 mm. The vessel

walls vary in thickness from 0.015 to 0.006+ mm. The lumina contain a few tyloses. The rays are 1-10+ cells broad, and numerous pitted. The prosenchyma cells are irregular in arrangement and shape, thick-walled (0.009± mm.), with numerous bordered pits. Wood-parenchyma is diffuse, thin-walled (0.002 mm.) and without resin or mineral crystals.

#### RADIAL SECTION

*Gross.*—The surface has a slight variation in texture due to the presence of broad rays.

*Minute.*—The vessels are straight, composed of segments  $1.8\pm$  mm. in length and bear greatly elongated, elliptical or scalariform, bordered or semibordered pits. The perforations are scalariform and composed of  $45\pm$  bars. The broad rays are heterogeneous, the cells of the wide portion being greatly elongated radially, and low axially. Cells at the margin or in the uniseriate rays or uniseriate portions of mixed rays are short radially and high axially. The walls are thin and numerous pitted. Such pits are small except where in contact with vessels, where scalariform pits occur. The uniseriate rays are homogeneous. The prosenchyma cells bear numerous bordered pits with slitlike orifices. Wood-parenchyma cells are diffuse, about five times as long as wide, empty or with resinlike contents, and bear numerous small pits, generally with circular or elliptical outlines.

#### TANGENTIAL SECTION

*Gross.*—The tangential surface is grayish-yellow and of even texture. Broad rays are visible without lens. Under lens the broad rays are numerous, about twice their width apart, many bluish in color.

*Minute.*—The vessels curve around the broad rays, and bear mostly scalariform pits. The rays are of three types: (1) uniseriate, (2) uniseriate in part, and (3) multiseriate. Cells in the uniseriate rays or the uniseriate part of the mixed rays are axially elongated. Those in the multiseriate rays or the multiseriate portion of the mixed rays are predominantly low and subcircular in outline. The rays are 1-10+ cells broad and up to 4.3+ mm. in height. The prosenchyma cells have vertically inclined slitlike bordered pits and are nonseptate.

#### MACERATION

The elements are free from spiral markings. The vessel segments are cylindrical, very long ( $1.8+$  mm.), and terminate in oblique ends. Pit markings are usually scalariform, but elliptical or subcircular outlines with lenticular or slitlike orifices occur. The prosenchyma fibers are very long, sometimes 2.85 mm. in length, 0.05 mm. in diameter, thick-walled (0.009± mm.), attenuate from about one-fourth their length, bear numerous broadly bordered slitlike pits, and have no spirals such as found in *Ilex opaca*. The tracheids are  $1.62\pm$  mm. long with irregularly pointed ends, thick walls (0.009± mm.) and are pitted with scalariform, elliptical, or circular pits, the latter with narrowly lenticular orifices.



## DISTINGUISHING CHARACTERS

The wood is light-colored, rather soft, diffuse porous and without growth-rings. The elements are without the spiral thickenings prevalent in the genus *Ilex*. The vessels are barely visible without lens, thin-walled, without tyloses, with scalariform pits and scalariform perforations. The rays are uniseriate, uniseriate in part, or multiseriate, and 1-10 cells broad and up to 4+ mm. high. The ray-cells are finely pitted, except in contact with vessels, where scalariform pits occur. The prosenchyma fibers are long and bear bordered pits. Wood-parenchyma is fairly abundant and diffuse in distribution.

## Family CELASTRACEAE

The Celastraceae are a family of trees, shrubs, and woody climbers of wide distribution. The climbing bitter sweet, *Celastrus scandens*, is a common American representative of this family.

The wood, as far as investigated (17), is characterized by vessels varying between 0.027 and 0.75 mm. Perforations are usually simple, but scalariform perforations also occur, either exclusively or along with simple perforations. The rays are of varied breadth, from 1-6 cells. The pits are bordered, and spiral thickenings occur in *Euonymus europaeus* L. The wood-prosenchyma generally has bordered pits, but simple pits occur; the lumina are wide. Wood-parenchyma is generally paratracheal.

***Perrottetia sandwicensis* A. Gray. OLOMEA.**

Material, xxi:x9:1410.

A shrub or tree 10-18+ feet in height. Common in the northeastern part of Maui, forming forests of nearly pure growth at elevations of 6,000± feet. It is common in the rain forests of all the islands of Hawaii but is sometimes found in the dry forest.

The wood is yellow brown in color, fairly soft, straight-grained, and without growth-rings. The wood was used to produce fire by friction. Two sticks were used: the upper, *Perrottetia*; the lower, *Hibiscus tiliaceus*.

## CROSS SECTION

*Gross.*—The rays and especially the vessels are not visible without lens. The surface shows no variation in color or structure to the naked eye. Under lens the rays are numerous and narrow, have a reddish color but do not differ greatly in color from the fibers. The pores are minute,

less in diameter than the width of the widest rays, very numerous, and diffuse.

*Minute*.—Vessels are rounded polygonal in outline, numerous, forming approximately half of the volume of the wood, generally single, occasionally grouped 2-6+ together, without tyloses, or other contents, small (0.066 mm.) in diameter, of nearly uniform size, and thin-walled (0.003 mm.). The rays are 1-6 cells wide. The cells contain resin, and are numerous pitted with small lenticular pits of uniform size, arranged in radial rows. The prosenchyma fibers are polygonal in outline, with wide lumina, and walls of medium thickness (0.003 mm.) with numerous bordered pits in the radial walls. The wood-parenchyma cells are very few and in contact with the vessels.

#### RADIAL SECTION

*Gross*.—Rays plainly visible without lens, reddish in color, and about 2 mm. in extreme height. The pores, under a lens, are small, straight, and very numerous, forming a large portion of the mass of woody tissue. The wood is straight-grained.

*Minute*.—The vessels have nearly parallel sides and have scalariform semibordered pits in contact with the ray-cells. The segments are long ( $1.3 \pm$  mm.), rather uniform in length, and have oblique end-walls with scalariform perforations composed of numerous fine bars (45+). The rays are composed partly of tubular cells  $0.03 \pm$  mm. high and somewhat elongated radially, and partly of cells  $0.03 \pm$  mm. radial diameter and elongated axially. The cavities contain a resinlike material. The radial walls in contact with prosenchyma have few small semibordered pits. The walls adjacent to vessels bear rows of elliptical or subcircular pits opposite each scalariform pit-cavity of the vessel. The prosenchyma fibers contain numerous resin plates resembling septae. The bordered pits are numerous, scattered, and have obliquely crossed, lenticular orifices.

#### TANGENTIAL SECTION

*Gross*.—To the naked eye there are no visible differences of color or structure. Under a lens, the vessels are minute, numerous, and straight; the rays are faint, reddish, narrowly linear in outline, and acutely pointed.

*Minute*.—Vessels are characterized by scalariform, elliptical, and circular-bordered or semibordered pits with lenticular and usually transverse orifices. The rays are highly resiniferous, 1-6 cells wide, and 1-45+ cells high. The cells vary from 0.03 to 0.09+ mm. in height, the higher cells occurring generally in the uniseriate marginal portions. The broad rays are irregularly heterogeneous.

#### MACERATION

The fibers are septate, numerous pitted on the radial walls except the short, irregular, tapering points, which are unpitted. The vessels are separated with difficulty from the fibers.

## DISTINGUISHING CHARACTERS

The wood is yellow-brown, fairly soft, and without growth-rings. The vessels are diffuse, generally single, uniform in size, very small, numerous, without tyloses, and pitted with scalariform, elliptical or circular-bordered pits. The perforations are scalariform and composed of numerous fine bars. The rays are irregularly heterogeneous, 1-6 seriate and 1-45+ cells high. The cells contain resin, and are generally pitted with rows of elliptical pit cavities communicating with the adjacent scalariform pit-cavity of the vessel. The fibers are septate, contain resin-like plates, and have numerous bordered pits on the radial walls, except for the short attenuate points. Wood-parenchyma cells are few, occur in contact with vessels, and contain resin.

## Family SAPINDACEAE

This family comprises 1,000 species of mainly tropical distribution. In Hawaii four genera occur.

The wood, according to Solereder, is in some species characterized by vessels with simple perforations or scalariform perforations near the primary xylem. Spiral thickenings are found in some genera. The pits are either bordered or semibordered. The wood-prosenchyma bears simple pits. The rays are 1-4 cells broad. Wood-parenchyma is not abundant.

**Sapindus saponaria** L. A'E, SOAPBERRY.

*Sapindus thurstonii* Rock

Material, ciii:80:1486.

The name *S. thurstonii* was applied to the Hawaiian form by Rock, who, on further consideration, concluded that the Hawaiian form is not specifically different from the American, *S. saponaria*. The Hawaiian a'e reaches a height of 80 feet and a diameter of 6 feet and grows at elevations of 4,000 feet. The wood is grayish-white streaked with black, soft, diffuse porous, without growth-rings, and straight-grained.

## CROSS SECTION

*Gross.*—The vessels are barely visible without lens, mainly isolated, elliptical in outline, and surrounded by wood-parenchyma, which extends in wavy tangential lines as wide or wider than the vessels. The lumina are mostly open and readily permeable to alcohol. The rays are barely visible without lens and much smaller than the vessels.

*Minute.*—Some of the vessels are grouped compactly two or more radially or, rarely, tangentially. The diameter is variable, but rarely exceeds

0.25 mm. Some of the lumina contain a resinlike or gummy material which stains deeply with safranin. The rays are 1-4 cells wide, and bend around the vessels. The cells are greatly elongated, and the walls finely pitted. The fibers are rounded polygonal in outline, with moderately thickened walls, and are irregularly arranged. Simple pits are present in radial and tangential walls. The wood-parenchyma cells are of somewhat larger diameter than the fibers, thin-walled, surround the vessels, and form numerous tangential wavy zones  $10 \pm$  cells wide. The rays widen in the parenchyma zones.

#### RADIAL SECTION

*Gross.*—A few of the vessels contain an amber-colored material and appear as yellow streaks. The rays are low and not prominent. Alternating bands of wood-parenchyma are visible with lens.

*Minute.*—The vessel segments are short; the pits are numerous, semi-bordered or bordered, and have lenticular or slitlike orifices; the perforations are simple and as large as the vessel lumina. The prolonged parallel pit orifices produce a spirallike effect. The rays are homogeneous; the cells low, greatly elongated radially, and finely pitted. The prosenchyma bears small simple pits in the radial walls. Wood-parenchyma cells are  $0.15 \pm$  mm. in length, of slightly larger diameter than the fibers, and with circular or elliptical pits  $0.003 \pm$  mm. in diameter. A few strands of short crystal-parenchyma are present.

#### TANGENTIAL SECTION

*Gross.*—Faint wavy zones of wood-parenchyma and a few vessels with yellow contents are visible without lens.

*Minute.*—The rays are elliptical in outline, with acute ends, mainly 3 or 4 cells wide, and up to  $35+$  cells high; the cells circular in outline, uniform in size with moderately thin walls.

#### MACERATION

The vessel segments are of variable short length, the pit markings slit-like, the perforations simple and as large as the vessel lumen, and the ends commonly without projections. The fibers are  $1.5 \pm$  mm. long, pitted in the central portion, and taper gradually into long, delicate, very sharp, unpitted ends.

#### DISTINGUISHING CHARACTERS

The wood is grayish-white, soft, diffuse porous, without growth-rings, and straight-grained. The vessels are visible without lens, and mainly isolated. The perforations are simple, and the lumina generally without contents and readily permeable to alcohol. The rays are homogeneous, 1-4 cells wide and up to  $35+$  cells high. Wood-parenchyma is abundant and present in numerous tangential bands, visible, in cross section, without lens. Crystal-parenchyma is present. The fibers are medium thick-walled and provided with simple pits.

**Dodonaea viscosa** L. AALII. Material, civ:x25:1480.

*Dodonaea* is largely an Australian genus. *D. viscosa* is a cosmopolitan species of wide distribution in the Tropics, and occurs in Hawaii at elevations from 1,000 to 4,000 feet. It is a small gregarious tree, reaching a height of 25 feet and a D. B. H. of 10 inches.

The dry wood is diffuse porous, reddish-brown in color (black heartwood), very hard, cross-grained, and without distinct growth-rings.

#### CROSS SECTION

*Gross.*—The vessels are visible with lens, isolated or in small groups. The rays are smaller than the pores, visible with lens. Fine irregular tangential lines of wood-parenchyma are barely visible without lens. The wood is not readily permeable to alcohol.

*Minute.*—The vessels are circular when isolated or compressed by contact, and variable in size but not commonly larger than 0.1 mm. in diameter. The walls are medium thin. The rays are 1-2+ wide and filled with a resinlike material. The fibers are polygonal in outline, very thick-walled, and have very small lumina. Wood-parenchyma cells are of nearly the same diameter as the fibers, but thin-walled, mostly filled with resinlike material, and surround the vessels or occur in irregular tangential lines from 1-15+ cells in breadth.

#### RADIAL SECTION

*Gross.*—Rays and bands of wood-parenchyma are visible with lens and contain a reddish resinlike material.

*Minute.*—The vessels have small bordered or semibordered pits of uniform size with lenticular orifices. The perforations are simple and of nearly the same diameter as the lumen. The rays are homogeneous, and composed of radially elongated cells filled with resinlike material. Wood-parenchyma cells are  $0.09 \pm$  mm. in length when in contact with vessels, or  $0.2 \pm$  mm. in the metatracheal bands. Short crystal-parenchyma cells in strands are many.

#### TANGENTIAL SECTION

*Gross.*—The rays, wood-parenchyma, bands, and vessels are visible with lens.

*Minute.*—The rays are elliptical in outline, acutely or obtusely pointed, 1-2+ cells broad, and 1-20+ cells high. The cells are mostly rounded polygonal in outline, of rather uniform size, and filled with resinlike material.

#### MACERATION

The vessel segments are  $0.36 \pm$  mm. in length, and bear numerous lenticular pit markings of uniform size. Commonly a very short, tongue-like

tip projects from one or both ends. The fibers are  $0.9 \pm$  mm. in length, very thick-walled, and taper gradually to sharp ends.

#### DISTINGUISHING CHARACTERS

The wood is diffuse porous, reddish-brown in color, with a black heartwood, very hard, and without distinct growth-rings. The vessels are small, visible with lens, isolated or in small compact groups. The perforations are simple. The wood is very slowly permeable to alcohol. The rays are homogeneous, 1-2+ cells broad, 1-20+ cells high, and filled with a resin-like material. Wood-parenchyma, filled with resinlike material, occurs in tangential bands, and a few strands of short crystal-parenchyma cells occur. The fibers are very thick-walled.

#### Order RHAMNALES

#### Family RHAMNACEAE

The Rhamnaceae are trees, shrubs, or climbers of general distribution. The wood is characterized by vessels with simple or rarely scalariform perforations and less commonly by spiral thickenings. The pits are bordered or semibordered. Wood-parenchyma is not abundant; the wood-prosenchyma bear simple pits.

**Colubrina oppositifolia** Brongn. KAULA. Material, lxxii:5:1471

This species reaches a height of 35 feet, a D. B. H. of 12 inches, and is endemic to Hawaii. It occurs on the arid leeward side of the island of Hawaii at elevations of 2,000 feet in association with *Mezoneurum Kauaiense*, *Myoporum sandwicense*, and other xerophytic species.

The wood is deep reddish-brown in color streaked with black with narrow zone of light-colored sapwood, very hard and with a specific gravity greater than 1. Faint growth-rings are present. The wood is the most difficult of all Hawaiian woods to section. Material treated six months in strong hydrofluoric acid could not be evenly cut in thin transverse sections of large size.

#### CROSS SECTION

*Gross.*—The vessels are visible with lens, diffuse, isolated or in small groups. The lumina, in heartwood, contain a light garnet-colored substance by reason of which the wood is not permeable to alcohol. The rays are much smaller than the vessels, visible with lens.

*Minute.*—The vessels are variable in diameter but rarely exceed 0.12 mm., elliptical in outline when isolated, or moderately compressed by

contact in mostly radial groups of 2-3 or rarely up to 8. The rays are 1-2 cells broad; the walls, thin; the pits, minute and obscured by resinlike contents. The fibers are of small diameter, polygonal in outline, very thick-walled, and in regular radial arrangement. Wood-parenchyma cells are of slightly larger diameter than the fibers, and are in contact with vessels, or diffuse, or in indistinct growth-ring zones in which compressed cells occur. Cells containing solitary crystals are frequent.

#### RADIAL SECTION

*Gross.*—Resinlike material is rather abundant. The rays are small but visible without lens.

*Minute.*—The rays are composed mainly of radially elongated cells, but square or axially elongated cells occur at the margin and frequently also in other portions of the rays. The cell cavities contain a resinlike material and crystals are often observed. The walls are mostly thin but some very thick-walled cells occur. The vessels have simple perforations and pits  $0.006 \pm$  mm. in diameter, of rather uniform size and bordered or semi-bordered pits with lenticular orifices. Wood-parenchyma cells are  $0.15 \pm$  mm. in length. Strands of short crystal-parenchyma are numerous.

#### TANGENTIAL SECTION

*Gross.*—The structural characters are visible with lens. The vessels contain globules of reddish material.

*Minute.*—The rays are 1-2 cells wide and 1-23+ cells high. The biseriate cells are low, elliptical in outline, and of nearly uniform size. The uniseriate cells are axially elongated.

#### MACERATION

The vessel segments are  $0.4 \pm$  mm. in length, cylindrical, and have a large simple perforation at the end. Projecting tips or ends are not common. The fibers are mostly less than 1 mm. in length, and have long, tapering, sharp ends.

#### DISTINGUISHING CHARACTERS

The wood is reddish-brown with a narrow zone of yellow sapwood, very hard and heavy, and with faint growth-rings. The vessels are diffuse, isolated, or in small radial rows, visible with lens, with simple perforations and not permeable to alcohol in the heartwood zone. The rays are 1-2 cells wide, 1-23+ cells high, and heterogeneous. The fibers are thick-walled and arranged in radial rows. Wood-parenchyma is fairly abundant and strands of crystal-parenchyma are many.

***Alphitonia excelsa*** Reiss. KAUILA. Material, lxxi:6:1472 (35 new list).

The kauila is an indigenous tree, growing on the arid leeward side of the islands at elevations of 2,600-3,000 feet. It reaches a

height of 80 feet and a D. B. H. of 2 feet. The species occurs also in Australia, Borneo, and Polynesia.

The wood is cherry-red in color with wide (2-3 in.) light yellowish-brown sapwood, hard, and with distinct growth-rings defined by alternating light-colored zones. It was formerly used for spears.

#### CROSS SECTION

*Gross.*—The vessels are diffuse, mainly in small radial rows, and visible with lens. The lumina are open and permeable to alcohol. The rays are much smaller than the vessels, and visible with a lens. Growth-rings are defined by dark zones of hard late-wood, alternating with light-colored zones of mucilage fibers.

*Minute.*—The vessels are mainly arranged in radial rows of 2-5+ together. A few vessels are adjacent tangentially and lateral perforations are present. The diameter is rather uniform, rarely exceeds 0.14 mm. The rays are 1-2+ cells wide, the walls thin, and with minute pits obscured by resinlike material. The fibers are thick-walled and lignified in growth-ring zones which alternate with zones of fibers with a thin outer lignified wall and an interior separating layer which stains only slightly with the hematoxylin-safranin stain, and reacts, to some extent, to mucilage tests. The transition from one zone to the other is gradual. Wood-parenchyma is sparingly developed and mostly in contact with vessels. No crystal-cells were found.

#### RADIAL SECTION

*Gross.*—The rays are fine but visible by reason of their reddish contents. The lumina of the vessels are mostly without contents. Alternating growth-ring layers of light-colored mucilage fibers are prominent.

*Minute.*—The pits of the vessels are bordered or semibordered, circular in outline, with short lenticular orifices and uniform in size. The perforations are simple and nearly as large as the vessel lumen. The rays are composed mainly of radially elongated cells, but square or axially elongated cells are present at the margins and sometimes at other parts of the rays.

#### TANGENTIAL SECTION

*Gross.*—The growth-ring zones are prominent and are defined by alternating zones of light-colored mucilage fibers and dark-colored, thick-walled, lignified late-wood fibers.

*Minute.*—The rays are 1-2 cells wide and 1-40+ cells high. Most of the cells are elliptical in outline, low, and of uniform size. Marginal cells and a few others are slightly elongated.

#### MACERATION

The fibers are commonly less than 1 mm. in length, with small, oblique, slitlike pit markings, and taper gradually to long, sharp, unpitted points.



The mucilage fibers are easily distinguished from the thick-walled lignified fibers by their inner separating layer.

#### DISTINGUISHING CHARACTERS

The wood is diffuse porous, light yellowish-brown in color, hard, and with growth-rings defined by zones of light-colored mucilage fibers. The vessels are visible with lens, grouped 1-5+ together, and have simple perforations. The lumina are open and readily permeable to alcohol. The rays are 1-2 cells broad, 1-40+ cells high, and heterogeneous. The fibers are thick-walled and lignified in zones. Wood-parenchyma is not abundant.

#### Order MALVALES

#### Family ELAEOCARPACEAE

This family comprises 7 genera of general distribution in the Tropics. Constant anatomical characters are lacking in the family. Both scalariform and simple perforations of the vessels occur and spiral markings may be present or absent. The rays are from one to several cells in breadth. Simple or narrowly bordered pits occur in the wood-prosenchyma, which is generally thin-walled and often septate. Wood-parenchyma is generally present and is often found abundantly.

#### *Elaeocarpus bifidus* Hook. et Arn. KALIA.

Material, xxxi:81:1433.

The genus consists of more than 60 species of trees with only *Elaeocarpus bifidus* occurring in Hawaii. This is an endemic species, reaching a height of 40 feet and a D. B. H. of 1 foot. It is confined to wet or boggy situations at elevations of 3,500-4,000 feet, and common on Kauai in association with *Straussia*, *Bobea*, *Cheirodendron platyphyllum*, *Cryptocarya mannii*, and *Pelia*. The bast is strong and is made into cordage.

The dry wood is whitish or blue-gray, soft, fine and even textured, fairly straight-grained, and without macroscopic growth-rings.

#### CROSS SECTION

*Gross.*—The vessels are small, visible with lens, and mostly in small radial groups. The rays are visible under lens, straight, smaller than the pores.

*Minute.*—The vessels are of rather uniform diameter ( $0.12 \pm$  mm.), with few tyloses, and grouped radially 2-6 together or sometimes side by

side tangentially. A few vessels are isolated. Lateral perforations (cf. fig. 7a) occur. The rays are straight or only slightly curved, 1-4+ cells broad, and slightly resinous. The pits are numerous, subcircular, rather small, 0.001-0.004+ mm. in diameter. The prosenchyma cells have walls of medium thickness (0.004 mm.), wide lumina, and are in rather definite radial arrangement. Growth-rings are indistinctly indicated by slight compression of one or more rows. Wood-parenchyma is sparingly developed and is mostly in contact with the vessels.

#### RADIAL SECTION

*Gross.*—The vessel groups are visible without lens, appearing as brownish lines. Lateral perforations are large and may be seen with a lens. The rays are 1.± mm. high, brownish in color, resinous, and plainly visible without lens.

*Minute.*—The radial walls of the vessels bear large irregular bordered, semibordered, or simple elliptical and some greatly elongated almost scalariform pits. Large elliptical or sometimes circular lateral perforations occur. Tyloses are sometimes observed. The rays are resinous. The cells in the interior portion of the wide rays are elongated radially. Those on the sides and especially the margins, are elongated axially. Some marginal cells extend vertically into pointed cells 0.24+ mm. high with a radial diameter of 0.03+ mm. The pits on the radial walls in contact with prosenchyma have long slitlike orifices. Pits on walls of adjacent ray-cells are circular or elliptical in outline and 0.001-0.006+ mm. in diameter. Walls in contact with vessels bear irregular, commonly greatly elongated, broadly semibordered or simple pits often 0.045+ mm. in length.

The prosenchyma walls bear numerous very narrowly bordered pits with crossed lenticular orifices exceeding the border. There are no septae. The wood-parenchyma cells are few, elongated, and mostly in contact with the vessels. The sides in contact with vessels bear long, transverse, elliptical, broadly semibordered or simple pits.

#### TANGENTIAL SECTION

*Gross.*—The rays are dark-colored, fine, but visible without lens. The vessels are visible with lens.

*Minute.*—The common walls between vessels bear large irregular distinctly bordered pits that vary from circular to elliptical or even scalariform in outline. The rays are from 1-4+ cells broad and 1-24+ cells high. The cells vary greatly in outline and size, with the smallest generally on the interior of the ray and the largest and highest on the sides and margins. The tangential walls of the prosenchyma cells have fewer pits than the radial walls.

#### MACERATION

The vessel segments are variable in length, but are not often more than 0.7 mm. long. The ends are generally oblique, and the perforations simple and generally elliptical in outline. Transverse circular perforations are uncommon. A tongue-like projection of variable length is commonly

present, often from both ends of the segment. Many lateral perforations occur. The prosenchyma is composed of fibro-tracheids reaching a length of 1.4+ mm. and tapering from near the middle. The pit markings generally extend to within a short distance of the end. The pit orifices are commonly long, slitlike and oblique.

#### DISTINGUISHING CHARACTERS

The dry wood is whitish or bluish-gray in color, diffuse porous, fine and even textured, and with microscopic growth-rings. The vessels are small, not visible without lens, with few tyloses, and simple large circular or generally elliptical perforations. The pits are large and vary from circular to scalariform. The prosenchyma is composed of medium thin-walled fibro-tracheids with very narrowly bordered pits. A few elongated wood-parenchyma cells occur in contact with the vessels.

#### Family MALVACEAE

The Malvaceae are herbs, shrubs, or trees of wide distribution. The wood is soft in the Hawaiian representatives, characterized by vessels with simple perforations and bordered, semibordered, or simple pits. The rays are 1-9 cells broad. Wood-parenchyma is abundant in some genera. The fibers may have thin or thick walls or bordered or simple pits.

**Hibiscus arnottianus** Gray. KOKIA. Material, xxxv:26:1435 (2 of new series).

This species is endemic to Hawaii, growing mainly along streams. The wood is dull yellowish-white or blue-gray in the narrow sapwood zone, soft, diffuse porous, and with macroscopic growth-rings.

#### CROSS SECTION

*Gross.*—The vessels are small, visible with lens, and mostly in small radial groups. The lumina are open and permeable to alcohol. The rays are as broad as the vessels.

*Minute.*—The vessels are thin-walled, rather variable in diameter, few more than 0.16 mm., and mostly grouped 2-8+ together radially, and occasionally as many as three wide tangentially are observed. Some compact groups of 6-10 or more are formed, which are nearly circular in outline. The rays are 1-5+ cells broad, thin-walled, and have numerous small circular pits in imperfect radial rows. The fibers are of large diameter, rounded polygonal in outline, and arranged more or less in radial rows. The walls are thin, and have small simple pits in both radial and tangential sides. Growth-rings are defined by a slight compression of narrow zones of fibers

and associated elements. Wood-parenchyma cells are of the same diameter as the fibers, slightly thinner walled, and diffusely distributed.

#### RADIAL SECTION

*Gross.*—The rays are plainly visible without lens, light-colored, and less than 2 mm. high. The wood is straight-grained and has a fine uniform texture.

*Minute.*—The elements are serried. Most of the vessels are somewhat constricted at the ends; the perforations, simple; the pits, circular uniform in size and with lenticular orifices. The fibers bear numerous small simple pits with oblique slitlike orifices in the radial walls. Wood-parenchyma cells are common, diffuse,  $0.15 \pm$  mm. long, and have numerous small circular pits 0.003 mm. in diameter. The rays are composed mostly of radially elongated cells, some with square or axially elongated cells at the margins or other portions of the ray. The pits are numerous, circular in outline, and  $0.003 \pm$  mm. in diameter.

#### TANGENTIAL SECTION

*Gross.*—The rays are visible but not prominent under a lens. The vessels are barely visible without a lens.

*Minute.*—The rays are 1-5+ cells wide and 1-50+ cells high. The cells are rounded in outline and nearly of uniform size. Sometimes slightly elongated cells are observed at the margin or other portions of the wide rays and generally in the uniseriate rays.

#### MACERATION

The fibers are of wide diameter, and long. The central third length is cylindrical. The ends taper at first abruptly into long, attenuate points. The pits are mostly confined to the central cylindrical portion. Long oblique slits are common in the inner layer of the wall.

#### DISTINGUISHING CHARACTERS

The wood is dull yellowish-white in color, soft, diffuse porous, and without macroscopic growth-rings. The vessels are visible with lens, mostly grouped, often compactly, 2-8+ together, thin-walled, and with simple perforations and bordered or senibordered pits. The lumina are open and permeable to alcohol. The rays are 1-5 cells broad, 1-50+ cells high and imperfectly heterogeneous. The fibers are of large diameter and long; the walls thin and with simple pits. Wood-parenchyma is fairly abundant and diffuse.

#### **Gossypium drynarioides** Seem. KOKIA.

*Kokia drynarioides* (Seem.) Lewt.

Material, xxxvi:65:1434.

This species is now nearly extinct, but a variety occurs in Oahu. It grew formerly on the west end of Molokai.

The wood is light yellowish-brown in color, streaked with reddish- or blackish-brown, soft, diffuse porous, without macroscopic growth-rings, and of fine, even texture.

#### CROSS SECTION

*Gross.*—The vessels are visible with a lens and mostly grouped 2-8+ together radially or to some extent tangentially. The lumina are without tyloses, but brownish contents may be present. The rays are brownish and as broad as the vessels. Fine reddish tangential lines of wood-parenchyma are visible with lens.

*Minute.*—The diameter of the vessels is variable, but seldom is found to exceed 0.18 mm.; the walls, thin; the lumina, often closed with a deep-staining resinlike material. The rays are 1-7 cells broad; the cells variable in length and width; the pits, numerous and very small; the cell cavities, with resinlike globular or massive material. Wood-parenchyma cells are of the same diameter as the fibers and arranged in narrow tangential lines  $3\pm$  cells wide. The vessels are surrounded by wood-parenchyma. Slightly compressed lines of wood-parenchyma and fibers indicate indistinct growth-rings. The fibers are rounded in outline, and arranged in a regular order of small and large diameters. The walls are thin and the pits simple.

#### RADIAL SECTION

*Gross.*—The rays are reddish-yellow, less than 2 mm. in height, and plainly visible without lens. Faint longitudinal striations due to fine vertical lines of wood-parenchyma are visible in good light or distinct under a lens.

*Minute.*—The vessels generally bear elongated slitlike pit apertures; the segments are short; the perforations, simple. The pits, where in contact with the rays, are circular or elliptical or elongated. Most of the orifices on the vessel side are slitlike and many are elongated. Wood-parenchyma cells are  $0.15\pm$  mm. long. The fibers bear numerous simple pits with long slitlike orifices. The rays are composed mainly of radially elongated cells of variable low height. Square or axially elongated cells occur irregularly at the margins and other portions of the rays.

#### TANGENTIAL SECTION

*Gross.*—Under a lens a mottled appearance is produced by the reddish-yellow wood-parenchyma zones.

*Minute.*—The rays are of an irregular elliptical outline, and composed of cells of irregular size and shape. The walls are thin, and deep-staining resinlike contents are present in the cell cavities. Some of the fibers bear pits in the tangential walls.

#### MACERATION

The vessel segments are short and truncate. The walls bear elongated slitlike pit markings of variable length. The fibers are short, cylindrical in the central portion, and taper abruptly into long, attenuate points.

## DISTINGUISHING CHARACTERS

The wood is yellowish-brown, soft, diffuse porous and without macroscopic growth-rings. The vessels are visible with lens, mostly grouped 2-8+ together, and composed of short segments with large simple, single perforate ends. The rays are 1-7+ cells broad, 1-40+ cells high, and irregularly heterogeneous. The cell cavities contain a resinlike material. Wood-parenchyma occurs in narrow tangential lines. The wood-fibers are thin-walled, short, and bear simple pits.

## Order PARIETALES

## Family GUTTIFERAE

The Guttiferae are a family of tropical plants, mainly trees and shrubs, of which only one genus, *Hypericum*, occurs outside the Tropics. Many species yield edible fruits. The vessels bear either simple or semi-bordered pits in contact with the rays; the perforations are simple; the rays are 1-4 seriate. The prosenchyma pits have narrow borders; chambered crystal-parenchyma occurs in a few genera.

***Calophyllum inophyllum* Linn. KAMANI.**

Material, xxxii:20:1441.

The genus *Calophyllum* consists of 55 species mainly in the Tropics of the Old World; four species occur in American Tropics. *Calophyllum inophyllum* is indigenous to the Hawaiian islands, and occurs as a littoral species in tropical Asia and Polynesia. It yields a resin called tacamahak. The tree attains a height of 50-60 feet, and yields wood of value for cabinet or special construction work.

The wood is red in color becoming slightly lighter in shade in the sapwood, diffuse porous, without growth-rings, resinous, rather soft, fine and even textured, cross-grained, and is easily worked.

## CROSS SECTION

*Gross.*—The vessels are scarcely visible without lens, much larger than the rays, generally solitary, and contain more or less resin and tyloses, but are not completely filled. The rays are very fine, reddish, and visible under a lens. Wood-parenchyma occurs in wavy tangential lines as broad as the pores.

*Minute.*—The vessels are solitary, circular or elliptical in outline, rather even in size, and  $0.18 \pm$  mm. in diameter. The cavities contain more or less

resin and tyloses. The rays are mainly uniseriate, and composed of elongated cells, filled with resin. The pits are small, rather numerous, subcircular, and  $0.003 \pm$  mm. in diameter. The prosenchyma cells vary greatly in size, outline, and arrangement. The lumina are wide, and resinous. The walls are  $0.003 \pm$  mm. in thickness, and obscurely pitted. The wood-parenchyma is metatracheal, resiniferous, composed of cells of greater radial diameter than the prosenchyma cells, and arranged in broken, wavy, tangential lines,  $4 \pm$  cells wide.

#### RADIAL SECTION

*Gross.*—Lines of dark-red wood-parenchyma visible without lens and as wide or wider than the vessels alternate with the lighter colored prosenchyma, appearing as fine striations. The rays are fine, but visible without lens. The elements are filled with a resinlike body.

*Minute.*—The vessels are composed of short, often bulging segments,  $0.5 \pm$  mm. in length, and with circular medium-sized bordered pits  $0.003 \pm$  mm. in diameter with lenticular, transverse or oblique orifices; or, in contact with the rays, large irregular circular or broadly elliptical simple pits,  $0.003-0.015+$  mm. in diameter. The perforations are simple, and the plane of perforation is transverse or somewhat oblique. Tyloses and resin are present in the lumina. The rays are composed mainly of radially elongated resinous cells. The marginal one or more rows consist of irregular cells, many slightly elongated axially. The radial walls bear large irregular simple pits which are circular, squarish, or elliptical in outline, in contact with vessels. The prosenchyma cells are intercrossed, many resinous, minutely pitted, and nonseptate, but often found to contain septalike resin plates. The wood-parenchyma occurs in bands  $4 \pm$  cells wide, and is composed of axially elongated resinous cells, whose radial diameter greatly exceeds that of the prosenchyma. The walls bear numerous rather irregular pits  $0.006 \pm$  mm. in diameter.

#### TANGENTIAL SECTION

*Gross.*—The surface is mottled by areas of dark-colored wood-parenchyma. The rays are fine and visible with a lens.

*Minute.*—The rays are mainly uniseriate and composed of rounded squarish cells, generally with a slightly elongated obtusely pointed cell at each margin.

#### MACERATION

The vessel segments are short, some of them bulging, and with large circular simple perforations. The plane of perforation is transverse or slightly oblique, and the end of the segment is often found to bear a slender tongue-like projection. The pit markings are in axial rows except for the large simple pit markings corresponding to the ray vessel pits. Numerous long tracheids occur. The prosenchyma is composed of rather thin-walled fibers  $0.1 \pm$  mm. long, tapering rather irregularly from near the middle. The pits are small, not numerous, and with slitlike, generally oblique orifices.

## DISTINGUISHING CHARACTERS

The wood is resinous, rather soft, red in color, with slightly lighter sapwood, diffuse porous, without growth-rings, and fine textured. All elements are resinous. The vessels are isolated, barely visible without lens, short segmented, with tyloses, simple perforations and with both bordered and simple pits. Numerous tracheids occur. The rays are mainly uniseriate, with coarse simple pits in contact with the vessels. The cells are chiefly elongated radially; the marginal cells are slightly elongated axially. The wood-parenchyma occurs in wavy tangential lines  $4\pm$  cells wide, which are visible without lens. The wood-prosenchyma is composed of rather thin-walled fibers of medium length, with small simple pits.

## Family FLACOURTIACEAE

This is a tropical family of 70 genera of trees and shrubs, without representatives in Europe or North America. Nearly all inhabit the lowlands. The family is represented in Hawaii by two species of *Xylosma*.

Both scalariform and simple perforations occur in the vessels and spiral thickenings occur in *Ryania*. Septate fibers have been found in certain genera. The fibers may possess either simple or bordered pits, and mucilage-reacting inner lamellae occur in some genera.

***Xylosma hawaiiense*** Seem. MAUA. Material, xxx:4:1442.

This genus is distributed in the Tropics of both Hemispheres with the exception of Africa. There are 42 species, two of which are Hawaiian. *Xylosma hawaiiense* is endemic to Hawaii, growing to a height of 30 feet with a D. B. H. of 1 foot. It occurs in the lower forest zone mainly on the arid leeward sides of the Islands in association with *Alphitona excelsa*, *Dracaena aurea*, and *Santalum pryrularium*.

The wood is reddish-brown with narrow zones of light and dark shades resembling narrow growth-rings. The wood is diffuse porous, fine and fairly even textured, and rather hard. The wood is rather heavy but very brittle.

## CROSS SECTION

*Gross.*—The vessels are visible with lens, diffuse, mostly in small groups, and larger than the rays. The rays are visible with lens, and reddish in color.



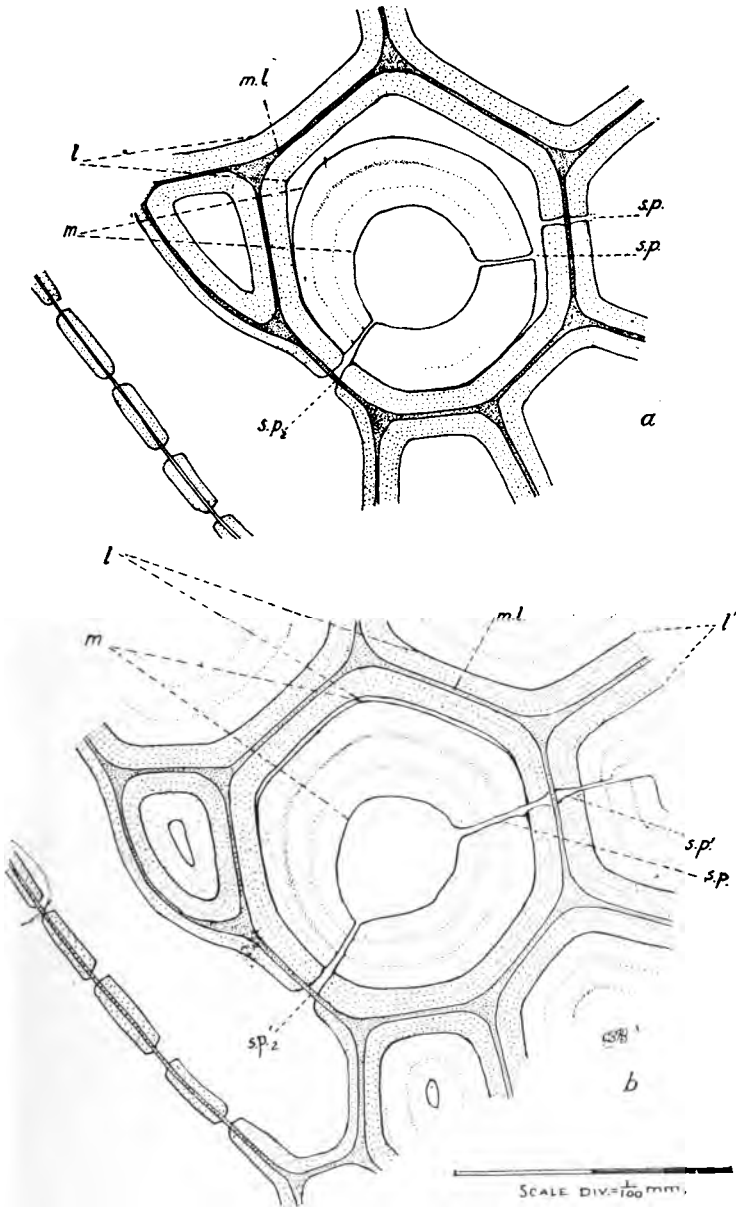


FIGURE 5. **a**, A laminated fiber of *Xylosma hawaiiense*,  $\times 3,000$  diameters, after desiccation; **b**, the same after being covered with water for 45 minutes, showing lignified outer layer (**l**), laminated mucilage-reacting layer (**m**), simple pit (**sp**), middle lamella (**ml**).

FIGURE 5. **b**, shows that after treatment with water all layers of the fiber are swollen, but the mucilaginous layers (**m**) more than the lignified layer (**l**). The simple pit (**sp**) comes into alignment after soaking. The simple pit (**sp<sub>2</sub>**) remains permanently in connection.

*Minute.*—The vessels are rather uniform in size,  $0.07 \pm$  mm. in diameter, part of them isolated, and part grouped in small radial groups or with occasional vessels adjacent tangentially; tyloses are few; lateral perforations are present between tangentially adjacent vessels. The rays are narrow, 1-2+ cells wide, and composed of narrow elongated cells usually in two rows. Wider less elongated cells occur, usually in one row. The cell-walls are thin,  $0.002 \pm$  mm., and bear small subcircular pits,  $0.001-0.004+$  mm. in diameter. The cavities contain a resinlike body and some of them large mineral crystals.

The fibers occur in nearly regular radial arrangement and have rather thick ( $0.009 \pm$  mm.) walls, with simple pits mostly in the radial sides. Zones of fibers possess a laminated structure of the wall. The outer layer of such fibers shown, in *l* and *l'* of figure 5, *a* and *b*, in which the outer layers of two adjacent fibers are shown separated by the middle lamella *m l*, is lignified, stains with safranin, and shrinks slightly in dehydration. The inner laminated layer, *m*, *m'* stains, variously but usually less deeply than the outer layer, shrinks greatly (*m*) on dehydration and swells without going into solution in water (*m l*) and responds to other mucilage tests. Alternating with such zones of mucilage-reacting fibers are fibers of the same dimensions, but whose walls are not lamellated and react strongly to tests for lignin. Chemical growth-rings are defined by the phloroglucinol hydrochloric acid test.

Wood-parenchyma is sparingly developed and is mostly in contact with the vessels.

#### RADIAL SECTION

*Gross.*—The radial surface is uniform in texture and color. The rays are not prominent even under a lens.

*Minute.*—The vessels have frequent lateral perforations. The segments are rather long ( $1.3 \pm$  mm.), the plane of perforation generally somewhat oblique, the perforations simple and elliptical, or rarely circular, in outline. The radial walls are largely in contact with ray-parenchyma, and bear rather small semibordered pits with transverse or oblique open lenticular orifices. Occasionally simple pits of large size and irregular outline occur. The uniseriate portions of the rays are composed mainly of high cells two or three times as high as their radial diameter. The biseriate portions are composed of radially elongated cells. The cavities are filled with a deep staining body and some have single large mineral crystals. The radial walls in contact with the vessels generally bear rather small circular semibordered pits with lenticular orifices, but larger, commonly elongated simple pits occur. The fibers are septate; the pit orifices long, slitlike, and vertical.

#### TANGENTIAL SECTION

*Gross.*—The surface is uniform in color and texture. The rays and vessels are visible but not prominent under a lens.

*Minute.*—The rays are mainly uniseriate or uniseriate in part, or 1-2+ cells wide and 1-50+ cells high. The uniseriate portions consist of axially elongated cells. A small portion, often less than one-third the height of the ray, is usually biseriate, consisting of small elliptical cells. The

common walls between vessels bear numerous bordered pits of medium size with oblique or transverse lenticular or slitlike orifices. The prosenchyma walls bear few pits.

#### MACERATION

The vessel segments are generally rather long ( $1.3 \pm$  mm.), and the ends more or less oblique, projecting beyond the perforation into a hollow or solid tapering end. The terminal perforations are commonly elliptical. The pits on the radial walls generally occur in grouped areas corresponding to the shape and size of the ray-cells with which they were in contact. The prosenchyma fibers taper from near the middle. The laminated fibers are extremely brittle and break with a conchoidal fracture except for the outer thin layer which generally splinters.

#### DISTINGUISHING CHARACTERS

The wood is reddish, with narrow zones of light and dark shades, diffuse porous, even textured, easily cut, heavy but brittle. The vessels are visible under a lens, and arranged mostly in small groups. The lumina are without tyloses; the perforations, simple. The pits are rather uniform in size ( $0.006 \pm$  mm.) and subcircular, with lenticular orifices. The rays are mainly uniseriate or uniseriate in part. The prosenchyma is septate, rather thick-walled, and laminated for the most part. Wood-parenchyma is very sparingly developed, and mostly adjacent to vessels.

#### Order MYRTIFLORAE

#### Family THYMELAEACEAE

This is a small family, consisting of 455 species of shrubs or trees or rarely herbs, of general distribution. *Dirca palustris*, the moose-wood, is a familiar American representative of this family. The secondary wood is characterized by vessels with simple perforations, and bordered or semibordered pits. Spiral thickenings occur in some of the genera. Wood-parenchyma is generally not abundant. The wood-prosenchyma generally has wide lumina and bordered pits. The medullary rays are 1-2 cells wide.

***Wilkstroemia sandwicensis*** Meisn. AKIA. Material, cvii:xi:1473.

The akia is endemic to the Hawaiian islands, and is most abundant on the lava fields of Hawaii, or at elevations of 5,000 feet in association with koa. It is a small tree 30 feet high. The wood is dull grayish or bluish-white, diffuse porous, very soft, and without distinct growth-rings.

## CROSS SECTION

*Gross.*—The vessels are small, visible with a lens, isolated or grouped 2-3+ in compact groups, both in radial and tangential directions. The lumina are open and very permeable to alcohol. The rays are visible with lens, smaller than the vessels.

*Minute.*—The diameter of the vessels is rather variable, but rarely exceeds 0.12 mm. The walls are thin, of nearly the same thickness as the fiber walls. The fibers are rounded polygonal in outline, of large diameter, have very thin walls, and are irregularly arranged. The rays are 1-2 cells wide and bear subcircular pits of medium size.

## RADIAL SECTION

*Gross.*—The surface has a dull luster. The rays and vessels are not prominent even under a lens.

*Minute.*—The elements are serried. The vessel segments are of uniform length. The pits are bordered or semibordered, circular in outline with lenticular orifices in the vessel walls, and of uniform diameter whether in contact with ray-cells or other elements. The perforations are simple and of nearly the diameter of the vessel lumen. The plane of perforation is transverse or nearly so. The rays are homogeneous; the cells, composed of thin-walled cells of moderate radial length; the pits, medium sized and subcircular. The orifices of the semi-bordered pits formed in contact with the vessels are circular in the ray walls, and of a diameter equal to the length of the lenticular orifices in the opposite vessel walls. The prosenchyma cells bear bordered pits with lenticular orifices. Wood-parenchyma is little developed.

## TANGENTIAL SECTION

*Gross.*—Faint longitudinal lines indicating vessel groups are visible without lens. The rays are small and visible with a lens.

*Minute.*—The rays are linear, with obtuse ends, 1-2 cells broad and 1-23+ cells high. The cells are rounded outline and of nearly uniform size. A few bordered pits are present in the tangential walls of the prosenchyma.

## MACERATION

The prosenchyma is composed of short fibro-tracheids, with a central cylindrical portion of large diameter, from which the ends taper irregularly into sharp points.

## DISTINGUISHING CHARACTERS

The wood is dull grayish-white in color, diffuse porous, very soft, and without distinct growth-rings. The elements are serried. The vessels are visible with a lens, isolated or in small rather compact groups, and bear either bordered or semibordered pits which are of uniform size. The perforations are simple. The rays are homogeneous, 1-2 cells wide and 1-23+ cells high. The prosenchyma is composed of short, thin-walled fibro-tracheids of large diameter, with bordered pits. Wood-parenchyma is spar-

ingly developed. The wood is readily distinguished from that of *Eugenia jambolana*, an introduced species, which has wider and more regular lines of nonresinous wood-parenchyma easily visible in cross section without lens, and vessels reaching 0.3 mm. in diameter, or twice the diameter of the vessels of *E. sandwicensis*. Also, the lumina of the vessels are open and readily permeable to alcohol.

### Family COMBRETACEAE

A family of woody plants, trees and shrubs, of wide distribution throughout the Tropics. There are three genera in Australia. Most of the members of this family yield tannin and some species, as *T. catappa*, yield dyes, or may be used for lumber. The seeds of some species are edible.

The wood is characterized by narrow medullary rays. The vessels are isolated, rarely grouped, and have bordered or semibordered pits even in contact with parenchyma. The wood-prosenchyma is characterized by simple, rarely bordered pits; some is septate, and may contain crystals. The wood-parenchyma is vasicentric, and may occur in tangential lines as in *Terminalia belleria*. Some species of *Terminalia* have chambered crystal-bearing parenchyma. Intercellular cavities may occur in the xylem (17), and interxylary phloem has been recorded for some species.

***Terminalia catappa*** L. KAMANI. Materials, xxxiii:45:1509.

The genus comprises over 100 species widely distributed in the Tropics, none of which are indigenous to Hawaii. *Terminalia catappa* has been introduced to the islands and widely planted because of its large size and other desirable characters. The fruit yields tannin, and the oily seeds are edible. This species is indigenous to Madagascar, the Malay Archipelago, and New Guinea, where it is characteristic of the littoral forest growth.

The wood is light brownish-yellow with a waxy luster, soft, fairly even textured, cross-grained, and with growth-rings visible without lens. Dark tangential streaks occur in some of the growth-rings.

### CROSS SECTION

*Gross.*—Growth-rings are defined by dark zones of late-wood sometimes containing circular cavities in zonal arrangement, plainly visible under

a lens and filled with a yellowish substance. The vessels are diffuse, dark-colored, visible without lens and without tyloses. The rays are barely visible without lens; tangential lines of wood-parenchyma occur throughout the ring.

*Minute*.—Growth-rings defined mainly by great increase in thickness of the fiber walls, with slight radial compression. The vessels are solitary for the most part, some of them in radial groups of 2-3+, nearly circular in outline except where grouped, rather uniform in size and sometimes  $0.3 \pm$  mm. in diameter with slightly thickened ( $0.006 \pm$  mm.) walls. The lumina are usually empty; the perforations, simple. The rays are 1-2+ cells wide and curve slightly around the vessels. The cell cavities are filled with brownish contents. The wood-fibers are polygonal in outline, with thin walls in early-wood and thick walls ( $0.006 +$  mm.) in late-wood, with large lumina throughout. The pits are simple. Wood-parenchyma cells surround the vessels, form broken tangential lines or extensions from the sides of the vessels, and generally contain a brownish material (fig. 6 a, mp, vp). There are many idioblasts with clustered crystals of calcium oxalate (fig. 6 c).

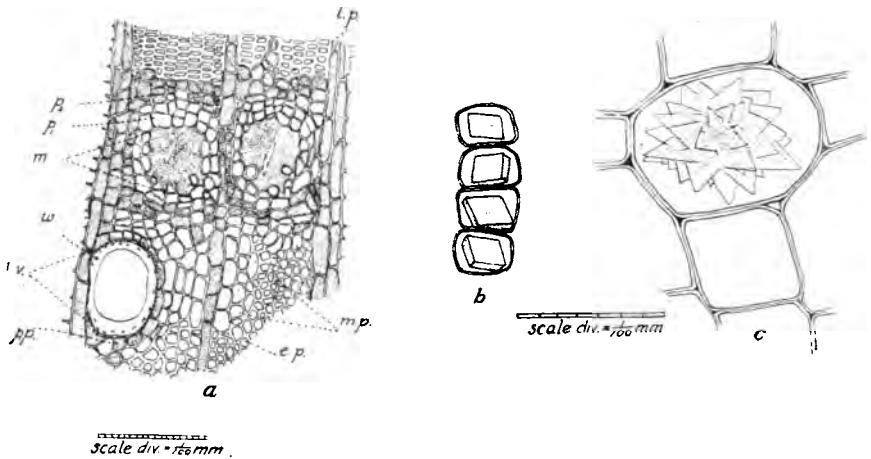


FIGURE 6. a, Cross section of *Terminalia catappa* wood showing: mucilage canal (m); isodiametric parenchyma layer (p1); compressed parenchyma layer, with cell content (p2); paratracheal parenchyma (pp); axially elongated metatracheal parenchyma (mp); vessel (v); perforate end-wall (w). b, Crystal-parenchyma of *Maba sandwicensis* wood with rhombohedral crystals. c, Idioblast with clustered crystals in wood-parenchyma of *Terminalia catappa*.

#### RADIAL SECTION

*Gross*.—The grain is irregular. Both rays and vessels are visible to the eye, and reddish or brownish in color. Intercellular cavities, when present, are easily visible without lens.

*Minute.*—The vessels bear numerous relatively coarse, indistinctly circular, elliptical, or hexagonal pits of  $0.009+$  mm. in diameter with broadly lenticular transverse or oblique orifices on all sides whether in contact with vessels or parenchyma. Those communicating between vessels are indistinctly bordered; those between vessels and parenchyma, narrowly semi-bordered. The segments are short,  $0.36\pm$  mm., and the plane of perforation is transverse. Perforations are simple and mainly terminal. The rays are homogeneous, composed of radially elongated cells,  $0.18\pm$  mm. in length, and  $0.02\pm$  mm. in height. The walls are thin, and bear numerous coarse circular or elliptical pits  $0.006\pm$  mm. in diameter. The prosenchyma fibers are nonseptate, minutely pitted, and intercrossed. The metatracheal wood-parenchyma cells are typically elongated, 1.2 mm. in length. The wood-parenchyma cells in contact with the vessels are shorter,  $0.06\pm$  mm. in length, and often somewhat irregular in shape. There are many globular idioblasts with clustered crystals of calcium oxalate.

#### TANGENTIAL SECTION

*Gross.*—The vessels, with the cells surrounding them, form conspicuous dark reddish-yellow lines. The rays, visible with a lens, form numerous short, narrowly linear, acutely pointed, dark-colored markings of the same dark color as the vessels.

*Minute.*—The rays are 1-2, rarely 3+ cells wide, 1-30+ cells high, and homogeneous. The cells are of rather uniform size, and shape, 0.015 mm. in tangential diameter and  $0.27\pm$  mm. high. The marginal cell is generally somewhat higher than the average. The wood-fibers are less intercrossed than in the radial plane. Secretory cavities are sometimes found, formed possibly traumatically. In the material examined, but one ring contained them, and these were in a continuous row on the outer face of a zone of late-wood (fig. 6, a). In cross section, the cavities are circular or elliptical and 0.1 mm. in radial diameter; the tangential diameter varies from 0.1 to  $0.06+$  mm. The cavities are filled with a viscous substance appearing deep yellow by transmitted light, staining deep red with safranin. The first one or two layers of cells lining the cavities are thin-walled, numerous pitted, isodiametric, usually empty parenchyma cells (fig. 6, a). Exterior to these occur one or more rows of cells with viscous contents, compressed transversely and more or less elongated axially. In tangential section these cavities are found to be confluent into one which occupies all the space except for the medullary rays which are bounded on the sides by the parenchyma layers above described. Some of the rays, as seen in the transverse section, are interrupted by the cavity, but continue on the opposite side.

#### MACERATION

The vessel segments are short, of large diameter, generally cylindrical, with transverse ends sometimes with a tongue-like projection from one end or rarely both ends. The pit markings are nearly uniform in size, and rather coarse. The fibers are attenuate from near the middle, usually more or less curved, minutely pitted, sharp pointed, and attain a maximum length of  $1.6+$  mm. The rays are 1-2 cells wide and 1-30+ cells high.

## DISTINGUISHING CHARACTERS

The wood is brownish in color, soft, fairly even textured, cross-grained, diffuse porous, and with growth-rings. The vessels are generally single, visible without lens, without tyloses, and with simple perforations. The segments are short; the plane of perforation, transverse. The rays are 1-2+ seriate, 1-30+ cells high, and homogeneous. Wood-parenchyma occurs in contact with the vessels and in broken tangential lines. Idioblasts with clustered crystals are many. The fibers are minutely pitted, nonseptate, of medium length, and attenuate from near the middle.

## Family MYRTACEAE

The Myrtaceae are evergreen shrubs or trees of which there are over 2,700 species confined to tropical or near tropical climates. The myrtle, Eucalyptus, *Psidium guajava*, and *Eugenia caryophyllata*, the unopened flower buds of which are the cloves of commerce, belong to this family.

The wood is characterized by vessels with simple or scalariform perforations, and bordered, semibordered, and sometimes simple, pits. The rays are 1-3 cells broad. Wood-parenchyma varies in amount according to the species. Bordered pits occur in the fibers.

***Eugenia malaccensis*** L. OHIA AI, mountain apple.

*Jambosa malaccensis* (L.) P. DC.

Material, lv:15:1453.

This species is of general distribution in the Pacific islands and is believed to have been introduced to Hawaii in prehistoric times by primitive man. It grows at low elevations on the windward side of the islands. The tree reaches a height of 60 feet. The fruit is edible.

The wood is reddish- or yellowish-brown in color, soft, without growth-rings, diffuse porous, of even texture, straight-grained, and in former times was used by the Hawaiians especially to carve into idols, and for other sacred purposes.

## CROSS SECTION

*Gross.*—The vessels are barely visible without a lens, very numerous, isolated, or in small radial groups of 2 or 3, or rarely more. The lumina are open and readily permeable to alcohol. The rays are much narrower



than the vessels and visible only with a lens. Tangential lines of wood-parenchyma are visible with a lens.

*Minute.*—The size of the vessels is slightly variable but the diameter rarely exceeds 0.2 mm.; the walls are very thin, and the outline is generally angular. The rays are 1-3+ cells broad and curve but slightly near the vessels. The pits are circular in outline and variable in diameter up to 0.009+ mm. but are obscured by resinlike contents which fill the cell cavities. The fibers are of medium diameter, many somewhat compressed tangentially, and arranged in radial rows. The walls are of medium thickness (0.005 mm.). The lumina commonly contain globules of resinlike material. Wood-parenchyma cells are thin-walled, of about twice the radial diameter of the fibers, are seldom compressed, and occur in numerous tangential bands  $4\pm$  cells wide alternating with bands of fibers of nearly equal width. The vessels are largely in contact with rays or wood-parenchyma.

#### RADIAL SECTION

*Gross.*—The rays are reddish in color and visible without a lens. The alternation of wood-parenchyma and fiber zones is visible but indistinct under a lens.

*Minute.*—The vessels are composed of segments of medium length with simple circular perforations, generally somewhat smaller than the vessel lumen. The bordered pits between vessels are generally crowded hexagonal in outline, 0.009 mm. in diameter, and with transverse lenticular orifices. Pits between vessels and ray-cells are irregularly elliptical in outline varying from widely to narrowly semibordered or simple, and varying from 0.009 mm. to 0.03 mm. in diameter. True simple ray vessel pits are common. Simple pits are also common between vessels and adjacent wood-parenchyma. Wood-parenchyma cells are 0.09 mm. in length in contact with vessels or  $0.27\pm$  mm. in the metatracheal zones. The fibers bear a few bordered pits with lenticular orifices. The rays are composed of three types of cells: (1) very low radially elongated cells present in the multiseriate portions; (2) higher, less elongated cells forming the larger part of the uniseriate portions of the rays; and (3) axially elongated cells often present at the margins.

#### TANGENTIAL SECTION

The rays are linear in outline, acutely pointed, 1-3+ cells wide and up to 50+ cells high. The rays are mainly uniseriate in part, with one or more multiseriate portions at irregular intervals. The uniseriate portion is composed of large rounded four-sided cells with often an axially elongated cell at the margin. The multiseriate portions are composed of small sub-circular cells. There are few if any pits in the tangential walls of the fibers.

#### MACERATION

The fibers are nearly straight and taper gradually into long, attenuate, very sharp ends. Irregular simple pit markings are numerous in the vessel walls.

## DISTINGUISHING CHARACTERS

The wood is reddish- or yellowish-brown in color, soft, without growth-rings, diffuse porous, and straight-grained. The vessels are barely visible with lens, numerous, isolated or in small groups, have simple perforations and bordered, semibordered, and simple pits communicating with the adjacent elements. The rays are linear in tangential section, and mainly uniseriate in part, 1-3+ cells wide and up to 50+ cells high. The cell cavities contain a resinlike material. The fibers bear bordered pits, have moderately thickened walls, and occur in narrow zones alternating with wood parenchyma.

***Eugenia sandwicensis*** Gray. OHIA HA. Material, lix:71:1457.

*Syzygium sandwicense* (Gray) Ndz.

*E. sandwicensis* is endemic to Hawaii, occurring throughout the group. It occurs on the lowlands and up to 4,000 feet. In the rain forest it attains a height of 60 feet and a diameter of 18 inches. The fruit is edible; the bark yields a black dye. The wood is durable, rather hard, reddish-brown in color, diffuse porous, and possesses an irregular grain.

## CROSS SECTION

*Gross.*—There are no growth-rings. The vessels are small, visible with a lens, numerous, isolated or grouped very compactly 2-6+ together in both tangential and radial directions. (There are many lateral perforations.) The lumina in heartwood become partly filled with tyloses or resinlike material and are only slightly permeable to alcohol. The rays are small and visible with a lens. Wood-parenchyma occurs in numerous tangential extensions from the radial sides of the vessels.

*Minute.*—The vessels are nearly circular in outline where isolated, or variously compressed where grouped. The size is variable but rarely exceeds 0.14 mm. The walls are thin, and lateral perforations are common. The rays are 1-3+ cells wide and filled with resinlike material. The fibers are rounded polygonal in outline with moderately thick walls and lumina often filled with resin. Wood-parenchyma cells of nearly the same diameter as the fibers, but thin-walled, are associated with the vessels and extend tangentially in irregular areas nearly as wide as the vessels and alternate with tangential lines of fibers.

## RADIAL SECTION

*Gross.*—The vessels are composed of long segments. Perforations are simple, usually circular and nearly as large as, or smaller than the vessel lumina. Lateral perforations are frequent. The pits are variable in size and shape. Bordered pits in the common vessel walls vary from circular to elliptical or elongated with lenticular or slitlike orifices. Pits between vessels and parenchyma or ray cells vary from semibordered to large and

simple. The rays are heterogeneous with radially elongated cells in the wide portions and axially elongated cells at the margins or uniseriate portions. The pits are usually obscured by resin but are large, elliptical, and narrowly semibordered or simple in contact with vessels. In contact with wood-parenchyma or other ray-cells, the pits are smaller and subcircular. The fibers bear a few narrowly bordered or simple pits with slitlike orifices. A resinlike material commonly obscures the pitting. Wood-parenchyma cells are  $0.15 \pm$  mm. in length and usually filled with massed material.

#### TANGENTIAL SECTION

*Gross.*—Wood-parenchyma, rays, and vessels are visible under a lens. with garnet-colored contents.

*Minute.*—The rays are  $3+$  cells wide,  $25+$  cells high, and irregularly linear or linear-elliptical in outline. The cell cavities are filled with a deep staining resinlike material which in some of the cells radiates in lines from the center.

#### MACERATION

The fibers are long ( $2 \pm$  mm.) and taper into long attenuate sharp points.

#### DISTINGUISHING CHARACTERS

The wood is reddish-brown in color, diffuse-porous, rather hard, and with an irregular grain. The vessels are small, visible with a lens, isolated or grouped compactly  $2-6+$  together, and with simple perforations and bordered, semibordered, and simple pits. The lumina become more or less filled with tyloses or resinlike material. The rays are heterogeneous,  $1-3$  cells wide and  $1-25+$  cells high. The fibers are rather thick-walled and alternate in irregular tangential lines with wood-parenchyma and vessels. A garnet-colored substance is present in the rays, wood-parenchyma, fibers, and vessels.

***Metrosideros villosa* Smith. OHIA LEHUA.**

*Metrosideros polymorpha* Gaud.

Material, lvi:42:1455.

The genus comprises about 40 species of trees or shrubs of which two-thirds are peculiar to Australia and New Zealand. Four species are endemic to the Hawaiian islands. *M. villosa* is a cosmopolitan species distributed throughout the volcanic islands of the tropical Pacific "but seemingly only in the Hawaiian group associated with endemic species" (6, p. 341) where it attains its best development, forming pure stands. It is the most variable species in the Islands (18, p. 325), possessing numerous described varieties (9, p. 127) ranging from large trees to prostrate shrubs. The fruits are dry capsules and the seeds small enough to be carried

to some extent by the wind. *M. villosa* ranges from the coast up to 8,000 feet (6, p. 342), but attains its best development in the middle forest zone at elevations of 2,000 to 4,000 feet, where it is associated with *Acacia koa*, *Cheirodendron gaudichaudii*, and similar species.

The wood is diffuse porous, reddish-brown in color, rather soft, with or without distinct growth-rings, and straight-grained. A medium-sized zone of sapwood is present distinguished from the heartwood by its more yellowish color and by the permeability of the tracheae to alcohol.

#### CROSS SECTION

*Gross*.—The vessels are barely visible with lens or, in some specimens (lxiii:1455), visible without lens, and are mostly isolated. The lumina are closed in the heartwood, with tyloses and resinlike material, but are open and readily permeable to alcohol in the sapwood. The rays are narrower than the vessels. Fine irregular and broken tangential lines of wood-parenchyma are visible with lens.

*Minute*.—The vessels are mainly circular in outline; some of them as large as  $0.27+$  mm. in diameter. The walls are  $0.003$  mm. in thickness. The rays are 1-2 cells wide and filled with a resinlike material. The fibers are polygonal in outline with mostly rather thick walls and are arranged in radial rows. In some cross sections the lumina of the fibers are closed with a resinlike substance. Wood-parenchyma cells are of nearly the same diameter as the fibers and mostly in contact with the vessels, but also extend in irregular tangential lines mostly from the radial sides of the vessels.

#### RADIAL SECTION

*Minute*.—The vessels consist of long segments with simple perforations somewhat smaller than the vessel lumen. The pits are variable. Sub-circular bordered pits  $0.006\pm$  mm. in diameter with lenticular orifices occur in the common walls between vessels. Narrowly semibordered or simple pits, varying from circular to long elliptical in outline and  $0.021\pm$  mm. in diameter, occur between vessels and wood-parenchyma or ray-parenchyma cells. Very few scalariform pits occur. The lumina become closed, in the heartwood, with tyloses and resinlike contents. The rays are composed of three shapes of cells: (1) very low radially elongated cells present in the multiseriate portions of the rays; (2) nearly square cells present in the uniseriate portion of rays; and (3) axially elongated cells at the margins. The pits are  $0.003\pm$  mm. in diameter between ray-cells, or between ray-cells and adjacent wood-parenchyma, and  $0.021\pm$  mm. in diameter between ray-cells and adjacent vessels. The cell cavities contain a resinlike mass which collects upon the walls and obscures the pitting except in favorable sections. Uniseriate, circular-bordered pits with narrowly lenticular orifices are present in the radial walls of the fibers. Wood-parenchyma cells are  $0.18\pm$  mm. in length.

## TANGENTIAL SECTION

*Gross.*—The rays are very narrow and barely visible with a lens.

*Minute.*—The rays are narrowly elliptical in outline, acute or obtuse at the margins, uniseriate, uniseriate in part, or 2-3 seriate in composition. Cells in the multiseriate parts are subcircular; those in the uniseriate parts, axially elongated, especially at the margins. Semibordered pits are common, in sections, between rays and adjacent fibers. The fibers bear rather numerous circular bordered pits with lenticular orifices in the tangential and radial walls.

## MACERATION

The fibers are long ( $1.8 \pm$  mm.), straight, and attenuate from near the middle into long sharp ends. The vessel segments are, as a rule, somewhat oblique at the ends, commonly with a tonguelike projection of varying length from one or both ends.

## DISTINGUISHING CHARACTERS

The wood is diffuse porous, reddish-brown in color, with yellowish-brown sapwood, rather soft, straight-grained, of fine even texture, resinous, and with or without growth-rings. Many of the vessels are visible without a lens, isolated, composed of long segments with simple perforations and with variable, simple, narrowly semibordered, and bordered pits in the walls. The lumina are plugged in the heartwood, with resinlike material and tyloses. The rays are 1-2+ cells wide and up to 40 cells high. The fibers are long, straight, fairly thick-walled, and bear bordered pits in radial and tangential walls. Wood-parenchyma is mostly in contact with vessels but extends in indefinite broken tangential lines.

## Order UMBELLIFLORAE

## Family ARALIACEAE

A family of 51 genera largely of tropical distribution. Most of the species are trees, shrubs, and climbers; a few are herbs. Familiar American representatives of this family are the Hercules club, *Aralia spinosa*, and herbaceous species of *Aralia* including ginseng.

The wood is characterized by vessels with simple or scalariform perforations, by broad medullary rays, and by the occurrence of secretory canals (17) in the rays in some of the genera. The wood-prosenchyma is characterized by simple pits.

***Tetraplasandra waimeae* Wawra. OHE KIKOOLA.**

Material, xxxvii:41:1426.

The genus *Tetraplasandra* consists of about 12 species, all but two species of which are endemic. *Tetraplasandra waimeae* is a

medium-sized tree, 30-40 feet high, and 12+ inches D. B. H. The species is endemic to the island of Kauai, at 3,600 feet. It is rather xerophytic and occurs in association with *Cryptocaria mannii*, *Bobea mannii*, *Sideroxylon sandwicense*, and *Elaeocarpus bifidus*.

The wood is nonresinous, yellowish-white, with silvery luster, and with little difference in color of heartwood, of medium hardness, even texture, straight-grained, and without growth-rings.

#### CROSS SECTION

*Gross.*—The vessels are not visible without lens, diffuse, generally in small radial groups, without tyloses, slightly smaller than the rays; rays, visible without lens, and light-colored.

*Minute.*—The vessels are small, rather uniform in size,  $0.1 \pm$  mm. in diameter, or, exceptionally, 0.15 mm., grouped mostly 2-3 radially together, occasionally 3-9+, have slightly thickened walls (0.006 mm.), are radially perforate (cf. fig. 7, a), and have few tyloses. The rays are 1-3+ cells wide, and straight; the cells, very thin-walled (0.001 mm.), empty, with numerous, generally circular pits 0.001-0.006 mm. in diameter. The prosenchyma cells are polygonal in outline, thick-walled ( $0.006 \pm$  mm.), with wide lumina, arranged in regular radial rows and with numerous simple pits in the radial walls. The wood-parenchyma is paratracheal, 1 cell deep, incompletely surrounding the vessels.

#### RADIAL SECTION

*Gross.*—The rays are conspicuous, slightly dark-colored,  $1 \pm$  mm. high, and visibly heterogeneous under a lens. The vessels are visible under lens; a few have dark contents.

*Minute.*—The vessels have bordered or semibordered or simple pits circular to long elliptical in outline. The perforations are simple, terminal and lateral in position (fig. 8, c). The lateral perforations are many, occur on the radial walls, and are commonly single instead of double as in *Cheirodendron* (fig. 7, b). The rays are heterogeneous, with marginal cells  $0.06 \pm$  mm. in radial diameter and  $0.1 \pm$  mm. in height. The central portion of the ray consists of radially elongated cells  $0.15 \pm$  mm. long and  $0.02 \pm$  mm. high. The radial walls bear numerous circular or elliptical pits variable in size when adjacent to parenchyma, and relatively larger, variable, elliptical, semibordered or simple pits when in contact with vessels. The prosenchyma cells are numerous and conspicuously marked with simple pits with narrowly lenticular, vertical orifices. Wood-parenchyma cells elongated ( $0.21 \pm$  mm.) in contact with vessels.

#### TANGENTIAL SECTION

*Gross.*—Rays are barely visible without lens, showing as fine lines of variable length up to 2+ mm. The vessels are difficult to distinguish, except those having dark contents.

The vessels bear elliptical or scalariform pits and are composed of long segments 1 mm., oblique at the terminal plane of perforation. The rays are 1-3+ seriate and from 1 cell to 70+ cells high; the uniseriate rays are homogeneous; the wider rays, imperfectly heterogeneous. The cells are very thin-walled and many break down in sectioning. Those in the wide rays are irregular in shape and size, but many, with the smaller less elongated cells, are surrounded on all sides by a layer more or less elongated axially. Most of the marginal cells are 2-4 times as high as wide. The uniseriate ray-cells are elongated axially. The fibers have few pits on the tangential walls.

#### MACERATION

The vessel segments are long and cylindrical with oblique ends, many of which have a tongue-like projection from one end or both ends. The pit markings are generally elliptical in outline with lenticular or slit-like orifices. The perforations are simple, and both terminal and lateral in position. Prosenchyma fibers are usually less than 1.3+ mm. in length, prismatic in shape, with abundant pit markings on the radial walls and short irregularly tapering and sometimes unpitted points.

#### DISTINGUISHING CHARACTERS

The wood is yellowish-white in color, of medium hardness, even textured, without growth-rings, straight-grained. The vessels are diffuse, arranged in small groups, smaller than the rays, have few or no tyloses, medium thin-walled, with elliptical bordered, semibordered, or simple pits, long segments, oblique ends, and simple perforations both terminal and lateral in position. Rays 1-3 seriate, up to 2+ mm. in height, imperfectly heterogeneous where more than one cell wide, and very thin-walled. The fibers are prismatic, nonseptate, with short tapering ends, of medium length, and rather thick-walled with open lumina, and conspicuously pitted on the radial walls. Wood-parenchyma cells are few and mostly in contact with the vessels.

**Dipanax gymnocarpa** A. A. Heller.

*Pterotropia gymnocarpa* Hbd.

Material, xxxviii:18:1427.

This genus is endemic to the Territory and consists of the three following arborescent species: *Pterotropia gymnocarpa*, *P. diphyrena*, and *P. kauaiensis*. *Pterotropia gymnocarpa* occurs in the rain forests at elevations of 2,000 feet or more, "associated with *Pelea sandwicensis*, *Euphorbia rockii*, *Hibiscus arnottianus*, *Syzygium sandwicense*, and *Elaeocarpus bifidus*" (18, p. 355). It is smaller, growing only 15-30 feet in height.

The wood is pale yellow in color with high luster, with a medium-wide zone of sapwood, which in seasoning may turn bluish.

The wood is soft, even textured, and straight-grained. The pith is large, circular,  $1\pm$  cm. in diameter.

#### CROSS SECTION

*Gross.*—Growth-rings are defined by deep-colored latewood. The vessels and rays are scarcely visible without lens; the vessels are diffuse, rather uniform in size, grouped  $2\pm$  together and slightly larger than the rays. The rays are straight and light-colored.

*Minute.*—Growth-rings are defined mainly by the tangential compression of the fibers. The vessels occur in small groups, or isolated, are sub-circular in outline, unless compressed by aggregation, of rather uniform size, and generally less than  $13+$  mm. in diameter with open lumina. Lateral perforations are common. The rays are straight,  $1-4+$  seriate, composed of short cells, with thin walls ( $0.002$  mm.); cavities, without resin or crystals; walls, numerous pitted with subcircular to elliptical pits, irregularly in radial rows, and varying from fine to coarse ( $0.001-0.009+$  mm.) in diameter. The fibers are in radial rows, rounded polygonal in outline, or tangentially compressed at the termination of a growth-ring. The walls are thin ( $0.003\pm$  mm.) with simple pits, most numerous on the radial walls; lumina, large except in latewood, commonly equal to eight-tenths the diameter of the fiber. Wood-parenchyma is not abundant, occurring as isolated cells mainly in contact with the vessels; the walls, thin; cavities, without resin or mineral crystals.

#### RADIAL SECTION

*Gross.*—The surface is light yellow in color and of uniform texture, and high luster. The rays are straight and fine but plainly visible without lens. The vessels are visible under a lens. Growth-rings are faint.

*Minute.*—The vessels are straight, composed of long segments with large simple perforations (cf. fig. 7, *b*, *p2*); pits, scalariform or large elliptical or circular bordered, with lenticular crossed orifices; perforations, commonly terminal, with abutting ends of segments turned inward (cf. fig. 7, *c*). As a rule the segments of a group are conterminous. The rays are composed of rather large thin-walled ( $0.002$  mm.) cells not greatly elongated. Those in the central portion are generally slightly longer radially; those at the margin, slightly elongated axially. The radial walls are minutely pitted in contact with prosenchyma, or coarsely pitted in contact with parenchyma, or with large elliptical to scalariform semibordered or simple pits in contact with vessels. Many of the fibers are conterminous, having numerous simple pits with slitlike orifices in irregular axial rows. Wood-parenchyma is not abundant and bears large elliptical semibordered or simple pits communicating with the vessels; cavities, as a rule, are empty.

#### TANGENTIAL SECTION

*Gross.*—The tangential surface is of uniform texture and yellow or bluish in color, with no structural differences visible without lens. Under lens the rays are slightly darker than the surrounding tissues, and appear



with narrow linear lanceolate, acutely pointed outlines. The vessels, on account of their light color and small size, are difficult to distinguish.

*Minute.*—The vessels show scalariform or crowded variously bordered pits with lenticular orifices, or, less commonly, coarse elliptical semibordered or simple pits in contact with parenchyma. Walls in contact with fibers are minutely pitted. The rays are linear or linear-lanceolate in outline, and acutely pointed at the margins. The cells are irregular in size, vary from 0.015 to 0.12 mm. in diameter, and generally have elongated cells at the margin. The fibers are sparsely pitted on the tangential walls.

#### MACERATION

The vessel segments have simple terminal (fig. 7, c) or lateral perforations as in figure 7, b, p2. In some segments each end extends into an overlapping tip (fig. 7, d). The length varies from 0.2 to 1 mm. The pit markings vary from lenticular to scalariform or open elliptical. The fibers are serried radially, and rounded prismatic in shape with short and irregular attenuate unpitted points, and from 0.7 to 1.3 mm. in length. The radial sides are numerous marked with slitlike slightly oblique pit orifices. Ray-cells are tabular, and generally numerous pitted with subcircular or broadly elliptical pits of varying sizes. Also cells occur with characteristic vessel- or prosenchyma-contact pits. The few wood-parenchyma cells are elongated and generally show scalariform markings.

#### DISTINGUISHING CHARACTERS

The wood is diffuse porous, soft, pale yellow with high luster, faint growth-rings, and bluish sapwood, of even texture and straight-grained. The vessels are arranged mainly in small groups, are visible with a lens, have simple perforations, terminal and lateral in position, are bordered, semi-bordered, or have simple variable pits that are sometimes seen in scalariform arrangement. There are a few scalariform perforations. The rays are 1-4 cells wide and commonly less than 1.5 mm. high. Simple or semi-bordered pits are formed in contact with vessels. The fibers have thin walls with numerous simple pits. Wood-parenchyma cells are few and mostly in contact with vessels.

***Panax gaudichaudii* DC. OLAPA.**

*Cheirodendron gaudichaudii* (D. C.) Seem.

Material, xxxix:28:1429.

The species attains a height of 40-50 feet and a diameter of 24 inches. It is common throughout Hawaii in the middle forest zone at elevations of 2,000-4,000 feet. The wood is light straw-yellow, diffuse porous, of medium hardness, without growth-rings, and without distinct heartwood.

#### CROSS SECTION

*Gross.*—The vessels are visible with lens, of rather uniform diameter, larger than the rays, many of them grouped in twos, and there are few tyloses. The rays are plainly visible without lens.

*Minute.*—The vessels are of rather uniform diameter ( $0.08 \pm$  mm.) and subcircular in outline or flattened by contact, grouped in twos for the most part, or, less commonly in threes or fours+; a few, usually of large diameter, occur singly; walls, thin ( $0.003$  mm.). Many partition walls, especially of the radial sides, are open in the middle on account of the presence of large lateral perforations (cf. fig. 7, *a* and *b*). Cavities are empty or have tyloses. The vessels are in contact with prosenchyma except where adjacent to rays or occasional wood-parenchyma cells. The rays are straight, from 1-4+ cells broad, thin-walled, numerous and conspicuously pitted on walls, and communicate with adjacent prosenchyma by simple pits. The cells in the broad rays are elongated ( $0.24 \pm$  mm.) or short ( $0.06$  mm.) in the uniseriate rays. The fibers are in rather regular radial rows, thick-walled ( $0.006 \pm$  mm.), and under high power are seen to be pitted conspicuously on radial and sometimes on tangential walls with simple pits. Lumina, large open; pectin lamella often found thickened at the angles. There are a few wood-parenchyma cells, generally in contact with vessels.

#### RADIAL SECTION

*Gross.*—The surface is of high luster, very uniform in texture and color; the rays are conspicuous, light-colored; the vessels not visible except under lens.

*Minute.*—The vessels are straight, with scalariform-bordered pits in mutual contact or with elliptical or scalariform semibordered or simple pits in contact with ray- or wood-parenchyma. Walls in contact with fibers bear few small subcircular or elliptical semibordered pits with lenticular orifices; segments, long ( $1.3 \pm$  mm.); perforations, highly variable from scalariform with few bars, to reticulate or simple with one or more large circular or elliptical openings, with the plane of perforation obliquely inclined toward the rays. The rays are heterogeneous with vertically elongated marginal cells, very thin-walled ( $0.002$  mm.), nonresinous, and numerous pitted on all walls except those in contact with fibers, where the pits are few, simple, and minute. Those communicating between ray-cells are small ( $0.003$  mm. in diameter), subcircular in outline, and tend to occur in radial rows. Pits communicating with vessels are generally scalariform or long elliptical and semibordered. The fibers bear numerous scattered simple pits with axially inclined slitlike orifices. Many terminate at the ray margins, with rounded ends. Wood-parenchyma is nearly absent, and mostly in contact with vessels that have semibordered or simple scalariform pits extending from one side to the other transversely across the wall in contact with the vessels.

#### TANGENTIAL SECTION

*Gross.*—The rays and vessels are visible with a lens, the surface appearing of very uniform texture and color. Under lens the rays appear of slightly darker color, short, and about as wide as the vessel cavities. The vessels are straight, without tyloses or resin, and of the same color as the fibers.

*Minute.*—The rays are elliptical in outline, 1-4+ cells wide and mostly less than 1 mm. in height. From one to three secretory canals are present in some of the rays. Such canals are broadly elliptical in outline (fig. 9, c) and  $0.07 \pm$  mm. in diameter. An inner somewhat irregular layer of small cells (*l p s*) lines the cavity. The occurrence of intercellular canals in dicotyledonous species constitutes a character of considerable systematic value as shown for the first time by S. J. Record (17). The rays usually terminate with a single cell, though some have two or more cells of 2-3+ times the average height of those in the central portion of the ray. The fibers bear few simple pits in tangential walls.

#### MACERATION

The vessel segments are long ( $1.3 \pm$  mm.), cylindrical, with obliquely truncated ends. The perforations are highly variable from scalariform to simple. The ray-cells are commonly elongated, 4-10 times as long as wide, and numerous and finely pitted; a few bear scalariform outlines, in contact with vessels; still others bear small pits in contact with prosenchyma. The relatively few marginal cells are distinguished by their tabular shape. The fibers are long ( $2 \pm$  mm.),  $0.03 \pm$  mm. in diameter, and taper somewhat irregularly many with ends irregularly bent, forked, wavy margined, or less commonly, rounded and blunt. The walls are  $0.006 \pm$  mm. in thickness, are numerous pitted in radial rows having scattered simple pits with axially inclined slitlike orifices. Some of the fibers are resinous. Wood-parenchyma cells are rare and may be distinguished by the transverse barlike scalariform markings formed in contact with vessels.

#### DISTINGUISHING CHARACTERS

The wood is of medium hardness, light-yellow, without growth-rings or distinct heartwood. The vessels are diffuse, generally grouped in twos, less frequently found singly or 2-4+ together; walls, thin with scalariform pitting; cavities, with few if any tyloses and little resin; segments, long, cylindrical; perforations varying from scalariform with few bars to reticulate, or simple with one or more large circular elliptical or irregular openings. The rays are mostly multiseriate (1-4+ cells wide), heterogeneous, and many contain one or more intercellular canals. The fibers bear simple pits with slitlike orifices, mostly on the radial walls. The fibers are about 2 mm. maximum length, and irregularly taper pointed. Some have forked ends. Wood-parenchyma cells are uncommon and adjacent to vessels.

***Panax platyphyllum*** Hook. et Arn. LAPALAPA.

*Cheirodendron platyphyllum* (Hook. et Arn.) Seem.

Material, xx:x4:1425.

This is an endemic species somewhat smaller than *Panax gaudichaudii*, occurring in the rain forests or on swampy ground at elevations of 4,000-6,000 feet. It is far less common than *C. gau-*

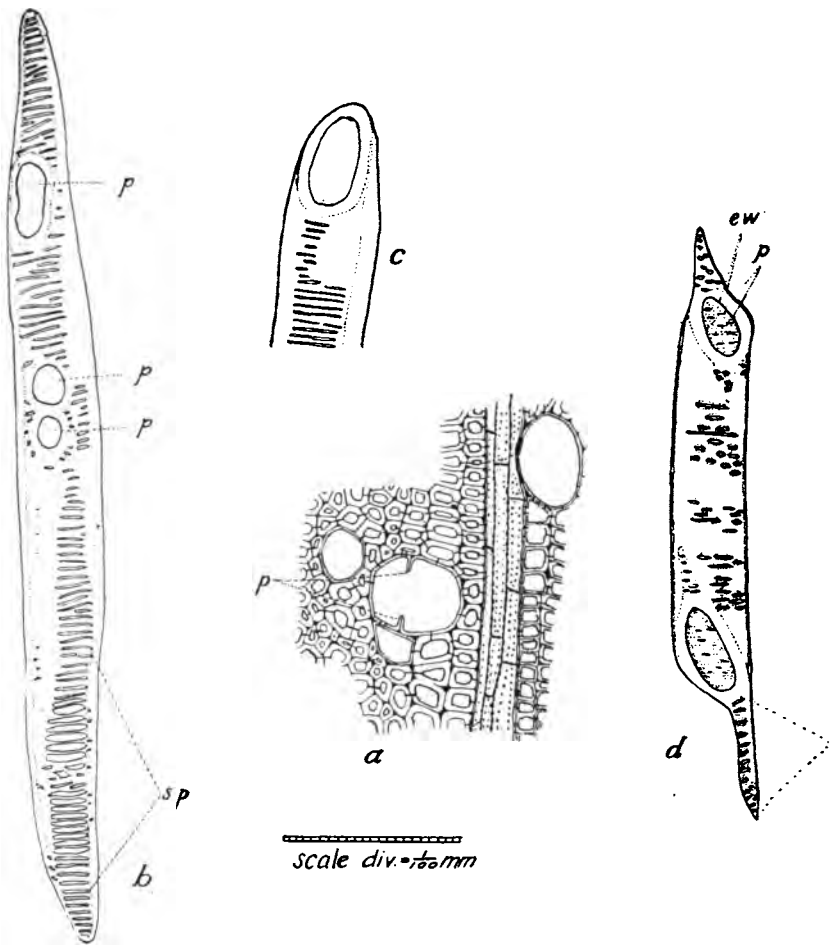


FIGURE 7. **a-c**, Sections of *Panax platphyllum* wood: **a**, cross section, showing lateral perforation (**p**); **b**, tracheal segment showing simple lateral perforations (**p**) and scalariform perforation (**sp**); **c**, tracheal segment showing terminal simple perforation; **d**, Tracheal segment of *Pterotropia gymnocarpa* wood showing end-wall (**ew**); perforation, simple, but smaller than the vessel-lumen (**p**); and tonguelike projection (**t**).

*dichaudii*, and is limited to the islands of Kauai and Oahu. It is associated with *Pelea* and *Dubautia*. The wood is pale yellow, of medium hardness, brittle, cross-grained, without growth-rings or distinct heartwood.

## CROSS SECTION

*Gross.*—The vessels are visible with lens, smaller than the rays, diffuse, grouped 2-4 together, mostly in twos, or some single.

*Minute.*—The vessels are subcircular in outline, except where flattened in contact, with few tyloses; the walls are thin (0.003 mm.); many partition walls show large perforations (fig. 7, *a*), through the radial walls between adjacent tracheae. The vessels are mainly in contact with fibers. The rays are straight, mostly multiseriate, and composed of numerous pitted, narrow, greatly elongated cells; cell-walls, thin (0.002 mm.). The fibers occur in rather irregular radial arrangement, are thick-walled (0.006± mm.) with wide lumina; radial walls of the fibers bear many simple pits. The middle lamella as a rule is thickened at the angles. Wood-parenchyma walls are uncommon, and occur mostly in contact with the vessels.

## RADIAL SECTION

*Gross.*—The color is grayish pale yellow, figured only by the slightly lighter color of the rays. The vessels are visible under lens, usually dark in color, and straight.

*Minute.*—The vessels have narrowly elliptical or scalariform bordered pits when in contact with vascular elements, or semibordered pits in contact with ray- or wood-parenchyma cells, or are sparingly pitted with minute pits when in contact with fibers. The perforations are highly variable, from scalariform to reticulate or simple, and occur on lateral (fig. 7, *b*) (generally radial) walls as well as on end-walls. The rays are heterogeneous, the central cells elongated radially. The marginal cells are shorter and higher, but variable, 0.03 to 0.18 mm. high axially and 0.06± mm. long radially. The walls are pitted abundantly with numerous, subcircular pits about 0.003 mm. in diameter which tend to occur in rows, or with coarse, elliptical or scalariform semibordered or simple pits in contact with the vessels. Cells which constitute the inner layer of the secretory canals (fig. 9, *b*) are variable in length and shape, with the axial walls obliquely inclined as if such cells had been pushed over in an outward direction parallel with the axis of the canal. The fibers bear irregularly arranged simple pits with slitlike orifices, either inclined with or oblique to the axis. Wood-parenchyma is not abundant, consisting of a few cells, mostly in contact with vessels, and bearing scalariform or broadly elliptical pits.

## TANGENTIAL SECTION

*Gross.*—The dull whitish-yellow surface is very uniform in texture and color. Under lens the rays are of slightly darker shade than the prosenchyma, low, mostly less than 3 mm. high, and much broader than the vessels, which are straight and commonly darker in color than the rest of the wood.

*Minute.*—The vessels have scalariform (or narrowly elliptical) pits except where in contact with fibers. The segments are of medium length (1.3± mm.) and cylindrical. The rays are broad (0.006 to 0.18 mm.) and imperfectly heterogeneous, or uniseriate and homogeneous. The broad rays

terminate at the margin, generally rather obtusely, and very few are more than 1.5 mm. high. Some of them contain 1 to 3 resin ducts. The cells composing all but the margins are subcircular in outline and  $0.015 \pm$  mm. in diameter. The marginal cell is commonly larger and irregular, though as a rule slightly elongated axially. The fibers are sparingly pitted on tangential walls with slitlike, simple pits. Wood-parenchyma is not abundant and occurs mostly in contact with vessels.

#### MACERATION

The vessel segments are cylindrical, 0.7 to 1.3+ mm. in length, and very variously pitted and perforated (fig. 7, b) on the lateral walls. Some segments show evidences of lateral fusion. Scalariform, reticulate, and large simple perforations occur in end-walls and in some of the lateral walls. Lateral walls which have been in contact with prosenchyma show few minute subcircular pit markings. Other walls show scalariform or narrowly elliptical pit markings. The ray-cells are generally elongated, 4-6 times as long as broad, with small simple pits in longitudinal rows. There are some cells with scalariform pit markings. Prosenchyma fibers are 1.5 mm. long or shorter and are numerous pitted on the radial walls, throughout the length of some of them. The points are often observed irregularly curved or bent or forked. Some of the fibers are resinous.

#### DISTINGUISHING CHARACTERS

Wood is distinguished from *Panax gaudichaudii* by its white color, duller luster, and more cross-grained wood. The rays, especially, are much broader than the vessels, many 10+ cells wide, or nearly twice as broad as in *P. gaudichaudii*.

#### Order ERICALES

#### Family EPACRIDACEAE

A family of shrubs or small trees confined mainly to Australia and Polynesia. There are 21 genera, all but one of which are to be found in Australia or Tasmania. The vessels have small lumina (0.03 mm.) and in many species 1-2 seriate medullary rays, the cells of which are elongated axially. The vessel walls bear bordered or semibordered pits. The perforations are simple, as a rule, but scalariform perforations occur. Spirals occur at the ends of the vessels of Epacris. The wood-parenchyma is little developed. Bordered pits occur in the walls of the prosenchyma.

**Cyathodes tameiameiae** Cham. PUKEAWE. Material, xxv:74:1438.

*Styphelia tameiameia* F. Muell.

This is the largest genus in the family, and most of the species are Australian. *Cyathodes tameiameiae* is indigenous to Hawaii,

where it is of general distribution at all elevations. It also occurs in Tahiti and in the Society Islands. A height of 10-15 feet is reached by this tree and a D. B. H. of 12 inches.

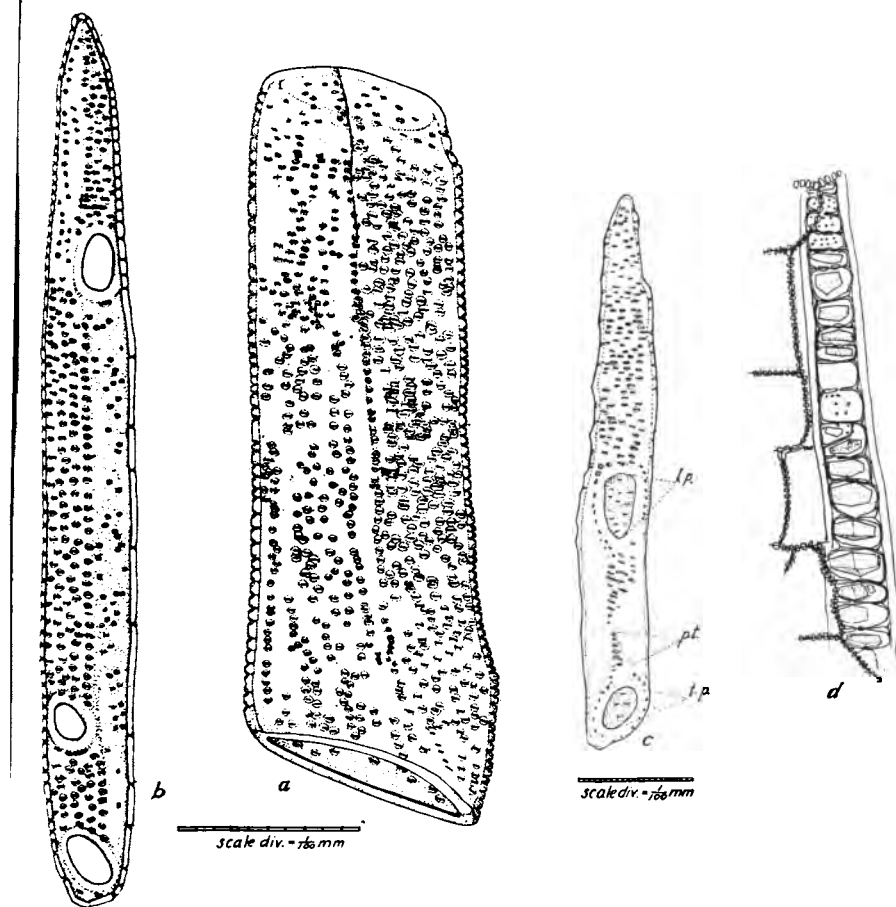


FIGURE 8. **a** and **b**, Sections of *Dubautia plantaguinea* wood: **a**, tracheal segment, truncate, and with simple terminal perforations, of nearly the size of the vessel lumen; **b**, tracheal segment with lateral perforations; **c**, tracheal segment of *Tetraplasandra waimaeae* wood, showing lateral perforation (lp); terminal perforation, smaller than the vessel lumen (tp); markings of overlapping tongue-like projection of the sequent vessel segment, now removed (pt); **d**, crystal-parenchyma of *Cyathodes tamciamiiae* wood, showing octahedral crystals.

The seasoned wood is deep reddish-brown in color with medium wide zones of light reddish-brown sapwood, resinous, of medium hardness, even and fine textured, slightly cross-grained, and with a very slight indication of growth-rings.

#### CROSS SECTION

*Gross.*—The rays are visible with lens and reddish in color. The vessels are diffuse, isolated, much smaller than the rays, and visible only under a lens.

*Minute.*—Most of the vessels are isolated, but a few are in contact. They are very small,  $0.06 \pm$  mm. in diameter, thin-walled ( $0.002$  mm.), without tyloses, but some contain a resinlike body. The rays are 1-8 cells wide, broader than the vessels, straight, mostly short-celled; the cell cavities are filled with large globules that stain deeply with safranin. The fibers are irregularly polygonal in outline, very variable in size ( $0.03 \pm$  mm.), with medium thick walls, pitted on all sides, and large rounded lumina. There is no definite arrangement. Growth-rings are indistinctly indicated by a slight flattening of the prosenchyma cells. Wood-parenchyma cells occur in numerous single-celled broken tangential rows. The cells have deep-staining contents similar to the rays. Crystal-parenchyma is present and as a rule is in contact with or within the rays.

#### RADIAL SECTION

*Gross.*—The rays are reddish but not conspicuous, and some of them are 2 mm. high. The vessels, visible under a lens, are very small, numerous, straight, and empty.

*Minute.*—The vessels are straight, with medium-long segments, and sides with few minute ( $0.003$  mm.) circular-bordered pits; perforations, simple, obliquely inclined, and terminal or lateral in position. The rays are composed of cells some of which are elongated axially and some radially. The radially elongated cells occur within (as determined from the tangential section); the axially elongated cells tend to occur at the margin and the outer portion of the radial sides. The cell cavities are filled with globules which stain deeply with safranin. The walls are thin ( $0.003$  mm.), numerous and finely pitted on the upper, lower, and tangential walls. The radial walls are numerous pitted with small subcircular pits  $0.003 \pm$  mm. in diameter, and are of nearly the same size even in contact with vessels. Such pits are commonly obscured by staining, but clear in glycerine. The prosenchyma is nonseptate with numerous circular-bordered pits on all walls similar to those in the vessels. Wood-parenchyma consists mostly of axially elongated finely pitted cells with globular contents which stain deeply with safranin. Crystal-parenchyma is present in places, often observed in association with the rays (fig. 8, d). The crystals are solitary, octahedral, and dissolve without effervescence in 10 per cent HCl.



## TANGENTIAL SECTION

*Gross.*—Structural details are scarcely visible without lens. Under lens the rays appear as reddish lines that are often observed as long as 2 mm. The vessels are smaller than the rays and difficult to distinguish.

*Minute.*—The vessels are numerous, fine, straight, sparingly and minutely pitted. The rays are from 1-6+ cells wide, and from 1-70 cells high, with cells filled with a resinlike substance. The cells in the broad rays are variable in shape, outline, and arrangement, but those with greatest

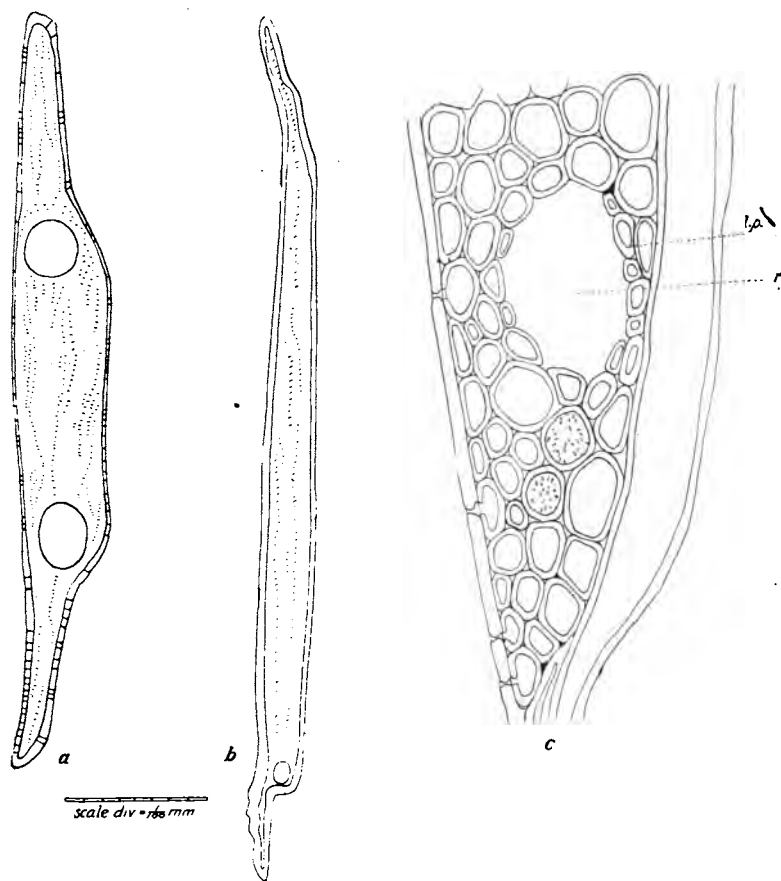


FIGURE 9. **a**, Tracheal segment of *Cyathodes tameiameiae*, terminating beyond the perforation in tracheid-like projections; **b**, tracheid-like cell of *Cyathodes tameiameiae*; **c**, ray of *Panax gaudichaudii*, showing secretory canal (**r**) and inner layer of small, pitted cells (**lp**).

axial elongation tend to occur at the margins or sides. Aggregations of rays occur.

#### MACERATION

The vessel segments are cylindrical, of medium length ( $0.4 \pm$  mm.), with simple perforations oblique as a rule and many near the end and lateral (fig. 9, *a*). A projecting tip of varying length is usually present at one end or both ends. The pit markings are minute, few, and resemble the pitting of prosenchyma. Intermediate forms between prosenchyma and tracheal elements are numerous (fig. 9, *b*). The prosenchyma is made up of fibro-tracheids with numerous bordered pits. The ends taper irregularly for about one-third the length of the fibro-tracheid. The pitting generally extends over the sides of the tapering portion. The walls are of medium thickness.

#### DISTINGUISHING CHARACTERS

The seasoned wood is deep reddish-brown with lighter colored sapwood, resinous, of medium hardness, even and fine textured without distinct growth-rings. The vessels are visible with a lens, numerous, isolated, without tyloses, minutely and sparingly pitted, and with simple perforations terminal, some lateral in position. The rays are 1-6 cells broad, and up to 2+ mm. in height, very resinous, and irregularly heterogeneous. The pits are small and are little if any larger where in contact with a vessel. The prosenchyma is composed of fibro-tracheids  $1 \pm$  mm. in length and pitted throughout with small bordered pits having long oblique slitlike orifices. Wood-parenchyma is metatracheal, resiniferous, and distributed in numerous broken lines 1 cell in width. Crystal-parenchyma is present but not abundant.

#### Family MYRSINACEAE

The Myrsinaceae are trees or shrubs of which there are about 770 species of general distribution in the Tropics. The wood is characterized by vessels with simple or scalariform perforations and by bordered, semibordered, and in some specimens simple pits. Some rays are as wide as six cells or wider. Wood-parenchyma is not abundant; the fibers bear simple pits and are commonly septate.

#### **Myrsine lessertiana** A. DC. KOLEA.

*Suttonia lessertiana* (A. DC.) Mez.

Material, xlvi:35:1447.

*M. lessertiana* is a variable species of the rain forests of Oahu, Hawaii, and of other islands of the group. It is endemic, attains a height of 60 feet and a D. B. H. of 24 inches. The wood is pinkish-yellow in color, resinous, with coarse reddish-brown rays, diffuse porous, rather hard, cross-grained, and without growth-rings.

## CROSS SECTION

*Gross.*—The vessels are small, visible with lens, isolated or in radial groups of twos, or rarely more, and circular in outline, or slightly compressed in contact. The lumina are mostly free from contents and permeable to alcohol. The rays are very broad ( $0.4 \pm$  mm.), with brownish resinlike contents.

*Minute.*—The vessels are nearly uniform in size and mostly less than 0.1 mm. in diameter. Occasionally lumina filled with a resinlike body are seen. The walls are 0.003 mm. in thickness. The rays are multiseriate, over twice as wide as the vessels, and composed of cells not greatly elongated. The cell cavities are filled with globular, resinlike material. The fibers are polygonal, of rather large diameter, medium-thick walls, and contain resinlike material in the lumina. Simple pits are present in all walls. Wood-parenchyma cells occur mainly adjacent to vessels, and contain resinlike material.

## RADIAL SECTION

*Gross.*—The rays are very prominent and reddish in color.

*Minute.*—The vessels are composed of segments of medium length, with simple, circular or elliptical perforations smaller than the vessel lumen; the pits are semibordered or bordered, small, numerous, and with variable long or short lenticular or slitlike orifices. The rays are composed of (1) a few radially elongated cells, (2) many nearly square cells, and (3) a number of axially elongated cells, especially at the margins, many of which show transition to fiberlike shapes. The ray pits are minute. Wood-parenchyma cells are  $0.12 \pm$  mm. in length.

## TANGENTIAL SECTION

*Gross.*—The rays are prominent and some of them as much as 9+ mm. in height.

*Minute.*—The longest rays are as much as 200+ cells high and 15+ cells wide. The cells are mostly broadly elliptical in outline, rather variable in size, with axially elongated cells at the margin or sides. Solitary mineral crystals occur in some of the cells. The fibers are septate.

## MACERATION

The fibers are short,  $0.9 \pm$  mm. in length, and have short irregularly tapering or forked ends. Pits are numerous and have oblique orifices.

## DISTINGUISHING CHARACTERS

The wood is pinkish-yellow in color, resinous, diffuse porous, rather hard, and without growth-rings. The vessels are small, visible in cross section with lens, isolated or in small groups, finely pitted, and with simple perforations; the lumina are generally open and permeable to alcohol. The rays are very broad, the longest as much as 0.9+ mm. in height, reddish in color, and very prominent on the radial surface. The fibers are short and rather thick-walled. Wood-parenchyma cells are mostly in contact with vessels.

Order EBENALES  
Family SAPOTACEAE

The Sapotaceae are trees or shrubs of general distribution in the Tropics and comprise about 445 species. The wood is characterized by vessels with simple or, rarely, scalariform perforations, and bordered, semibordered, and in connection with the rays, simple pits. The rays are narrow, 1-6 seriate. Wood-parenchyma occurs in tangential lines. Wood-prosenchyma is thick-walled with small lumina and bears simple pits.

**Sideroxylon sandwicense** (Gray) Benth. and Hook. ALAA.

Material, cii:33:1477.

The genus *Sideroxylon* comprises over 100 species. Those occurring in Hawaii are mainly xerophytic, and characteristic especially of the leeward sides of the islands. *S. sandwicense* grows to a height of 50 feet and occurs as an endemic species generally throughout the Territory except in the island of Hawaii, where the species is absent. The wood is yellow, streaked with black, hard, straight-grained, diffuse porous, and with faint growth-rings.

CROSS SECTION

*Gross.*—The vessels are small, visible with a lens, and mostly grouped many together, in radio-tangential series. The lumina are mostly open and permeable to alcohol. The rays are smaller than the pores, visible but not prominent under a lens. Numerous fine tangential lines of wood-parenchyma are visible with a lens.

*Minute.*—The vessels rarely exceed 0.12 mm. in diameter; the walls are rather thin (0.003 mm.). The rays are 1-2+ cells wide; the cells, mostly elongated and minutely pitted. The fibers have thick walls, small lumina, and small simple pits. Wood-parenchyma cells are of nearly the same diameter as the fibers, but have thin walls, are numerous and arranged irregularly in tangential rows. Growth-rings are defined by the relative abundance of wood-parenchyma and fibers.

RADIAL SECTION

*Gross.*—The rays and wood-parenchyma are visible but not prominent under a lens.

*Minute.*—The vessels bear simple perforations as a rule somewhat smaller than the vessel lumen. The pits are bordered with lenticular orifices between adjacent vessels, and large, narrowly semibordered, or

simple between vessels and ray-cells or wood-parenchyma. The rays are composed partly of radially elongated cells, partly of nearly square cells, and in small part, of axially elongated cells. Large simple or narrowly semibordered pits occur where adjacent to vessels. Wood-parenchyma cells are  $0.09 \pm$  mm. long, and in numerous, mainly single, rows; the pits are small or minute.

#### TANGENTIAL SECTION

*Gross.*—Wood-parenchyma and rays are barely distinguishable even under a lens.

*Minute.*—The rays are mainly uniseriate or uniseriate in part with one or more biseriate portions. In the uniseriate portions the cells are axially elongated, especially at the margins. In the biseriate portions the cells are much smaller with little or no elongation.

#### MACERATION

The vessel segments are long in proportion to diameter; the pit markings, mainly small; but there are many large elliptical or irregular simple pits. The perforations are generally smaller than the vessel lumen. Many of the vessels project beyond the perforations into short tongue-like ends. The fibers are mainly under 1.4 mm. in length, straight, and taper from near the middle into sharp points.

#### DISTINGUISHING CHARACTERS

The wood is yellow, diffuse porous, hard, straight-grained with growth-rings. The vessels are visible with a lens, grouped in large radio-tangential series. The perforations are simple and the pits bordered, semi-bordered, and simple. The rays are 1-2 cells wide and up to 40 cells high. The fibers are thick-walled, with small lumina, and bear simple pits. Wood-parenchyma is abundant and arranged in tangential rows.

#### Family EBENACEAE

The Ebenaceae are mainly tropical or subtropical plants and numerous, especially in the East Indies and Malayan Archipelago. *Maba* is the only genus of this family occurring in Hawaii, and only *Maba hillebrandii* Seem. is endemic, *M. sandwicensis* occurring also in Fiji.

The secondary wood is characterized by 1-2+ seriate rays, vessels with simple perforations, bordered or semibordered pits, abundant wood-parenchyma distributed both in tangential lines, sometimes found only 1 cell in breadth, and around the vessels. Crystal-parenchyma may occur. The wood-prosenchyma is char-

acterized by bordered pits with slitlike orifices often extending beyond the border. Some members have deep-colored heartwood.

**Maba sandwicensis** A. DC. LAMA. Material, xxiv:22:1432.

*Maba sandwicensis* is a tree of 20-40 feet in height and 12 inches D. B. H. It is of general distribution in dry or rarely in wet situations in the Territory, and there are many forests of pure growth. It occurs (2) in association with *Aleurites moluccana*, *Pittosporum hosmeri* var. *longifolia*, *Antidesma pulvinatum*, or with *Straussia*, and *Metrosideros*.

The seasoned wood is hard, even textured and gritty, light reddish-brown with portions yellowish and faintly tinged with red. It was formerly used for sacred purposes.

#### CROSS SECTION

*Gross.*—There are no growth-rings. The vessels are small, visible under a lens, and in small radial groups. The rays are visible under a lens, much smaller than the vessels. Numerous, narrow, tangential, wavy lines of wood-parenchyma are visible with lens.

*Minute.*—The vessels are diffuse, part of them isolated and part grouped radially 2-6+ together. The walls are moderately thickened (0.006 mm.) and, when grouped, possess angular outlines. The cavities are without tyloses or other contents. Rays 1-2 cells wide, comparatively straight, with numerous small (0.002± mm.) subcircular pits. Wood-parenchyma occurs in numerous narrow tangential bands, usually 1 cell wide. Numerous isolated cells contain single mineral crystals (fig. 6, b). Wood-prosenchyma cells are of small diameter (0.016± mm.), thick-walled (0.006± mm.), with small lumina, and bear frequent pits.

#### RADIAL SECTION

*Gross.*—The rays are indistinctly visible without lens. The vessels are visible with a lens. The wood is straight-grained, and somewhat resinous.

*Minute.*—The vessels are straight, with short (0.04± mm.) segments with simple terminal perforations. The pits are small, subcircular with narrow lenticular, oblique or transverse orifices, bordered or semibordered. The ray-cells are minutely pitted in contact with prosenchyma. In contact with the vessels, numerous semibordered pits are formed of nearly the same diameter as the vessel pits. The cell cavities are empty or nearly so. The uniseriate rays are composed of cells nearly square (0.03± mm.) or elongated axially (0.06± mm.). The other rays are composed partly of low radially elongated cells, and partly of square or axially elongated cells similar to those in the uniseriate rays and, as a rule but not invariably, are at the margin. The prosenchyma is nonseptate but contains light-colored resin plates. The wood-parenchyma is composed partly of axially elongated cells 0.09± mm. in length, in long single cell rows alternating at regular dis-

tances with the prosenchyma, and partly of numerous crystal-parenchyma cells commonly 1 cell wide and 2-20+ in a strand.

#### TANGENTIAL SECTION

*Gross.*—The vessels are visible with lens, empty, and straight. Faint striations are produced by lines of wood-parenchyma.

*Minute.*—The vessels have numerous small crowded pits with faint hexagonal outlines and short lenticular transverse or somewhat obliquely inclined orifices. The rays are mainly uniseriate or uniseriate in part. The uniseriate rays are composed of axially elongated cells  $0.05 \pm$  mm. high, or with a slightly longer acutely pointed cell at each margin. Those that are uniseriate in part have a biseriate central portion composed of cells typically circular or broadly elliptical in outline. The uniseriate margin is composed of one to several elongated cells of the same description as in the uniseriate rays. Only a few are typically biseriate. The rays are from 1-30+ cells in height. Wood-parenchyma is without orderly arrangement.

#### MACERATION

The vessel segments are of rather uniform length, the pit markings small, numerous, and evenly distributed or variously grouped. The ends are commonly, but not invariably, nearly transverse and may have a short projecting tip. The prosenchyma fibers are slender, more or less wavy, thick-walled, with small lumina containing resin. The central third is pitted. The ends taper from near the middle third into long needle-like or curved points, many of them with jagged edges. The fibers are  $1 \pm$  mm. in length.

#### DISTINGUISHING CHARACTERS

The wood is light reddish-brown or whitish in portions, hard, gritty, fine and even textured, straight-grained, without growth-rings, but with many narrow concentric lines of wood-parenchyma visible with lens. The vessels are small, diffuse, commonly in small radial groups, without tyloses, medium thick-walled, with medium short segments, as a rule, but not invariably, transverse at the ends, with simple perforations, and numerous small pits with transverse or somewhat oblique lenticular orifices. The rays are 1-2 cells wide, imperfectly heterogeneous when more than one cell wide. The wood-prosenchyma is thick-walled, with small lumina transversed by resin plates, and bears bordered pits with extended slitlike orifices. Wood-parenchyma occurs in numerous tangential lines 1 cell wide; chambered crystal-parenchyma is abundant.

#### Order CONTORTAE

#### Family OLEACEAE

The Oleaceae comprise about 390 species of shrubs or trees of general distribution in the tropical and temperate climates. *Olea*

*europaea*, *Ligustrum*, and *Fraxinus*, belong to this family. *Osmanthus sandwicensis* is the only representative in Hawaii.

The wood is characterized by vessels with simple or, rarely, scalariform perforations, and bordered or semibordered pits. Spiral thickenings may occur. The rays are 1-4 seriate. The wood-prosenchyma has either bordered or simple pits. Septae and spirals have been found in the prosenchyma of certain genera.

***Osmanthus sandwicensis*** Benth. and Hook. PUA or OLOPUA.

Material, lxiv:21:1463.

This species is endemic to the Territory and is one of the most common trees on the dry leeward sides in the lower forest zone. It grows to a height of 60 feet and has a D. B. H. of 3 feet. The wood is reddish- or yellowish-brown in color with dark or blackish streaks or zones. The sapwood is yellow. It is diffuse porous, very hard, with indistinct growth-rings.

#### CROSS SECTION

*Gross.*—The vessels are small, visible with a lens, and mostly in groups of 2-10+. The lumina in heartwood are filled with an amber-colored body and impermeable to alcohol. The rays are smaller than the vessels, light-colored, and not visible without a lens. Growth-rings are defined by zones of wood-parenchyma. (Very numerous fine tangential lines of wood-parenchyma visible with lens.)

*Minute.*—The vessels are mostly in irregular groups of 2-10+ each, extending in both radial and tangential directions. The size of the vessels is nearly constant throughout the growth-rings, though variable in the groups, and rarely exceeds 0.14+ mm. in diameter. The rays are 1-2 cells wide; the walls, minutely pitted. The fibers are arranged in radial rows, possess thick walls, and rather small but variable lumina, and simple pits. Wood-parenchyma is moderately abundant, of rather greater radial diameter than the fibers, and distributed mostly in tangential zones or lines, 1-2+ cells wide and at a distance of 2 to 12+ fibers apart. Also wood-parenchyma is relatively more abundant in comparatively broad zones which define the growth-rings.

#### RADIAL SECTION

*Gross.*—The elements are more or less filled with an amber-colored body. The rays and zones of wood-parenchyma are barely visible without a lens. The grain is irregular.

*Minute.*—The vessels are composed of segments of medium length, with simple perforations slightly smaller than the vessel lumen. The pits are small, circular in outline with short lenticular orifices in the vessel wall, uniform in size and bordered or semibordered. The rays are heteroge-



neous, with radially elongated cells in the central portion and generally square cells at the margin. The pits are small even in contact with vessels. Wood-parenchyma pits are minute and grouped or arranged in circles. The fibers possess simple pits with long slitlike orifices.

#### TANGENTIAL SECTION

*Gross.*—The rays are low, narrow and indistinct under a lens.

*Minute.*—The rays are elliptical in outline with obtuse or acute points, mostly biseriate and commonly less than 14 cells high. The cells are comparatively uniform in size, those at the margin being slightly elongated axially.

#### MACERATION

The fibers are of medium length, of rather small diameter, and irregularly bent or curved, tapering into irregular sharp ends.

#### DISTINGUISHING CHARACTERS

The wood is reddish- or yellowish-brown in color with dark streaks and yellow sapwood. It is diffuse porous, very hard, cross-grained, and with rather indistinct growth-rings. The vessels are small, visible with a lens, mostly grouped irregularly 2-10+ together, and filled with an amber-colored substance in heartwood. The perforations are simple and the pits small and uniform in size. The rays are mostly biseriate and low. The fibers are arranged in radial rows, thick-walled, with small lumina and simple pits. Wood-parenchyma is fairly abundant and in narrow tangential lines or in broader zones defining the growth-rings.

#### Family APOCYNACEAE

A family of mainly tropical distribution, of both woody and herbaceous forms. There are 133 genera, comprising in all 1,000 species. A few are trees, a large number are woody climbers (lianes) or shrubs, and the remainder herbaceous perennials. Three genera with arborescent species are represented in the Territory: namely, *Pteralyxia*, *Ochrosia*, and *Rauwolfia*. Familiar representatives are the oleander (*Nereum oleander*) and Indian hemp (*Apocynum*).

The secondary wood is, so far as known, characterized by narrow medullary rays, by vessels with simple perforations, and by bordered, semibordered, or, rarely, simple pits. The wood-prosenchyma has bordered or simple pits. The pith of some of the wood contains stone cells, and phloem occurs in all the sections examined, either as a continuous ring or as isolated bundles at the margin next or near to the wood.

**Rauwolfia sandwicensis** A. DC. HAO. Material, vii:59:1423.

Small tree, sometimes shrub, 20 feet high and 12 inches D. B. H., closely resembling *Ochrosia*. It attains best development in rich soil not too dry, but grows in dry situations at elevations of 2,000 feet. This is the only species of the genus represented in the Territory.

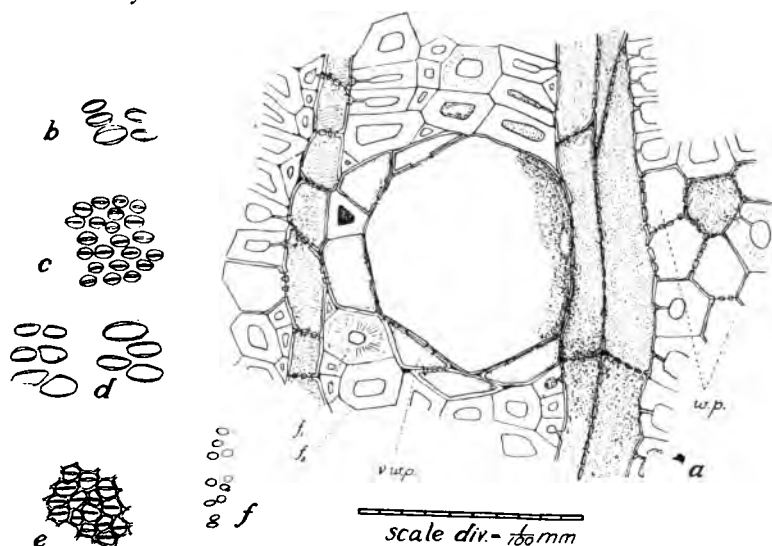


FIGURE 10. Sections of *Rauwolfia sandwicensis* wood: **a**, cross section, showing wood-parenchyma (**wp**), wood fiber, nonstriated (**fn**), wood fiber, striated (**fs**), wood-parenchyma in contact with vessel (**wpv**); **b-e**, sections showing radial pitting; **b**, semibordered pits communicating between vessels wood-parenchyma; **c**, ray-vessel pits varying from semibordered to simple; **d**, crowded bordered pits, in common wall between vessels; **e**, rounded bordered pits, in common wall between vessels; **f**, simple pits occurring in common wall between ray-cells.

The dry wood is of medium hardness and weight, fine-grained, deep reddish-brown with yellowish-brown sapwood, not greatly different from the heartwood in appearance; fairly straight-grained.

#### CROSS SECTION

*Gross.*—The vessels are diffuse, visible under lens, scattered, seldom grouped; rays, fine, scarcely visible without lens. There are no distinct growth-rings.

*Minute.*—The vessels are subcircular in outline, rather even in size, isolated or grouped irregularly 2-4+ together, and compressed. Diameters of more than 0.12 mm. are few. The walls are very thin (0.003 mm.) and follow the contour of the surrounding elements (fig. 10, *b*); the lumina are without tyloses, but contain a resinlike substance. The perforations are simple; segments, cylindrical and long ( $0.8 \pm$  mm.). The rays are 1-3 cells wide, thin-walled, and contain resin which in heartwood generally fills the cavities. The wood-parenchyma is thin-walled (0.003 mm.), of about the same diameter as fibers, mainly paratracheal in distribution, and 1 cell deep (fig. 10, *a*, *v.w.p.*), but with somewhat irregular metatracheal grouping (fig. 10, *a*, *w.p.*) tangentially with the vessels; no crystals are present, but cavities of metatracheal parenchyma as a rule are filled with resin. The fibers are in regular radial arrangement, about 0.03 mm. in diameter, thick-walled (0.006 mm.), some of them thicker (0.01 mm.), and show radiating striations (fig. 10, *a*, *f*). Some of the cavities are filled with resin.

#### RADIAL SECTION

*Gross.*—There is little evidence of growth-rings or other differences in texture or color. Rays are curved, causing curved surfaces in splitting, but fibers comparatively straight; under lens can be seen regular alternate vertical dark and light-colored layers corresponding to prosenchyma on the one hand and vessels on the other.

*Minute.*—The vessels are without tyloses, have thin transparent walls, generally pitted with elliptical semibordered pits communicating with neighboring wood-parenchyma cells (fig. 10, *b*) or a somewhat larger form (fig. 10, *d*) communicating with adjacent ray-cells. Less frequently smaller but more numerous bordered pits with lenticular orifices (fig. 10, *d* or *e*) are found communicating with an adjacent vessel. The rays are distinctly heterogeneous, composed in the central portion of low, radially elongated cells 0.017 mm. high, and often over 0.09 mm. in length. The marginal cells are  $0.07 \pm$  mm. high and  $0.036 \pm$  mm. long. The walls are very thin (0.002 mm.) and numerous and finely pitted on the upper, lower, and tangential walls. The radial walls are coarsely and conspicuously pitted in contact with vessels. Pits found in contact with other elements are small and not visible except in favorable sections.

The wood-parenchyma cells are thin-walled, pitted with numerous small pits (fig. 10, *f*) wherever in contact with parenchymatous elements. As a rule the cells are elongated, 2-3 times as long as wide—some even longer; metatracheal cells are usually filled with resin. The prosenchyma cells are thick-walled, pitted sparsely with small, inconspicuous bordered pits with slitlike orifices. A few are filled with resin.

#### TANGENTIAL SECTION

*Gross.*—The texture is even with little variation in grain; luster, dull. Rays are minute and indistinct.

*Minute.*—Rays are commonly 3 cells wide, but range from 1-4 cells; height varies from 0.03 mm. to 1.5+ mm. The marginal portions of the

rays are composed of cells which have an average height of two to several times the height of those composing the central portion, and the marginal portion of most of the rays is prolonged into a uniseriate edge, often observed as much as 5+ cells in height.

#### MACERATION

The vessel segments have large elliptical pit markings (fig. 6, *b-f*). The fibers are of exceptional length (2.34 mm.), thick-walled (0.006-0.009 mm.), and gradually attenuate from the middle into sharp unforked points. Wood-parenchyma cells commonly show the pit markings of figure 10, *f*, but have both larger and smaller pits according to the elements with which they have been in contact.

#### DISTINGUISHING CHARACTERS

The wood is diffuse porous, without growth-rings or very distinct heartwood, and reddish-brown in color. The vessels are diffuse, some grouped, very thin-walled, without tyloses, with simple perforations, and bordered pits with slitlike orifices in contact with other vessels, or large narrowly semibordered pits in contact with rays. The rays are heterogeneous,  $3\pm$  cells wide and bear coarse semibordered or even simple pits in contact with vessels. Wood-parenchyma occurs in imperfect tangential lines and also about the vessels. The fibers are long, thick-walled, and bear bordered pits.

**Ochrosia sandwicensis** Gray. HOLEI. Material, vii:b131:1422.

Shrub or tree 10-25 feet high, and 8 inches D. B. H. It is endemic and is abundant only in dry places on the island of Maui at elevations of 2,500 feet, back of Makawao on the slopes of Haleakala, and on the lava fields of Auahi (18). The wood is grayish-yellow in color, of medium hardness, fine texture, and is straight-grained. Indistinct growth-rings are present.

#### CROSS SECTION

*Gross.*—The vessels are small and visible with, or some without, a lens, diffuse, without tyloses, and grouped radially 2-5 together or singly. The rays are visible with a lens. Growth-rings are defined by narrow reddish lines.

*Minute.*—The vessels vary in size but are mostly under 2 mm. in diameter. The walls are thin ( $0.006\pm$  mm.); the lumina are without resin or tyloses. Tracheids are often present,  $0.03\pm$  mm. in diameter, and indistinguishable in this section from vessels of this diameter. The rays are usually uniseriate, rarely biseriate, coarsely and conspicuously pitted (fig. 11, *b*) on all walls, and slightly resinous. The cells are mostly 4-7 times as long as broad. The fibers are irregular in size and arrangement (fig. 11, *b*),  $0.02\pm$  mm. in diameter. A narrow zone, 1-3 cells wide, of

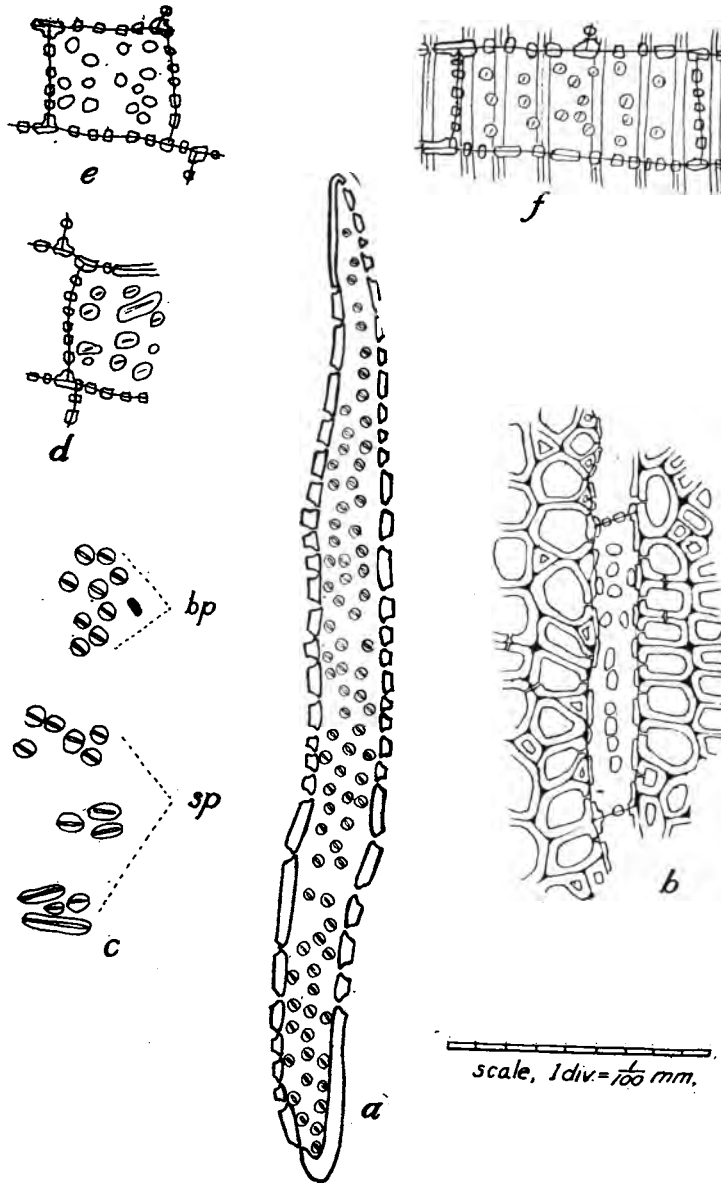


FIGURE 11. Sections of *Ochrosia sandwicensis* wood: **a**, tracheid from maceration; **b**, cross section, showing fibers and ray-cells; **c**, vessel pits, showing bordered pits (**bp**) between vessels and semibordered pits (**sp**) between vessels and ray- or wood-parenchyma; **d**, ray-pits formed in contact with vessels; **e**, ray-pits formed between parenchyma cells; **f**, ray-pits formed in contact with fibers.

compressed fibers defines the outer limit of growth-rings. The thickness of the fiber walls (0.003 mm.) varies but little. There is little, if any, other constant distinction between early- and late-wood. Wood-parenchyma is rather abundant, paratracheal and metatracheal in distribution, and thin-walled (0.002 mm. in thickness). The paratracheal cells are variously flattened in contact with vessels and adjacent elements, irregular in outline, often observed somewhat larger than the surrounding fibers, and copiously and coarsely pitted. The metatracheal cells extend in tangential lines 1 or 2 cells wide, and are generally at the beginning of a growth-ring in contact with the flattened fibers terminating the preceding ring; the cells are commonly four-sided, and equal or slightly exceed adjacent fibers in size.

#### RADIAL SECTION

*Gross.*—The wood is straight-grained, of even texture with a silky luster.

*Minute.*—The vessels have numerous, but not crowded, bordered pits circular in outline with narrowly lenticular, as a rule oblique, orifices when in contact with vascular elements (fig. 11, *d*) or elliptical to circular semibordered or simple pits when in contact with ray- or wood-parenchyma (fig. 11, *c*); perforations, simple; segments, many cylindrical but variable; the plane of perforation varies from transverse to somewhat oblique. The rays are imperfectly heterogeneous, composed of cells varying greatly in ratio of length to height, but typically about twice as long as high, coarsely and numerous pitted on upper and lower walls and bearing upon their radial walls three classes of pits: (a) large irregular elliptical semibordered or simple pits  $0.01 \pm$  mm. in length in contact with vessels (fig. 11, *d*); (b) simple pits, as a rule smaller and less elongated, when in contact with parenchyma; and (c) small circular semibordered pits in contact with prosenchyma. The fibers have numerous bordered pits with slit-like orifices and are nonseptate. The wood-parenchyma occurs mostly in continuous longitudinal strands copiously and coarsely pitted with simple pits when in contact with parenchyma, or with small semibordered pits in contact with prosenchyma, or with large irregular semibordered or simple pits in contact with vascular elements.

#### TANGENTIAL SECTION

*Gross.*—The surface is dull brownish-yellow with uniform texture. The vessels and particularly the rays are not prominent even under a lens.

*Minute.*—The vessels have very numerous bordered pits in contact with vessels (fig. 11, *c*), or elongated semibordered or simple pits in contact with parenchyma. The vessel segments are somewhat irregular in shape, short, 1 to 4 times as long as broad, with the plane of perforation commonly more or less oblique. The rays are mainly uniseriate or biseriate in part, and 1-13+ cells high; the cells, widely variable but mainly 2-3 times higher than broad, and slightly resinous. The fibers have few pits in the tangential walls.

## MACERATION

Some vessels have a tongue-like projection from one or both ends. Tracheids (fig. 11, *a*) are common,  $0.4 \pm$  mm. long, without spirals, and numerous and finely pitted. The fibers are  $0.9 \pm$  mm. long, and  $0.02 \pm$  mm. in diameter, the ends attenuate, often forked, curved and irregular, with numerous small pit markings with slit-like orifices, in the radial walls.

## DISTINGUISHING CHARACTERS

The wood is of medium hardness and weight, fine-grained, yellowish, diffuse porous, with growth-rings visible without lens; no heartwood. The vessels are barely visible without lens, have no tyloses, are mostly grouped radially 2-5 together; the pits have slit-like orifices; perforations, simple; segments, short; walls, thin. Tracheids are present,  $0.4 \pm$  mm. long, without spirals (fig. 11, *a*). The rays are homogeneous, uniseriate or rarely biseriate; cells, all coarsely and numerous pitted on all sides. Fibers are nonseptate and often have forked ends, numerous pitted on the radial walls with small bordered pits. Wood-parenchyma occurs adjacent to or in contact with vessels, also in tangential lines or at the beginning of growth-rings.

Order TUBIFLORAE  
Family SOLANACEAE

The Solanaceae are herbs, shrubs, or, rarely, trees, of temperate and tropical climates. The center of distribution is in Central and South America.

The wood is characterized by vessels with simple perforations, and bordered, semibordered, or simple pits. The perforations are simple; the rays, as a rule, narrow. The fibers bear either simple or bordered pits. Wood-parenchyma is not abundant.

***Solanum sandwicense*** Hook. et Arn. Material, cv:xii:1474.

This species is endemic to Oahu and Kauai, grows only 4-6 feet high and is shrubby. The wood is light yellow in color with silky luster, soft, cross-grained, diffuse porous or slightly ring-porous, and with growth-rings.

## CROSS SECTION

*Gross.*—The vessels are small, visible with lens, and for the most part grouped compactly 2-6+ together. The walls are thin; the lumina, open and very readily permeable to alcohol. The rays are much smaller than the vessels.

*Minute.*—The vessels vary greatly in size but rarely exceed 2 mm. in diameter. The diameter diminishes in late-wood and increases abruptly in the early-wood where the vessels are also somewhat more numerous. The

rays curve irregularly around the vessels, are 1-3 cells wide and numerous pitted with small circular pits of nearly uniform size. The fibers are irregularly polygonal in outline, thin-walled, with large lumina irregularly arranged, and somewhat compressed in the final several rows of a growth-ring. Wood-parenchyma cells are few and mostly in contact with the vessels.

#### RADIAL SECTION

*Gross.*—The rays are fine but visible without lens.

*Minute.*—The rays are heterogeneous with radially elongated cells except at the margin where the cells are square or slightly elongated axially. The pits in contact with the vessels vary from semibordered to simple, and circular in outline, and  $0.009 \pm$  mm. in diameter. The fibers bear few small circular-bordered pits with short lenticular orifices in the radial walls.

#### TANGENTIAL SECTION

*Gross.*—The vessels are rather prominent on the tangential surface, and easily visible without a lens. The rays are small and visible with a lens.

*Minute.*—The rays are linear, elliptical in outline with acutely pointed ends. The width varies from 1 to 3 cells; the height, from 1 to 22+ cells. The cells are of nearly uniform size or elongated at the margin.

#### MACERATION

The vessel segments are of medium length, with simple perforations nearly the size of the vessel lumen. The pit markings are rather coarse, uniform in size, with large, elongated, lenticular orifices. A few simple pits are present. The fibers are of medium length and taper with some irregularity into long attenuate ends.

#### DISTINGUISHING CHARACTERS

The wood is light-yellow with a silky luster, soft, cross-grained, diffuse porous or slightly ring-porous, and with growth-rings. The vessels are small, visible with lens, mostly in small compact groups, and bear large simple perforations. The vessel pits are rather coarse, uniform in size, with long lenticular orifices, and bordered except in contact with the rays where the pits vary from semibordered to simple. The rays are heterogeneous, 1-3 cells wide and up to 22+ cells high. The fibers are irregularly arranged, have rather thin walls, large lumina, and a few circular-bordered pits. Wood-parenchyma is limited to a few cells mostly in contact with the vessels.

$\beta$  var. Hbd. is distinguished from the species by the broader higher rays, smaller and more commonly isolated vessels, and the shorter more irregular fibers.

#### Family MYOPORACEAE

The Myoporaceae, comprising over 100 species, are chiefly confined to Australia. The wood is characterized by vessels with



simple perforations and with semibordered pits in contact with ray- or wood-parenchyma. The rays are narrow; wood-parenchyma not abundant. Simple pits occur in the wood-prosenchyma.

***Myoporum sandwicense*** (D. C.) A. Gray. NAIO.

Material, xlviii:41:1449.

*Myoporum sandwicense* is an endemic species occurring on the leeward sides of the islands, from sea level to 10,000 feet. At 2,500 feet the tree reaches a height of 50-60 feet and a D. B. H. of 3 feet. It grows, according to Rock (18, p. 427), at the higher levels, in association with *Sophora chrysophylla*, *Raillardia*, and *Styphelia*, or, at lower levels, with *Xylosma hawaiiense*, *Ochrosia*, *Dodonaea viscosa*, *Colubrina oppositifolia*, and *Mesoneurum kauaiense*.

The wood has a spicy odor, is yellowish-brown in color, diffuse porous, hard, with a waxy luster, indistinct growth-rings, and a resinlike substance in the rays and other elements. It is used as a substitute for sandalwood.

CROSS SECTION

*Gross.*—The vessels are small, visible with a lens, few, and mostly arranged in small radial groups of 2-3 cells. Tyloses and an amber-colored body plug the vessels and render the wood impermeable to alcohol. The rays are yellowish and smaller than the vessels.

*Minute.*—The vessels are variable in size but mostly under 0.12 mm. in diameter. The rays are 1-3 cells wide and contain a deep-staining body obscuring the pits, which are circular, fairly numerous, and  $0.003\pm$  mm. in diameter, and best observed in maceration. The fibers are rounded polygonal in outline, arranged in radial rows, have rather thick walls and medium-sized or small lumina, many of which are filled with deep-staining globular resinlike contents. Wood-parenchyma is not abundant and mostly in contact with vessels.

RADIAL SECTION

*Gross.*—The rays are small, deep yellow in color, and distinct.

*Minute.*—The vessels consist of rather short segments with simple perforations and small bordered or semibordered pits of uniform size with lenticular orifices. Tyloses and resinlike material are abundant in the lumina. The rays are composed of radially elongated cells in the broader portions, and of nearly square cells in the narrower portions, and in the uniseriate rays. Axially elongated cells are infrequently observed, but some occur at the margin. Small semibordered pits are formed in contact with the vessels. The fibers bear small simple pits with slitlike oblique orifices.

## TANGENTIAL SECTION

*Gross.*—The wood is of fine, uniform texture. The rays are small and barely visible with a lens.

*Minute.*—The rays are of two kinds: (1) elliptical, acutely or obtusely pointed, bi- or tri-seriate rays, 2-3 cells wide and up to 20 cells high; (2) uniseriate rays, 1-3+ cells high. The cells in the wide rays are of nearly uniform size or slightly elongated at the margins. The cells in the uniseriate rays are slightly elongated axially.

## MACERATION

The vessel segments are of irregular medium length and vary in shape. The pit markings are small and uniform in size. The fibers are of medium length and taper irregularly into sharp points.

## DISTINGUISHING CHARACTERS

The wood has a spicy odor, is yellowish-brown in color with a waxy luster, diffuse porous, hard, with indistinct growth-rings. The vessels are visible with a lens, mostly in small radial groups, composed of irregular segments with simple perforations and small bordered or semibordered pits. The vessel lumina are plugged with tyloses and resinlike material. The rays are uniseriate, bi- or tri-seriate, and few more than 20 cells high. The fibers are rather thick-walled with medium-sized lumina and simple pits with oblique slitlike orifices. Wood-parenchyma is not abundant and mostly in contact with the vessels.

## Order RUBIALES

## Family RUBIACEAE

The Rubiaceae are trees, shrubs, or perennial, rarely annual, herbs, erect or climbing, comprising in all about 4,500 species of general distribution in the Tropics, and of which at least 50 species occur in Hawaii. *Cinchona* (yielding quinine), *Ourouparia* (yielding catechu), *Coffea*, and other important officinal plants belong to the Rubiaceae.

The wood is characterized by vessels with simple or, rarely, scalariform perforations and bordered or semibordered pits; rays, 1-8+ cells wide. Wood-parenchyma, little or abundant. Both simple and bordered pits occur in the wood-prosenchyma.

***Gardenia brighami*** Mann. *NAV. Material*, lxxvii:x29:1501.

The genus *Gardenia* comprises about 70 species "distributed over tropical Africa, Asia, and Australia" (18). Two species are endemic to the Islands. *G. brighami*, according to Rock (18, p. 433), occurs on the dry leeward sides of Hawaii in association with

Xylosma, Nototrichium, *Bobea sandwicensis*, *Nothocestrum*, *Osmanthus*, *Sideroxylon*, and others. It is endemic to the Territory and is most abundant on Molokai. The tree grows to a height of 18 feet with a D. B. H. of 8 inches.

The wood is brownish-yellow in color, with a dull luster, diffuse porous, hard, cross-grained, of fine even texture, and with indistinct growth-rings.

#### CROSS SECTION

*Gross.*—The vessels are visible with a lens, rather numerous, mostly isolated, circular in outline, with open lumina filled with white gum and not permeable to alcohol. The rays are much narrower than the vessels.

*Minute.*—The vessels are circular in outline, of uniform size, thin-walled, mostly under 0.07 mm. in diameter and generally adjacent to fibers. The rays are 1-3 cells wide, minutely pitted, and filled with a deep-staining resinlike substance. The fibers are rounded polygonal in outline, in irregular order, with medium thick walls and open lumina. Bordered pits are present in both radial and tangential walls. Wood-parenchyma is fairly abundant; the cells, of about the same diameter as the fibers, and diffuse. Growth-rings are defined by zones of comparatively thick-walled but not compressed fibers associated with few wood-parenchyma cells.

#### RADIAL SECTION

*Gross.*—The rays are small, brownish, and not prominent. The wood is of fine uniform texture and color.

*Minute.*—The vessels are composed of rather short segments with large simple perforations of nearly the same diameter as the vessel lumen. Small circular-bordered pits with short lenticular orifices are formed in vertical rows in contact with the fibers, and semibordered pits of the same diameter varying from annular to piceiform in contact with the ray- or wood-parenchyma cells. Lateral circular perforations  $0.012 \pm$  mm. in diameter occur, here and there, communicating with adjacent ray- or wood-parenchyma cells. A few simple pits of the same diameter were found. It is possible that the perforations occur as a result of a breaking up of very delicate closing membrane subsequent to the death of the cell. The rays are imperfectly heterogeneous, being composed, as a rule, of radially elongated cells. Many marginal cells are nearly square. The pits are of small diameter. The fibers bear uniseriate circular-bordered pits with lenticular orifices. Elongated wood-parenchyma cells are scattering, and strands of short crystal-parenchyma cells common.

#### TANGENTIAL SECTION

*Gross.*—The rays are brownish in color, low, narrow, and visible under a lens.

*Minute.*—The rays are elliptical, mostly biseriate, and less than 17 cells high. The cells have thin walls, broadly elliptical in outline or slightly elongated at the margin of the ray. The fibers bear uniseriate circular-bordered pits with short lenticular orifices, in the tangential walls.

## MACERATION

The vessel segments each usually bear one or two circular or sub-circular perforations,  $0.012 \pm$  mm. in diameter, through the lateral walls. The terminal perforations are large and of nearly the same diameter as the vessel lumen. The pits are very small, not numerous or crowded. The fibers are mostly less than 1.3 mm. in length, wavy, and taper from near the middle to sharp points.

## DISTINGUISHING CHARACTERS

The wood is brownish-yellow in color with a dull luster, diffuse porous, hard, cross-grained, of fine even texture, and with growth-rings. The vessels are very small, visible with a lens, circular in outline with lumina open and permeable to alcohol. The perforations are simple; the pits, mostly small, and numerous, and bordered or semibordered. The terminal perforations are simple and large. Small lateral perforations are present. The fibers bear uniseriate bordered pits, and have walls of medium thickness. Wood-parenchyma is diffuse. Short crystal-parenchyma strands are many. The rays are mostly biseriate and up to 17 cells high.

**Electronia odorata** (Forst.) F. v. M. WALAHEE.

Material, lxxix:29:1507.

This species grows to a height of 20 feet, at low levels on the leeward side of Hawaii and of other Pacific islands. The wood is whitish-yellow in color with a dull luster, is diffuse porous with a tendency to be ring-porous, and hard.

## CROSS SECTION

*Gross.*—Growth-rings are defined by narrow zones of fibers in which comparatively few vessels occur. The vessels are small, visible with a lens, and mostly isolated; the lumina open and readily permeable to alcohol; rays, slightly narrower than the vessels.

*Minute.*—The vessels are rather variable in diameter, and diminish in size in the late-wood, but rarely exceed 0.07 mm. in diameter. The rays are 1-3+ cells wide, and nearly free of cell contents. The walls bear minute circular pits. The fibers are rounded polygonal in outline, irregularly arranged, very thick-walled, and have small lumina. Wood-parenchyma cells are of nearly the same diameter as the fibers, thin-walled, and diffuse. The vessels are largely in contact with fibers.

## RADIAL SECTION

*Gross.*—The rays are fine but easily visible without a lens. The surface is of fine even texture and of nearly uniform color.

*Minute.*—The vessels are composed of long segments with simple perforations somewhat smaller than the vessel lumen. The pits are small, circular in outline, not numerous, except in contact with ray- or wood-parenchyma or, rarely, other vessels. The pits are bordered or semi-bordered, and have short lenticular orifices in the vessel walls. The rays

are heterogeneous, with cells that, as a rule, are radially elongated in the biseriate and triseriate portions and nearly square cells in the uniseriate parts or at the margins. The pits are minute, uniform in size and not numerous except in contact with vessels. The fibers bear uniseriate bordered pits with nearly vertical lenticular orifices. The pits of the wood-parenchyma cells are minute and commonly grouped or arranged in a circle within a thin-walled area.

#### TANGENTIAL SECTION

*Gross.*—The tangential surface is of fine uniform texture. The growth-ring zones are visible but not prominent.

*Minute.*—The rays are mostly elliptical in outline and 1-3+ cells wide; a few, uniseriate; others, uniseriate in part. Rays rarely exceed 25 cells in height. The cells in the uniseriate portions and ray margins are axially elongated. Those in the wider portions are nearly circular in outline. The fibers bear few pits in the tangential walls.

#### MACERATION

The vessel segments are long and cylindrical; the pit markings, small and variously arranged. The fibers are long, rather straight, of small diameter, and taper gradually into sharp points.

#### DISTINGUISHING CHARACTERS

The wood is whitish-yellow in color with a dull luster, diffuse or slightly ring-porous, and hard. The vessels are visible with a lens, mostly isolated, with bordered or semibordered pits of uniform size, simple perforations, and open lumina permeable to alcohol. The rays are 1-3+ cells wide and up to 25+ cells high. The fibers are thick-walled with small lumina and uniseriate bordered pits in the radial walls. Wood-parenchyma cells are many and diffusely distributed.

***Bobea mannii*** Hbd. AHAKEA. Material, lxxiv:60:1508.

The genus *Bobea* is partly endemic to the Hawaiian islands, and comprises about five species. *Bobea mannii* is endemic and, according to Hillebrand (9, p. 173), occurs on Kauai at elevations of 2,000-3,000 feet. The wood is yellowish in color, diffuse porous, without growth-rings, rather hard, and straight-grained.

#### CROSS SECTION

*Gross.*—The vessels are visible with a lens, isolated or in mostly radial groups of 2-7+. The rays are of the same width as the vessels, and visible without a lens.

*Minute.*—The vessels are variable in size, especially in the groups, but rarely exceed 0.15 mm. in diameter. The walls are thin, the lumina open and readily permeable to alcohol. The rays are 1-4+ cells wide, free of contents, and with frequent minute, circular pits. The fibers are sharply polygonal in outline, arranged in fairly regular radial rows, and are of

large diameter with thick walls and open lumina. The pits are simple or very narrowly bordered. Wood-parenchyma cells are of the same diameter as the fibers, but thin-walled, fairly numerous, and diffuse.

#### RADIAL SECTION

*Gross.*—The rays are low but distinct without a lens.

*Minute.*—The vessels are composed of long segments with small simple perforations of less than one-half the diameter of the vessel lumen. The pits are bordered or semibordered, small, of uniform size, and circular in outline with lenticular orifices in the vessel wall. The rays are composed of radially elongated cells in the wide portion and of nearly square cells in the uniseriate parts or at the margins. Some of the cells are axially elongated. The pits are small throughout. The fibers bear a few simple or narrowly bordered pits with slitlike orifices. Wood-parenchyma cells bear minute pits and are  $0.18 \pm$  mm. long.

#### TANGENTIAL SECTION

*Gross.*—The rays are low, elliptical, as broad as the vessels, and of nearly the same color as the adjacent tissues.

*Minute.*—The rays are 1-4+ cells wide, 1-33+ cells high, and uniseriate, uniseriate in part, or multiseriate, with cells subcircular in outline in the multiseriate portions and axially elongated cells in the uniseriate parts.

#### MACERATION

The fibers are long with uneven sides and taper gradually into sharp points.

#### DISTINGUISHING CHARACTERS

The wood is yellow in color, diffuse porous, without growth-rings, nonresinous, rather hard, and nearly straight-grained. The vessels are visible with a lens, mostly in radial groups, with small bordered or semi-bordered pits of uniform size and small simple perforations. The rays are 1-4+ cells wide, 1-30+ cells high, and heterogeneous. The fibers are of large diameter, thick-walled with open lumina, and bear simple or narrowly bordered pits. Wood-parenchyma is fairly abundant and diffuse.

***Straussia hawaiiensis*** Gray. KOPIKO ULA.

Material, lxxxix:79:1497.

The genus *Straussia* is endemic to Hawaii, where it is represented by 7 species. It is related to *Psychotria* and *Chasalia* with American and Asiatic affinities, and consists of "trees and dichotomous terete branches" (9, p. 178). *S. hawaiiensis* grows to a height of 20-35 feet, with a diameter of about 12 inches. It occurs on the leeward side of Hawaii, at elevations of about 3,000 feet, in association with *Metrosideros*, *Myoporum*, *Xylosma*, and *Clermontia* (18, p. 453). The wood is reddish-brown in color, rather hard, diffuse porous, with indistinct growth-rings.

## CROSS SECTION

*Gross.*—The vessels are visible with a lens, rather numerous, in loose radial arrangement; the lumina, open and permeable to alcohol. The rays are broader than the vessels.

*Minute.*—The vessels are variable in size but rarely exceed 0.09 mm. The rays are multiseriate, minutely pitted, and contain globules of deep-staining substance. The fibers are rounded polygonal in outline, with rather thick walls; the lumina, of medium diameter; the pits narrowly bordered or simple. Wood-parenchyma is little developed.

## RADIAL SECTION

*Gross.*—The fibers are intercrossed; the rays, easily visible, and reddish-brown in color.

*Minute.*—The vessels are composed of long segments with numerous small bordered or semibordered pits with short lenticular orifices in the vessel walls. The perforations are simple, circular or elliptical in outline, many less than one-half the diameter of the vessel lumen, and commonly lateral as well as terminal in position. The rays are composed partly of radially elongated cells, partly of nearly square cells. Axially elongated cells are often found at the margin. The pits are small, circular in outline, and rather numerous. Globules of a deep-staining substance are present in the cell cavities. The fibers bear many simple or narrowly bordered pits with oblique extended slitlike orifices.

## TANGENTIAL SECTION

*Gross.*—The wood is of fine uniform texture. The rays are small and indistinct under a lens.

*Minute.*—The rays are for the most part broadly elliptical in outline, mainly under 6 cells broad and less than 50 cells high. The cells are irregular in size and shape, those in the interior of the ray being generally smaller and subcircular in outline. Those at the sides and margins are generally irregularly elongated axially. There are few uniseriate rays. The fibers are irregularly intercrossed and have few pits in the tangential walls.

## MACERATION

The tracheal segments as a rule terminate beyond the perforation in a tongue-like or tracheidlike projection. The fibers are mostly less than 1.3 mm. in length and taper irregularly into mostly short obtuse ends.

## DISTINGUISHING CHARACTERS

The wood is reddish-brown in color, rather hard, diffuse porous, and with indistinct growth-rings. The vessels are visible with a lens, in loose radial arrangement; the lumina, open and permeable to alcohol. The rays are broader than the vessels, heterogeneous, 1-6+ cells broad, and typically less than 50 cells high. The fibers have rather thick walls, lumina of medium size, and simple or narrowly bordered pits. There is little wood-parenchyma.

**Straussia kaduana** (Cham. et Schlecht.) Gray. KOPIKO KEA.

Material, lxxxii:11:1500.

This species occurs mainly in the mountains of Oahu, reaching a height of 20 feet. The wood is grayish-brown in color, diffuse porous, rather soft, without growth-rings, cross-grained, and of fine even texture.

#### CROSS SECTION

*Gross.*—The vessels are small, visible with a lens, mostly in radial rows of 2-10+; the lumina, mostly filled with tyloses and not permeable to alcohol. The rays are narrower than the vessels.

*Minute.*—The vessels are somewhat variable in diameter, but rarely exceed 0.12 mm. The rays are commonly less than 6 cells wide, with resin-like globular contents. The fibers have walls of medium thickness and large open lumina. There is little wood-parenchyma.

#### RADIAL SECTION

*Gross.*—The rays are reddish-brown, small, and not prominent.

*Minute.*—The vessels are composed of exceptionally long segments with simple perforations, some in twos and many less than one-half the diameter of the vessel lumen. The pits are mainly small, circular in outline and bordered or semibordered, with lenticular orifices in the vessel walls, but vary slightly in contact with the rays, tending to become elongated and even simple. Tyloses are abundant. The rays are composed of three types of cells: (1) a low radially elongated type commonly in the interior of multiseriate portions; (2) cells nearly square in outline, in the uniseriate portions and at the sides of the multiseriate parts; (3) axially elongated cells, as a rule at the margins. The pits are small, numerous, circular in outline, uniform in size and shape, except in contact with vessels where larger, variable, elongated semibordered, or, rarely, simple pits occur. Deep-staining resinlike contents are present in the cells. The fibers are septate and bear irregularly arranged piceiform-bordered pits.

#### TANGENTIAL SECTION

*Gross.*—The wood is of fine uniform texture. The rays are reddish, small, and visible with a lens.

*Minute.*—The rays are of a variable, narrowly elliptical outline with acute ends, 1-4+ cells wide and generally less than 25 cells high. The cells in the interior of multiseriate parts are commonly small and slightly or not at all elongated; those at the sides and in the uniseriate parts, for the most part moderately elongated axially; many of those at the margins greatly elongated axially. The fibers bear few pits in the tangential walls.

#### MACERATION

The vessel segments are sometimes found truncate, and bearing a tongue-like projection from one or both ends, and many terminate in tracheid-like ends of considerable length. The fibers are broad and prismatic



in the central portion, with short attenuate, mostly unpitted, rather obtusely pointed ends, and a few are as much as 2+ mm. in length.

#### DISTINGUISHING CHARACTERS

The wood is grayish-brown in color, diffuse porous, rather soft, without distinct growth-rings, cross-grained, and of fine even texture. The vessels are visible with a lens, mainly arranged in radial groups, have tyloses, and are slowly or not at all permeable to alcohol. The perforations are simple, and smaller than the vessel lumen. The pits are mainly small, bordered or semibordered, or, rarely, simple. The fibers have medium-thick walls, large open lumina, and bordered pits in the radial walls. The rays are heterogeneous, composed of three cell types, 1-4+ cells broad and as a rule less than 25 cells high. Wood-parenchyma is nearly absent.

**Straussia onocarpa** Hbd. KOPIKO. Material, lxxiii:64:1504.

This species is endemic to the Territory, grows to a height of 50 feet at elevations of about 2,800 feet, and is not abundant. The wood is rather hard, deep reddish-brown in color, diffuse porous, and without distinct growth-rings.

#### CROSS SECTION

*Gross.*—The vessels are extremely small, visible under good lens, isolated or in small radial groups, with open lumina permeable to alcohol. The rays are broader than the vessels, and visible with a lens.

*Minute.*—The vessels are rather variable in diameter, some of them not easily distinguished from the fibers; the largest, rarely over 0.09 mm. in diameter. The walls are thin (0.003 mm.). The fibers have walls about twice as thick as the vessel walls, large open lumina, and simple or very narrowly bordered pits. The rays are multiseriate and have a maximum width greater than that of the vessels. The ray-cells and some of the fibers contain globules of resinlike substance. Wood-parenchyma is nearly absent.

#### RADIAL SECTION

*Gross.*—The texture is very fine and even. A reddish resinlike substance is present in the rays and other elements.

*Minute.*—The vessels bear small circular-bordered or semibordered pits of uniform size; the perforations, simple, many of them less than one-half the diameter of the vessel lumen; the segments, exceptionally long. The rays are composed of radially elongated cells in the interior, and of one or more rows of axially elongated cells at the margin. Cells square in outline occur in other portions. The fibers bear numerous simple pits with slitlike orifices and are septate.

#### TANGENTIAL SECTION

*Gross.*—The wood is of fine uniform texture with resinlike material in the elements. The rays are fine and indistinct.

*Minute.*—The rays are mainly elliptical in outline, some with long uniseriate margins, 1-6+ cells broad and generally less than 30 cells high.

The cells in the interior of multiseriate parts are mainly small, variable, but as a rule not greatly elongated. Those at the sides, margins, and uniseriate portions are mainly axially elongated. The fibers bear few or no pits in the tangential walls.

#### MACERATION

The tracheal segments are uniformly very long ( $1.3 \pm$  mm.). The pit markings are small, circular, uniform in size, and numerous. The perforations are simple, many less than one-half the diameter of the vessel lumen, and sometimes two are found near together. Many of the segments terminate beyond the perforation in tracheid-like ends. Tonguelike projections also occur. The fibers are prismatic or subcylindrical in shape, with short, attenuate, mostly unpitted, rather obtuse, irregular ends, and few exceed 1.9 mm. in length.

#### DISTINGUISHING CHARACTERS

The wood is rather hard, deep reddish-brown in color, diffuse porous, and without distinct growth-rings. The vessels are visible with a lens, and composed of very long segments with small simple perforations, small circular-bordered or semibordered pits, and open lumina. The rays are heterogeneous, 1-6+ cells wide, and generally less than 30 cells high. The fibers have walls of medium thickness, large open lumina, and simple pits. Wood-parenchyma is nearly absent.

**Psychotria hexandra** Mann. Material, lxxx:x18:1506.

The genus comprises 350 species, distributed generally in the Tropics. *P. hexandra* occurs on Kauai and Oahu, and is endemic to Hawaii. The tree grows to a height of 20 feet. The wood is grayish-brown in color, diffuse porous, rather soft, cross-grained, of fine even texture, and without distinct growth-rings.

#### CROSS SECTION

*Gross.*—The vessels are small, visible with a lens, arranged mainly in radial rows of 2-10+ together. The wide rays are of nearly the same width as the diameter of the large vessels.

*Minute.*—The size of the vessels is somewhat variable but seldom found to exceed 0.12 mm. The lumina are open or with few tyloses, and permeable to alcohol. The rays are 1-6 cells wide and contain a resinlike substance. The pits are small, subcircular, and rather numerous. The fibers are rounded polygonal in outline with medium-thick walls and large lumina. The pits are simple and mostly in the radial walls. There is little wood-parenchyma.

#### RADIAL SECTION

*Gross.*—The rays are reddish, small, not prominent; texture and color are nearly uniform.

*Minute.*—The vessels are composed of long ( $1.3 \pm$  mm.) segments with small circular perforations, many of which are less than one-half the diam-

eter of the vessel lumen. The pits are small, circular in outline, uniform in size, and bordered or semibordered, with short lenticular orifices in the vessel wall. The rays are composed of radially elongated cells in the multiseriate interior, and of square or axially elongated cells at the sides, uniseriate portions, or at the margins. The pits are small, circular in outline, and of uniform size. The fibers are septate and bear numerous simple pits with slitlike orifices in the radial walls.

#### TANGENTIAL SECTION

*Gross.*—The rays are small, and visible with a lens.

*Minute.*—The rays are 1-6+ cells wide and mainly less than 20 cells high, with rounded cells of variable small size in the multiseriate portion and axially elongated cells in the uniseriate parts or at the margins, or, in some rays, at the sides. The fibers bear few or no pits in the tangential walls.

#### MACERATION

Many of the vessel segments terminate in tracheid- or tongue-like ends, and approach the fibers in length. The fibers are long ( $1.9 \pm$  mm.) wide, pitted on the radial walls, except for the short irregularly tapering ends.

#### DISTINGUISHING CHARACTERS

The wood is grayish-brown in color, diffuse porous, rather soft, cross grained, of fine even texture, and without distinct growth-rings. The vessels are visible in cross-section with a lens, mainly in radial groups of 2-10+, and with lumina with few tyloses, but permeable to alcohol. The segments are long; the perforations, simple and small; the pits, small, circular, uniform in size, and bordered or semibordered. The rays are irregularly heterogeneous, 1-6+ cells wide and as a rule less than 20 cells high. The fibers are medium thick-walled, with open lumina. Wood-parenchyma is nearly absent. Wood very similar to lxxxiii, which is evidently *Straussia onocarpa*.

#### **Coprosma rhynchocarpa** A. Gray. PILO.

Material, lxxxvi:82:1496.

The genus comprises about 50 species, of which the majority are found in New Zealand. *C. rhynchocarpa* is a small tree 20 feet high, endemic to Hawaii, at elevations of 4,000-6,000 feet. The wood is whitish-yellow in color or gray from fungi, diffuse porous, soft, straight-grained, and without distinct growth-rings.

#### CROSS SECTION

*Gross.*—The vessels are small, visible with a lens, mostly in radial or sometimes tangential compact groups of 2-10+ together. The lumina are open and permeable to alcohol. The rays are smaller than the vessels.

*Minute.*—The vessels are of variable size but rarely exceed 0.15 mm. in diameter, and have thin walls. The rays are 1-4+ cells wide and with

numerous circular pits  $0.006 \pm$  mm. in diameter, mostly in radial rows; cell cavities mostly without contents. The fibers are rounded polygonal in outline, with very thin walls and open lumina; large diameters occur in regular radial arrangement in alternation with the small diameters (of the fiber ends). Wood-parenchyma is difficult to distinguish from the fibers, has slightly thinner walls, is abundant, surrounds the vessels, and is diffusely distributed among the fibers.

#### RADIAL SECTION

*Gross.*—The elements are serried. The rays are of the same light color as the other tissues, fine and not prominent. The texture is fine and uniform.

*Minute.*—The vessels are composed of segments of medium length with commonly large simple perforations. The pits are bordered or semi-bordered, small, numerous, often crowded, and nearly uniform in size. The fibers are without septae, and have numerous small simple pits with short, oblique, open, lenticular orifices. Wood-parenchyma cells are abundant, distinguished from the fibers by their transverse walls, and by the larger grouped pits. Microscopic growth-rings are indistinctly defined by slightly compressed, slightly thicker walled fibers.

#### TANGENTIAL SECTION

The rays are 1-4+ cells broad, and mostly less than 35 cells high. Multiseriate rays are composed of rounded cells of somewhat variable size, but infrequently elongated. The uniseriate rays are composed either of rounded or slightly elongated cells. The fibers bear pits in the tangential walls.

#### MACERATION

The vessel segments are mainly truncate at the ends; the fibers, rather long and broad, cylindrical in the central portion, with rather long, attenuate, mostly unpitted, extremely delicate ends.

#### DISTINGUISHING CHARACTERS

The wood is whitish in color, diffuse porous, soft, straight-grained, and with often indistinct microscopic growth-rings. The vessels are of small diameter and composed mainly of truncate segments of medium length with simple perforations and bordered or semibordered pits, all of nearly uniform size. The fibers are rather long and broad, with rounded outlines in cross-section; the walls, thin; the pits, simple, and present in all walls. Wood-parenchyma is abundant, of nearly the same diameter as the fibers, but with slightly thinner walls, and disposed around the vessels or diffusely among the fibers.

**Coprosma longifolia** A. Gray. PILO. Material, lxxvi:48:1498.

*C. longifolia* is endemic to Hawaii and attains a height of about 15 feet with a short trunk of several inches in diameter. It is reported from Kauai and Oahu, at elevations of about 2,500 feet.

The wood is soft, grayish or bluish-white in color, with a silky luster, diffuse porous, without distinct growth-rings.

#### CROSS SECTION

*Gross.*—The vessels are small, visible with a lens, and mostly arranged in small compact groups of 2-6+ together. The size is variable but vessels rarely exceed 0.12 mm. in diameter; the lumina, open and permeable to alcohol. The rays are 1-4+ cells wide, mostly without cell-contents; the pits, mostly small and irregularly arranged, but variable. The fibers are mostly somewhat compressed, with the tangential diameter greater than the radial; the walls, rather thin; the lumina, open; the pits, simple and mostly present in the radial walls. Wood-parenchyma occurs mainly in contact with or adjacent to vessels.

#### RADIAL SECTION

*Gross.*—The rays are small but distinct. An amber-colored substance is present in the rays and vessels.

*Minute.*—The vessels are composed of rather long segments with simple perforations terminal or lateral in position and mostly smaller than the vessel lumen. The pits are large but variable in size and shape from circular or long elliptical or, rarely, scalariform; those in contact with parenchyma vary from semibordered to simple. The rays are composed mostly of radially elongated cells in the central portion and of axially elongated cells at the margin. The pits are small and subcircular, except where in contact with vessels, where large irregularly elliptical semibordered or simple pits occur. The fibers bear simple pits in the radial walls with slitlike orifices extending beyond the closing membranes.

#### TANGENTIAL SECTION

*Gross.*—The rays are small but distinct by reason of their brownish contents.

*Minute.*—The rays are heterogeneous, 1-4+ cells wide and as a rule less than 35 cells high. The cells of the wide rays are variable in size and shape but mostly small and rounded in the interior and elongated at the margins. Those in the uniseriate rays are also more or less elongated. The fibers are unpitted in the tangential walls.

#### MACERATION

The vessel segments terminate, as a rule, in tonguelike or tracheid-like ends. The fibers are long, narrow, straight, and taper from near the middle into long sharp ends.

#### DISTINGUISHING CHARACTERS

The wood is soft, grayish- or bluish-white in color with a silky luster, diffuse porous, and without distinct growth-rings. The vessels are visible in cross section with a lens, and mainly arranged in small compact groups; perforations simple; pits bordered, semibordered, or simple, large and variable in outline. The rays are heterogeneous, 1-4+ cells wide, and less than 35 cells high. The fibers have rather thin walls, large lumina, simple

pits in the radial walls, and are slightly compressed radially. Wood-parenchyma occurs mostly in contact with the vessels.

**Morinda citrifolia** Linn. NONI KUAHIWI.

Material, lxxxv:26:1503.

The genus *Morinda* comprises about 46 species of shrubs, trees, or climbers distributed in tropical climates of both hemispheres. It is best represented in Asia and the Oceanic islands. *M. citrifolia* is a cosmopolitan species believed to have been introduced at an early date by the Hawaiians. It occurs in cultivated areas, and was valued because of dye obtained from roots and bark. The fruit yields an oil and is eaten in Fiji. The tree reaches a height of only 15 feet, with a trunk of a few inches in diameter. The wood is deep yellow in color, diffuse porous, soft, straight-grained, without growth-rings, and of fine uniform texture.

CROSS SECTION

*Gross.*—The vessels are visible with a lens, isolated or in small rather compact radial and tangential groups. Some of the lumina are plugged with a yellowish substance but are usually open and the wood very permeable to alcohol. The rays are not as wide as the vessels.

*Minute.*—The vessels have very thin walls and are variable in size but rarely exceed 0.19 mm. in diameter. The rays are 1-4+ cells wide and bear minute pits. The fibers are not as numerous as wood-parenchyma, are rounded polygonal in outline, rather thick walled with open lumina of medium size, and few pits. Wood-parenchyma is of the same diameter as the fibers, thin-walled, very abundant, and diffusely distributed.

RADIAL SECTION

*Gross.*—The wood is of even texture and color, with a dull luster. The rays are not distinct.

*Minute.*—The vessels are composed of rather short segments with large simple perforations and small, numerous bordered or semibordered pits of uniform size. The rays are composed mainly of radially elongated or square cells commonly in the ventral portions, with many axially elongated cells at the margins. The pits are small.

TANGENTIAL SECTION

*Gross.*—The surface is of uniform texture with indistinct structural features.

*Minute.*—The rays are 1-4+ cells wide and may exceed 60 cells in height. The cells are mainly irregularly elliptical in outline with many axially elongated cells at the margins or sides.

## MACERATION

The vessel segments are mainly truncate; the fibers, long, narrow, rather straight, with long attenuate sharp points.

## DISTINGUISHING CHARACTERS

The wood is deep-yellow in color, with dull luster, diffuse porous, soft, straight-grained, without growth-rings, and of fine uniform texture. The vessels are rather large but indistinct without a lens, isolated or arranged in small compact groups, have mostly open lumina, short segments, large simple perforations, and small numerous bordered or semibordered pits. The rays are 1-4+ cells broad, and some of them exceed 60 cells in height. The fibers have rather thick walls, lumina of medium size, few pits, and are not as abundant as the parenchyma, which is of the same diameter as the fibers and diffusely distributed.

## Order CAMPANULALES

## Family COMPOSITAE

The Compositae comprise about 10,000 species of herbs, shrubs or, rarely, trees of general distribution especially in warm climates. The 56 endemic Hawaiian representatives show American affinities. *Raillardia* is a xerophytic genus of high elevations. The wood is characterized by vessels with simple or rarely scalariform perforations, bordered or semibordered pits. The rays are variable, and sometimes lacking. The interior of the broad rays is composed of radially elongated cells surrounded by axially elongated cells that merge gradually into prosenchyma. The fibers bear simple pits and may be septate. Wood-parenchyma occurs mainly near or in contact with vessels.

***Dubautia plantaginea*** Gaud. NAENAE. Material, xxii:1:1439.

The genus *Dubautia* is endemic to Hawaii and shows affinities with *Raillardella* of isthmian America. *D. plantaginea* is a small tree, 10-16 feet high, of general distribution in the rain forest of the islands. The wood is light grayish-yellow, rather soft, of fine even texture, without growth-rings or distinct heartwood, and is straight-grained.

## CROSS SECTION

*Gross.*—The vessels are visible with a lens, diffusely distributed, smaller than the rays, isolated or in small compact groups of 2-3+ together. The lumina are without tyloses or other contents. The rays are light-colored but not prominent.

*Minute.*—The vessels vary slightly in size but few exceed 0.16 mm. in diameter. The walls are thin and lateral perforations many (fig. 8, *b*). The rays are multiseriate and composed of cells of slight if any elongation; the pits are minute and numerous. The fibers are rounded polygonal in outline, rather thin-walled with open lumina, and bear numerous simple pits in the radial and tangential sides; they occur in regular radial arrangement, the large diameters in orderly alternation with small diameters of the fiber points as in *Charpentiera* (fig. 2, *b*). Wood-parenchyma is not abundant and is mostly in contact with vessels.

#### RADIAL SECTION

*Gross.*—The rays may reach a height of 4+ mm. but are not prominent. The elements are serried.

*Minute.*—The vessels are composed mainly of short truncate segments with large simple perforations, or occasionally found with lateral perforations or with tracheid-like or tongue-like ends (fig. 8, *A* and *B*). The pits are numerous, small, circular or elliptical, bordered or semibordered, but not simple. The rays are composed of cells nearly square in outline or elongated axially; the pits, numerous, minute, and subcircular, and not large in contact with vessels. The fibers bear minute simple pits in vertical arrangement.

#### TANGENTIAL SECTION

*Gross.*—The wood is of uniform texture. The rays are indistinct; many of the vessels are slightly dark-colored.

*Minute.*—The rays are multiseriate, elliptical in outline with acute margins, usually less than 4 mm. high and less than 0.2 mm. broad. The cells are variable in size, and mostly somewhat axially elongated. At the sides elongated cells occur merging into the prosenchyma.

#### MACERATION

The fibers are short and broad, cylindrical in the central portion with short tapering rather obtuse points.

#### DISTINGUISHING CHARACTERS

The wood is light-colored, soft, diffuse porous, and without growth rings. The elements are serried. The vessels are small, visible in cross section with a lens, isolated or in small compact groups, and are composed of short segments with mainly truncate ends, large simple perforations, small bordered or semibordered pits, and open lumina. The fibers have rather thin walls, large open lumina, and simple pits. Wood-parenchyma is not abundant and is mostly in contact with vessels.



## KEY

- (1) Secondary growth present (2).
- (1) Secondary growth absent.....*Pandanus tectorius*, p. 240
- (2) Vessels present (3).
- (2) Vessels absent, tracheids in bundles.....*Dracaena aurea*, p. 241
- (3) Wood with intraxylary phloem, or other soft tissue which withers  
away on drying, leaving the wood chambered (4).
- (3) Wood not chambered (8).
- (4) Raylike strands present (5).
- (4) Raylike strands absent.....*Nototrichium sandwicense*, p. 251
- (5) Strands distinct (6).
- (5) Strands not distinct.....*Pisonia grandis*, p. 257
- (6) Strands as broad as the vessels.....*Charpentiera obovata*, p. 249
- (6) Strands narrower than the vessels (7).
- (7) Wood separating into concentric lamellae.....*Pisonia excelsa*, p. 254
- (7) Wood not separating into concentric lamellae.....*Pisonia sandwicensis*, p. 255
- (8) Vessels with scalariform perforations (9).
- (8) Vessels with simple perforations (10).
- (9) Wood red .....*Byronia sandwicensis*, p. 293
- (9) Wood whitish .....*Perrottetia sandwicensis*, p. 295
- (10) Ray-vessel pits varying from semibordered to simple (11).
- (10) Ray-vessel pits semibordered (29).
- (11) Wood-parenchyma in zones, tangential lines, or diffuse (12).
- (11) Wood-parenchyma limited to the vicinity of vessel, or absent (19).
- (12) Wood-parenchyma diffuse (13).
- (12) Wood-parenchyma in zones, tangential lines (14).
- (13) Rays mainly 1 cell wide (18).
- (13) Rays 1-3 cells wide.....*Cryptocarya mannii*, p. 259
- (14) Vessels mainly grouped (15).
- (14) Vessels mainly isolated (17).
- (15) Vessels in large radio-tangential groups of often more than 20.....*Sideroxylon sandwicense*, p. 338
- (15) Vessels in small groups (16).
- (16) Wood-parenchyma abundant, in broad tangential lines.....*Eugenia malaccensis*, p. 318
- (16) Wood-parenchyma not abundant, in fine tangential lines.....*Eugenia sandwicensis*, p. 320
- (17) Rays mainly uniseriate.....*Calophyllum inophyllum*, p. 308
- (17) Rays 1-4 cells wide.....*Rauwolfia sandwicensis*, p. 344
- (18) Vessels mainly isolated.....*Aleurites moluccana*, p. 287
- (18) Vessels mainly in radial rows.....*Euphorbia rockii*, p. 289
- (19) Pits between vessels circular, or nearly so, in outline (24).
- (19) Pits between vessels varying to scalariform (20).
- (20) With secretory canals in the rays (21).
- (20) Without secretory canals in the rays (22).
- (21) Rays usually less than 5 cells wide.....*Panax gaudichaudii*, p. 327
- (21) Rays often over 5 cells wide.....*Panax platyphyllum*, p. 329
- (22) Wood rather hard (23).

- (22) Wood soft ..... *Elaeocarpus bifidus*, p. 303  
(23) Rays 1-3 cells wide ..... *Tetraplasandra waimeae*, p. 323  
(23) Rays 1-6 cells wide ..... *Dipanax gymnocarpa*, p. 325  
(24) Vessels mainly isolated (25).  
(24) Vessels mainly grouped (28).  
(25) Wood nearly white ..... *Solanum sandwicense* var.  $\beta$ , p. 340  
(25) Wood red, brown, or yellow (26).  
(26) Wood red ..... *Metrosideros villosa*, p. 321  
(26) Wood yellow or brown, rather hard (27).  
(27) Wood yellow, soft, or with reddish brown heartwood .....  
..... *Artocarpus incisa*, p. 243  
(27) Wood brownish yellow, rather hard .....  
..... *Rhus semialata*, var. *sandwicensis*, p. 291  
(28) Vessels in small compact groups ..... *Solanum sandwicense*, p. 349  
(28) Vessels in long radial rows ..... *Pipturus gaudichaudianus*, p. 245  
(29) Wood-parenchyma more or less abundant, in zones, tangential lines,  
or diffuse (30).  
(29) Wood-parenchyma limited to the vicinity of vessels or absent (58).  
(30) Wood-parenchyma in zones or tangential lines (31).  
(30) Wood parenchyma diffuse (47).  
(31) Vessels mainly isolated (32).  
(31) Vessels mainly grouped (37).  
(32) Rays often over 20 cells broad ..... *Lirythrina monosperma*, p. 273  
(32) Rays under 20 cells broad (33).  
(33) Wood soft, whitish yellow ..... *Sapindus saponaria*, p. 297  
(33) Wood red, brown, or blackish (34).  
(34) Wood soft ..... *Terminalia catappa*, p. 315  
(34) Wood hard (35).  
(35) Rays 1-6 cells broad ..... *Cyathodes tameiameiae*, p. 332  
(35) Rays 1-2 cells broad (36).  
(36) Fibres often with concentric lamellae ..... *Mezoneurum kauaiense*, p. 269  
(36) Fibres usually without concentric lamellae ..... *Dodonaea viscosa*, p. 153  
(37) Rays mainly uniseriate ..... *Ochrosia sandwicensis*, p. 346  
(37) Rays often more than 1 cell wide (38).  
(38) Rays 1-7 cells broad (39).  
(38) Rays less than 7 cells broad (41).  
(39) Wood very hard ..... *Sophora chrysophylla*, p. 271  
(39) Wood soft (40).  
(40) Wood-parenchyma in distinct zonal arrangement .....  
..... *Gossypium drynariodes*, p. 306  
(40) Wood-parenchyma in indistinct tangential rows .....  
..... *Hibiscus arnottianus*, p. 305  
(41) Wood whitish and soft or rather soft (42).  
(41) Wood red or reddish brown (45).  
(42) Rays 1-2 cells broad, vessels mainly in radial rows .....  
..... *Melicope cinerea*, var.  $\delta$ , p. 284  
(42) Rays 1-3 cells broad, vessels mainly in small radial groups (43).  
(43) Wood-parenchyma in broad, distinct zones (44).