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Cryptogams: Ferns and fern allies

W.P. de Winter and V.B. Amoroso (Editors)

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Foreword

When surveys of useful plants are published, ferns and fern allies (pteridophytes) are not usually or only very rarely mentioned and if so, they are attributed ornamental value. As can be learnt from this volume, however, the uses of ferns and fern allies comprise almost all uses that are known for seed plants. Uses of fruits and seeds are excepted of course, because pteridophytes do not reproduce by seed but by spores.

In addition to the ornamental value which most ferns possess, numerous ferns are also used in traditional medicine and many ferns are used as food, e.g. the starch accumulated in the rhizome, the young leaves (croziers) as a vegetable, the salt remaining after burning is used for flavouring and several ferns are valuable as fodder, green manure and fibre, tree ferns for timber, large leaved ferns for thatching. Contemporary developments have engendered applications such as mosquito control, energy production, decontamination of waste water and soils and as a prophylactic against nerve gases.

The economic value of ferns and fern allies is difficult to estimate because statistics hardly exist. For ornamental ferns, including live plants and cut foliage, the annual trade value is estimated at about 200 million US$. Pteridophytes used in herbal medicine constitute a considerable trade volume because they are supplied to numerous consumers. Scientific knowledge about the pharmacological properties of medicinal ferns is by no means complete, but the research interest is growing. Several pteridophytes contain promising compounds (alkaloids, phenols) and it can only be hoped that this publication may contribute towards stimulating further research. Ferns as food really do have potential but here also more research is needed, not only to improve palatability but also to find reliable methods to take promising species into cultivation to create a more constant supply.

South-East Asia with its more than 4000 pteridophyte species could play an important role in developing a sustainable fern market. It is hoped that this volume, which contains up-to-date information on more than 100 species, will contribute to a better understanding of this underestimated group of plants and that it will stimulate research in many directions in order to guarantee maintenance of the rich genetic diversity alongside sustainable exploitation of this group of beautiful plants.

January, 2003
Professor Aprilani Soegiarto
Chairman of the Prosea Board of Trustees
Jakarta, Indonesia

1 Introduction

1.1 Definition and diversity

1.1.1 Pteridophytes (Pteridophyta)

Within the vascular plants, the pteridophytes constitute the third major group besides the angiosperms (flowering plants) and the gymnosperms (which includes the conifers and the cycads). The pteridophytes are apparently characterized by a negative character, namely the lack of flowers and seeds of even the simplest kind. Instead, they reproduce by means of spores, single, unfertilized cells designed to be dispersed and give rise to an alternating generation of completely different and much simpler plants, the prothalli. In section 1.4.3 this will be described by some detail. Four classes of pteridophytes are distinguished, which are briefly introduced below (see also Figure 1).

Ferns (Pteropsida)

Ferns are the best known and dominant class, both in number of species and in number of individuals. They are characterized within the pteridophytes by their large leaves. Their often delicately divided leaves frequently shun direct sunlight and dominate the aspect of many forests. One family excepted (*Ophioglossaceae*), they all can be easily determined as ferns by the young leaves that burgeon curled up spirally, not without reason often compared with the top end of a violin (fiddle-head), or a bishop's staff (crozier).

Clubmosses and related families (Lycopsida)

The clubmosses and related families constitute a second class. They have small leaves (cylindrical and rush-like in one family) with the sporangia borne in the leaf-axils. The clubmosses and the spikemosses are the better known members of this class. The unsuspecting observer will often take them for mosses, though they are generally coarser and sturdier. Some scrambling species may attain a length of several metres with solid, cord-like main axes. The clubmosses as a rule do not compete well with modern plants and they are mostly found in niche habitats as epiphytic, epilithic and terrestrially growing species in mountain heaths. The spikemosses on the other hand are, at least in the Asian tropics, predominantly found in the shade of the forest floor or as low epiphytes. The third member family of this class, the grass-like aquatic quillworts, has few species in tropical South-East Asia, and all are very rare. Most representatives are found in clear mountain lakes and rivers.

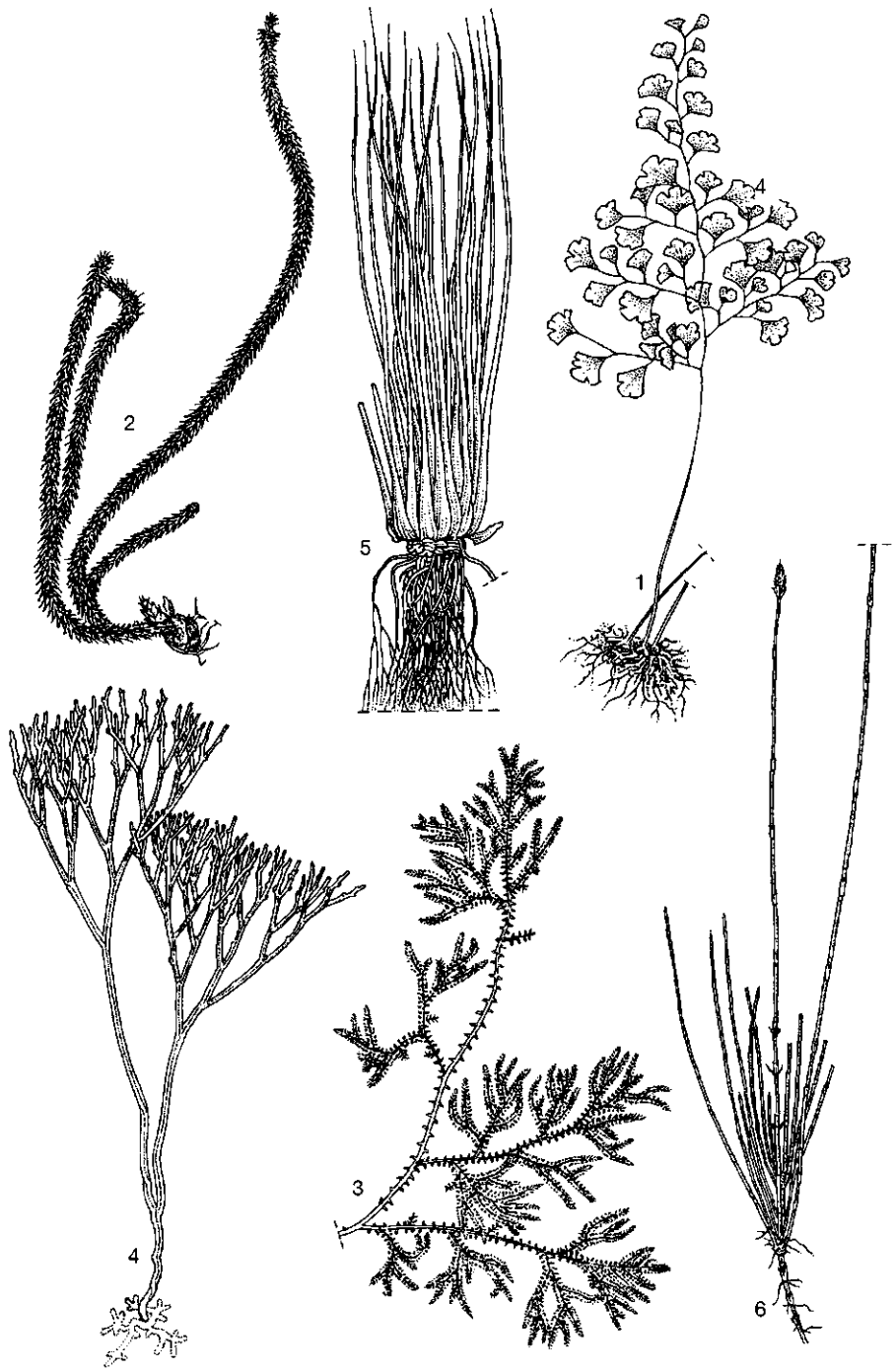


Figure 1. Representatives of the main groups within the *Pteridophyta* – 1, a fern (*Adiantum capillus-veneris* L.); 2, a clubmoss (*Huperzia monticola* Underw. & F.E. Lloyd); 3, a spike moss (*Selaginella opaca* Warb.); 4, a whisk fern (*Psilotum nudum* L.); 5, a quillwort (*Isoëtes philippinensis* Merryl & Perry); 6, a horsetail (*Equisetum ramosissimum* Desf.).

Horsetails (Sphenopsida)

Horsetails are characterized by the stems, consisting of distinct nodes, with more or less conspicuous vertical ridges. The stems may bear whorls of branches, each a little below a sheath of much reduced leaves. The sporangia are borne on sporangiophores, which are arranged in strobili (spikes). Usually there is a single strobilus at the top of the stem, but additional ones may develop at the top of the branches. In some species (not in South-East Asia) the spike-bearing stems are pale without chlorophyll, thicker and of softer texture than the sterile stems. Generally they are found on rather moist soils. They vary in size from 10 cm up to 12 m tall and to 2.5 cm in diameter, and in growing habit from insignificant to aggressively invasive.

Whisk ferns (Psilopsida)

Of the vascular plants, the members of the whisk ferns have the least complex organization. The plants consist of (sparsely or profusely) dichotomously branched axes, arising from a subterranean rhizome. The rhizome is rootless, and this is a unique feature of whisk ferns among all vascular plants. Two genera have representatives in South-East Asia, which grow as epiphytes, or terrestrially in humus-rich soil or mounds of humus.

1.1.2 Choice of species

Contrary to most Prosea volumes, the present volume does not focus on a specific commodity, but rather on a taxonomically specified group of plants. The criteria for including species therefore had to be reformulated as not every one of the thousands of pteridophyte species has been recognized as a valuable resource to humans. Hence, the criterion for selection for this volume is whether any mention is made in the literature of the use of a species occurring in South-East Asia. One exception was made, however, for the use as an ornamental. Although their popularity has fluctuated, for the last centuries ferns have appealed to many gardeners and indoor-plant lovers for their delicate shapes and exotic allure. Virtually any kind of fern that can be found, transplanted or reproduced and kept alive has found a use as an ornamental somewhere, though not often on a large scale. To avoid a pointless enumeration of species for which only incidental interest has been shown, only those ornamental species that have become commercially important are included in Chapter 2.

Mosses are not vascular plants and they do not belong to the pteridophytes. However, the very few moss species covered by Prosea do not justify a separate subvolume and therefore they have been included in this subvolume in Chapter 3.

1.1.3 Origin and geographic distribution

The species diversity of a region, expressed as the number of species, varies from almost none in polar and arid regions and isolated islands to as many as 2000 in New Guinea. The highest diversity of pteridophyte species is found at

lower latitudes, but even in the tropics, highly diverse regions are paralleled by very poor areas. By far the most diverse areas are the tropical mountains. At a rough estimate, 65% of the pteridophyte species are found in the wet tropics in areas without a marked dry period. The taxonomic diversity of the tropics is furthermore expressed by large numbers of genera and families, many of which do not occur in more temperate regions.

Some 4400 pteridophyte species are known from South-East Asia. At present, worldwide 10 500–11 300 species have been described, a number that is expected to increase to about 12 000–15 000 (Roos, 1996). The region therefore ranks amongst the world's richest fern floras. Other regions with high pteridophyte diversity include the western American mountain ranges from southern Mexico to Bolivia, south-eastern Brazil and Madagascar. Remarkably, intermittent regions such as Amazonia, continental Africa and the Indian subcontinent are much less diverse (Tryon, 1986).

Some 30% of the fern species have relatively small ranges and some of them even are limited to a single mountain. Less than 10% of the species have very wide to cosmopolitan ranges, while the bracken (*Pteridium aquilinum* (L.) Kuhn) is ranked among the top ten most abundant vascular plants of the world.

Homosporous ferns all have a nearly equivalent capacity for dispersal and migration. Estimates of the annual spore production of an individual fern range, depending on the species and size, from 100 000 to 3 billion. A single spore can, by self-fertilization, give rise to an adult sporophyte. Evidence from floras of oceanic islands shows that 800 km distance is not a significant barrier to the migration of a fern flora (Tryon, 1986). Still geographic barriers do exist. Several fern species have naturalized after deliberate or inadvertent introduction by humans, sometimes with detrimental effects to the indigenous vegetation. Large intermittent areas without suitable habitats, such as deserts and oceans, can effectively block the expansion of a species' distribution. High mountain ranges also seem difficult to pass.

Nevertheless, the differences in species ranges must be based on the ecology of the environment rather than dispersal. The ecological flexibility of the various life stages of a fern (spore germination, gametophyte, sporophyte) may vary considerably. Thus long-living sporophytes may persist in areas where they can no longer reproduce sexually. This makes it hard to explain the observed species ranges.

Most fern families have wide distributions and only a few of the smaller ones are confined to South-East Asia and northern Australia, for example *Cheiropleuriaceae*, *Dipteridaceae* and *Matoniaceae*. While several genera have representatives in a limited region only, many others have a circumglobal distribution. This is explained partly by their great age. During the tens to hundreds of millions of years of their existence they have had opportunities to cross the barriers raised by the oceans which, in past eras, were narrower than they are nowadays. The oldest genera even preceded the disintegration of the Triassic Pangea into the predecessors of the present continents.

1.2 Importance of ferns and fern allies

Pteridophytes are not normally thought of as useful plants. Good (1933) puts it straight from the shoulder: 'the pteridophytes (ferns and their allies) are also

relatively useless'. The best he could make of them are their dead remains amassed as coal to be used as fuel. The world's coal deposits originate from vast pteridophyte forests that lived during the carboniferous era, before the onset of seed plants. No vast fortunes are to be made from the cultivation of any of the species and the only occasion the general population is likely to take notice is when a fern becomes an aggressive and successful weed. Nevertheless, agricultural societies dependent on what the land can offer them have appreciated the value of ferns more keenly. May (1978) published a review of the uses of pteridophytes throughout the world, listing over 100 applications of various fern species. Ferns are found to provide food, medicine, fibre, craft and building material, abrasives and of course decoration (Croft, 1985).
Table 1 shows a survey of primary and secondary uses of the described species and genera in this volume. Uncertainty exists as to what extent reported uses still continue. Throughout this subvolume the information compiled is often based on literature sources that are over 50 years old (e.g. Burkill, 1935; Heyne, 1927; Ochse, 1931; Quisumbing, 1951). Often no indications were available that the cited uses still continue to be practised into present times. In these cases it has been decided to use the past tense, although recent applications could not be ruled out and, as incidental experiences suggest, present day applications might still be very much the same.

1.2.1 Food

Starch

Several fern species store starch as a reserve, especially in the rhizome. In the past these ferns served as an supplementary food source or to produce alcohol. However, due to the low quantity and quality of the starch, this habit has nowadays been largely abandoned. Species treated within this volume that have served as source of starch include *Angiopteris evecta* (G. Forst.) Hoffm., *Cibotium barometz* (L.) J. Smith, *Cyathea* spp. and *Pteridium aquilinum* (L.) Kuhn.

Vegetables

Many fern species have been recognized as having leaves that can be eaten as a vegetable. Some of them have an exquisite taste and are sold as a delicacy. Especially the young leaves that are still curled (croziers) or partly curled are consumed. When the leaves mature, the increasing concentrations of certain chemical constituents such as alkaloids, damage the taste and in some species may eventually impose adverse health effects upon the consumer. The older leaves also become unpalatable as a result of the build-up of structural material.

The ferns most commonly used as a vegetable in South-East Asia are the 'green fern' *Diplazium esculentum* (Retz.) Swartz and the 'red fern' *Stenochlaena palustris* (Burm.f.) Bedd. The way in which they are prepared varies in accordance with the cook's preference from salad to steamed, boiled, or fried.
In an experiment in the Philippines cooked fiddleheads of the following ferns have been tried as a vegetable or as a component of a stew: *Acrostichum au-*

Table 1. Primary (●) and secondary (•) uses of the treated species and genera.

species or genus	medicine	ornamental	vegetable	fibre	starch	manure	fodder	insecticide	stimulant	absorbent	salt	thatch	dye	anti-erosion	timber	abrasive	flavouring	research
Acrostichum aureum	•	•	●									•						
Adiantum	•	●	•	•														
Ampelopteris prolifera	•		●															
Amphineuron terminans				●														
Angiopteris evecta	•	•	●		•													
Asplenium	•	●	•	•					•		•							
Azolla pinnata			•			●	•											
Blechnum	•	•	●		•													
Cephalomanes javanicum	●																	
Ceratopteris thalictroides	•	•	●			•												•
Cheilanthes tenuifolia	●	•																
Cibotium barometz	●	•		•				•										
Cyathea	•	•	•	•	•		•				•				●			
Cyclosorus heterocarpus	●	•																
Davallia	•	●																
Dicranopteris linearis	•	•		●										•				
Diplazium	•	•	●	•														
Dipteris conjugata	●																	
Drynaria	•	●	•						•									
Equisetum ramossissimum	●															•		
Helminthostachys zeylanica	•	•	●	•														
Hemionitis arifolia	●	•																
Huperzia carinata	•	●																
Huperzia phlegmaria	•	●																
Huperzia serrata	●																	
Hypolepis punctata	●	•																

Table 1. Continued.

species or genus	medicine	ornamental	vegetable	fibre	starch	manure	fodder.	insecticide	stimulant	absorbent	salt	thatch	dye	anti-erosion	timber	abrasive	flavouring	research
Loxogramme scolopendrina		●		●														
Lycopodiella cernua	●	●		●				●		●				●				
Lycopodium clavatum	●	●								●								
Lycopodium complanatum	●									●								
Lygodium	●		●	●					●									
Marsilea crenata	●	●	●		●		●											
Microlepia speluncae	●		●															
Microsorum	●	●	●														●	
Nephrolepis	●	●	●	●	●	●												
Odontosoria chinensis	●	●											●					
Oleandra neriiformis	●																	
Onychium siliculosum	●	●																
Ophioglossum pendulum	●	●	●															
Ophioglossum reticulatum	●		●															
Pityrogramma calomelanos	●	●								●								
Platycerium bifurcatum	●	●																
Pleocnemia irregularis	●		●															
Pteridium aquilinum	●		●	●	●	●	●	●			●	●	●					
Pteris	●	●	●	●						●								
Pyrrosia	●																	
Rumohra adiantiformis		●																
Schizaea dichotoma	●																	
Selaginella	●	●	●	●														
Selliguea feei	●	●																
Stenochlaena palustris	●	●	●	●														
Taenitis blechnoides	●																	
Tectaria	●	●																

reum L., *Angiopteris evecta* (G. Forst.) Hoffm., *Blechnum orientale* L., *Cyathea contaminans* (Wall. ex Hook.) Copel., *Diplazium esculentum*, *Nephrolepis hirsutula* (G. Forst.) C. Presl, *Pleocnemia irregularis* (C. Presl) Holttum, *Pteris ensiformis* Burm.f. and *Stenochlaena palustris* (Burm.f.) Bedd.). *Diplazium esculentum* was found to be the most palatable. Other factors determining the suitability of fern fronds as vegetables include the production rate of new leaves, and the availability of young fronds throughout the year. There have been some experiments to bring *Diplazium* into cultivation, but up till now most if not all of the supply to the markets is harvested from the wild.

Flavourings

Remarkably many fern species accumulate metal salts from the soil in which they root. For a few species, in areas with difficult access to other sources of salt, this has led to a use that involved burning the fern down to their ash, which is rich in salt. The ash is strewn on cooked food before consumption, or mixed with water and drunk. The salt, like most other vegetable salts, is higher in potassium content than common salt.

1.2.2 Medicine

The most common use, in terms of the number of species involved, is medicinal. Most records are based on uses in traditional medicine. A number of species were described in pharmacopoeias many centuries ago and have been continuously used in herbal medicine ever since. No pteridophytes are used at present as a source of (western) pharmaceutical compounds, though of some the constituents are being synthesized.

In the past doubt has been expressed as to whether the supposed medicinal value of ferns is due to their properties and that they should be attributed to the psychological and placebo-effect (Croft, 1999). It is noteworthy, however, that the same or related fern species have found similar medicinal applications even on different continents. Furthermore, in several cases laboratory research has revealed biological activities of fern extracts that could account for the medicinal uses in traditional and herbal medicine.

Traditional medicines are often prescribed for internal use as decoctions of infusions. Both preparation processes are water based, but lipophylic solvents such as ethanol often extract other pharmacologically active compounds, such as antibiotics, that are not or hardly present in the aqueous solutions (Kelmanson et al., 2000). Extraction with wine, as is practised in old European herbals, is not commonly done in tropical South-East Asia.

Currently, most research efforts on the efficacy of pteridophytes as medicines, or as a constituent of formulations, are concentrated around Chinese herbal medicine (CHM, also known as TCM or traditional Chinese medicine). CHM has always been used by the Chinese communities in South-East Asia, and nowadays also by an increasing number of others, as an alternative or in addition to pharmaceutical medicine. Integration of CHM and pharmaceutical medicine has only recently started to come to fruition, due to differences in philosophies, research standards and the inaccessibility of the Chinese literature. Claims by CHM about remedies for diseases that still present unanswered

challenges to pharmaceutical medicine (e.g. see *Selaginella* Pal. Beauv. uses for cancer and *Huperzia serrata* (Thunb. ex Murray) Trevis. for Alzheimer) have led to increased interest in ethnobotany and research into herbal medicine.

1.2.3 Structural materials

The trunk of tree ferns is sometimes used as instant construction material for bridges and fences. The fibrous material is resistant to decay and long-lasting. In some areas it is used for the construction of houses too, but possibly only where tree ferns are plentiful and other suitable timber is scarce. The stem can be cut into sections of the desired dimensions, polished and then made into vases, pencil holders and umbrella holders, or split and the harder portion used for inlaying or making fancy boxes and frames.
Fibrous splints can be obtained from the petioles and rachises of various species, and these are used for making ropes and wickerwork. Especially *Lygodium* Swartz is still a popular material and apart from products for personal use such as cases, belts and baskets, items are produced for the handicraft and tourist industry.

1.2.4 Ornamentals

Most ferns can be kept as ornamentals as long as adequate care is provided. Before introducing a species as an ornamental some key factors must be considered that may influence its commercial success. These factors comprise a combination of characters that make a fern attractive to the customers and properties that are important to the commercial growers.
Currently successful ornamental fern species have the following common characteristics: closely placed fronds which give them a full foliage look, symmetry in overall outline, small to medium size, an evergreen habit and at least one unusual characteristic that makes them special, e.g. colour, texture, or shape. Moreover, they should be able to stand adverse cultural conditions and not too sensitive to relative humidity or temperature when marketed for indoor use, or they need to be inexpensive enough to be disposable.
Commercial nurseries demand species that are inexpensive to produce and deliver to the market. Fast-growing species are preferred, such as those that can be reproduced by spores or mass vegetative cloning (tissue culture). The ferns should be resistant to measures to control diseases and pests. Finally they should not easily be damaged during transport from the grower to the market (Hoshizaki, 1992).
When evaluating a fern species for ornamental use one should bear in mind the great variation in climate between the various international markets. Outdoor horticultural markets range from cool temperate to tropical with various regimes of precipitation and relative humidity. Ferns for indoor use may not be expected to experience so much variation in temperature, but relative humidity will be different in e.g. centrally-heated buildings in northern temperate areas and air-conditioned or open constructions in warmer zones.
South-East Asia has been the origin of several commercially interesting ornamental fern species. *Platycerium bifurcatum* (Cav.) C. Chr. and *Asplenium*

nidus L. have become rather important products. Without doubt, other species could also be developed, although it is questionable whether growers within the South-East Asian region are able to compete on the international markets due to transport costs and plant-hygiene import restrictions. For local markets ferns are often gathered from the forest. Most of these are common and can be collected in quantity without endangering the species, but locally there may be adverse impacts on the forest diversity.

1.2.5 Other uses

Ferns have traditionally been used for various other purposes. The decorative values of ferns and their allies have invited their use for personal decoration, either casually or for ceremonial occasions. Especially fibrous species (*Dicranopteris* Bernh., *Lygodium* Swartz) or those that form long, flexible strings that can be interwoven without breaking (*Selaginella* Pal. Beauv., *Lycopodium* L.) are suitable for this purpose. Houses and ceremonial places were also decorated with ferns, either by adorning them on purpose, or by just allowing ferns to remain where they appeared spontaneously.
Ferns have also found a place in rituals and magic. Leaves of *Nephrolepis* Schott were placed among the bones of deceased close relatives at death ceremonies in New Guinea. Magical properties were attributed to *Blechnum orientale* L., *Drynaria* (Bory) J. Smith and *Hemionitis arifolia* (Burm.f.) T. Moore.
The rough surface of horsetails, caused by fine crystals of silica on their stem surface, found a special use as a scouring and smoothing aid. The sandpaper-like qualities of *Equisetum ramosissimum* Desf. have led to its use in shaping and smoothing tools, ornaments and weapons, but is also acknowledged to be useful for cleaning pans and other cooking utensils.
Although many of the traditional uses have been abandoned and replaced by modern materials, nevertheless new applications still arise. Ferns frequently are the subject of various fields of scientific research. Modern uses include widely differing applications such as sewage water treatment, hydrogen production, gold prospecting, composting and the development of new pharmaceutical products.

1.2.6 Economic aspects

The annual trade value of ornamental and cut foliage ferns is estimated at 150–300 million US$. Despite this considerable amount, statistics on the global fern production and trade are not easily obtained as auction sales are monitored by regional offices and rarely published in national censuses. Consequently, the economic facts and figures presented here do not offer a coherent view of the economic role of the fern trade.
In the Netherlands the most traded ferns are *Nephrolepis*, *Asplenium* and *Adiantum*. In 1997, 12 million *Nephrolepis* plants were produced by tissue culture. Still, a substantial part of the propagation is achieved by means of spores, or by taking cuttings (especially of *Selaginella*). Originally, the tissue-culture laboratories were mainly found in western Europe, but at present the sector is expanding to eastern Europe (Poland) and Asia (Sri Lanka, Indonesia) (Vidalie, 2000).

In Florida (United States) fern production in 1996 amounted to a wholesale value of 97 million US$. The total production of leatherleaf fern (*Ruhmora)* in the United States in 1997 was 60 million US$, with a production area of 1750 ha.
In 1999 Japan imported cut stems worth 4 billion yen, which for a substantial part were ferns from China, the United States and Costa Rica. Cut flowers and ferns are the third ranking agricultural export commodity in Costa Rica, following bananas and coffee. The main obstacle to Costa Rican flower and fern exporters is the infrastructure, which is inadequate for rapid transport abroad. The primary market for Costa Rican ferns is the European Union (mostly The Netherlands and Germany). In 1995 the total export value for ferns was about 50 million US$, with a yearly growth of 10–20%.
Ferns may also play a role in the local economy. Little is known about the impact of diffuse markets, such as represented by the roadside booths selling ornamentals, either collected from the wild or propagated in artisanal gardens. The use of traditional medicine may involve both economic and logistic factors. Occasionally, local economies specialize in ferns. In the State of Rio Grande do Sul (Brazil) *Rumohra adiantiformis* (G. Forst.) Ching is abundant in early stages of degraded forest areas. In meeting the demand from flower shops, this species has been heavily exploited since 1970s, and has become the major source of income for an estimated 3000 families in the Brazilian Mata Atlântica Biosphere Reserve (Elisabetsky & Coelho de Souza, 2001).
Pteridophytes used in herbal medicine must constitute a considerable trade volume, as they are supplied to a consumer market worth billions of dollars. However, as far as is known neither the production nor the trade flows are being monitored.

1.3 Properties

Many pteridophytes exhibit relatively slow growth while preferring conditions that would normally be considered unhealthy from a phytopathological point of view. Nevertheless, indications of damage caused by fungi or invertebrate herbivores are rare. A diverse phytochemical armament of widely differing degrees and types, including antibiotics, which is taxonomically widespread among the pteridophytes, is probably the most effective and widespread strategy in promoting direct vegetative survival. However, little is yet understood about which substances are employed to achieve effective defence and exactly what they are targeted against (Page, 2002). Not only the sporophytes are armed with a load of repellents, but also the gametophytes and even the spores. In ferns occur chemically unusual intra-cellular cements that bind cells together, different from those of spermatophytes (Manton, 1950). They may be indigestible to those animals with an HCl-mediated digestive tract.
The wide molecular diversity of secondary metabolites throughout the plant kingdom represents an extremely rich biogenic resource for the discovery of novel drugs and for developing innovative drugs. Not only do plant species yield raw material for useful compounds, the molecular biology and biochemistry provide pointers for rational drug development. Many of the compounds found in pteridophytes fall into two groups, the alkaloids and the phenols. Some important groups with their most important classes are briefly summarized below (abridged from from de Padua et al., 1999).

1.3.1 Alkaloids

The term 'alkaloid' is used here for plant-derived compounds containing one or more nitrogen atoms (usually in a heterocyclic ring) and usually having a marked physiological action on humans or animals. Alkaloids in plants are believed to be waste products and a nitrogen source. They are thought to play a role in plant protection and germination and to be plant growth stimulants. Alkaloids are especially common in lycopods. Many alkaloids are pharmaceutically significant, e.g. huperzine A, a reversible inhibitor of the enzyme acetylcholinesterase, that is involved in the breakdown of the neurotransmitter acetylcholine.

1.3.2 Phenols and phenolic glycosides

Phenols probably constitute the largest group of secondary plant metabolites. They range from simple structures with one aromatic ring to complex polymers such as tannins and lignins. Examples of phenolic classes include tannins, coumarins and their glycosides, quinones, flavonoids, lignans and related compounds.

Tannins

The chemistry of tannins is complex. Tannins are able to react with proteins. On being treated with a tannin, a hide absorbs the stain and is protected against putrefaction, thereby being converted into leather (for more information, see Lemmens & Wulijarni-Soetjipto, 1992). Though tannins are widespread in plants, their role in plants is still unclear. They may be an effective defence against herbivores, but it is likely that their major role in evolution has been to protect plants against fungal and bacterial attack. The high concentrations of tannins in the non-living cells of many trees (heartwood, bark), which would otherwise readily succumb to saprophytes, have been cited in support of this hypothesis. Some authorities consider tannins to be waste products and it has also been suggested that leaf tannins are active metabolites used in the growing tissues. However, tannins in different plant species probably have different functions. Tannins are used against diarrhoea and as antidotes in poisoning by heavy metals. Their use declined after the discovery of the hepatotoxic effect of absorbed tannic acid. Recent studies have reported that tannins have anticancer and anti-HIV activities.

Coumarins and their glycosides

Coumarins are benzo-α-pyrone derivatives that are common in plants both in a free state and as glycosides. They give a characteristic odour of new-mown hay and occur, for instance, in the hay-scented fern *Dryopteris aemula* (Aiton) O. Kuntze. They are biosynthetically derived via the shikimic acid pathway. The biological activities reported are spasmolytic, cytostatic, molluscicidal, antihistaminic and antifertility.

Quinones

Quinones are oxygen-containing compounds that are oxidized homologues of aromatic derivatives and are characterized by a 1,4-diketo-cyclohexa-2,5-diene pattern (paraquinones) or by a 1,2-diketo-cyclohexa-3,5-diene pattern (ortho-quinones). Some quinones have some medicinal value in the form of antibacterial and cytotoxic activities, others are powerful fungicides, laxatives or hair colourants.

Flavonoids

Flavonoids are the compounds responsible for the colour of flowers, fruits and sometimes leaves, or contribute to the colour by acting as co-pigment. Flavonoids protect the plant from UV-damaging effects. The basic structure of flavonoids is 2-phenyl chromane or an Ar-C_3-Ar skeleton. Recently, flavonoids have attracted interest due to the discovery of their pharmacological activities as anti-inflammatory, analgesic, antitumour, anti-HIV, antidiarrhoeal, anti-hepatotoxic, antifungal, antilipolytic, anti-oxidant, vasodilator, immunostimulant and anti-ulcerogenic. Examples of biologically active flavonoids are rutin for decreasing capillary fragility and quercetin as antidiarrhoeal.

Lignans and related compounds

Lignans and related compounds are derived from condensation of phenylpropane units. Neolignans are also condensation products of phenylpropanoid units, but the actual bond varies and involves no more than one β-carbon (8-3', 8-1', 3-3', 8-0-4' for example). Designated lignans or neolignans result from the condensation of 2–5 phenylpropanoid units (e.g. sesquilignans and dilignans, lithospermic acid). Lignans are substances deposited at the end of the formation of the primary and secondary cell walls. Lignans display antitumour pharmacological activity.

1.3.3 Terpenoids and steroids

Terpenoids and steroids are derived from isoprene (a 5-carbon unit), which is biosynthesized from acetate via mevalonic acid. Monoterpenes are the most simple constituents in the terpene series and are C_{10} compounds. They arise from the head to tail coupling of two isoprene units. Sesquiterpenoid lactones are well known as bitter principles. Sesquiterpenes possess a broad range of biological activities due to the α-methylene-γ-lactone moiety and epoxides. Their pharmacological activities are antibacterial, antifungal, anthelmintic, antimalarial and molluscicidal.

Diterpenes

Diterpenes constitute a vast group of C_{20} compounds arising from the metabolism of 2E,6E,10E-geranylgeranyl pyrophosphate. They are present in some animals and plants. Diterpenes have some therapeutic applications. For instance, taxol and its derivatives from *Taxus* L. are anticancer drugs. Other ex-

amples are forskolin, with antihypertensive activity, zoapatanol, an abortifacient and stevioside, a sweetening agent.

Triterpenes

Triterpenes are C_{30} compounds arising from the cyclization of 3S-2,3-epoxy, 2,3-squalene. Tetracyclic triterpenes and steroids have similar structures, but their biosynthetic pathway is different. Steroids contain a ring system of three 6-membered and one 5-membered ring; because of the profound biological activities encountered, many natural steroids together with a considerable number of synthetic and semi-synthetic steroidal compounds are employed in medicine (e.g. steroidal saponins, cardioactive glycosides, corticosteroid hormones, mammalian sex hormones). The pharmaceutical applications of triterpenes and steroids are considerable. Cardiac glycosides have been used in medicine without replacement by synthetic drugs.

Saponins

Saponins constitute a vast group of glycosides which occur in many plants. They are characterized by their surfactant properties; they dissolve in water and, when shaken, form a foamy solution. Saponins are classified by their aglycone structure into triterpenoid and steroid saponins. Most saponins have haemolytic properties and are toxic to cold-blooded animals, especially fish. The steroidal saponins are important precursors for steroid drugs, including anti-inflammatory agents, androgens, oestrogens and progestins. Triterpene saponins exhibit various pharmacological activities: anti-inflammatory, molluscicidal, antitussive, expectorant, analgesic and cytotoxic. Examples include the ginsenosides, which are responsible for some of the pharmacological activity of ginseng and the active triterpenoid saponins from liquorice.

1.4 Botany

1.4.1 Taxonomy

Among the extant land plants, the ferns are only surpassed in diversity by the angiosperms. Worldwide their number is estimated at about 12 000 species in about 225 genera. Until the early 20th Century the extant pteridophytes were subdivided into three classes:
- the *Pteropsida* (also *Filicopsida*, *Polypodiopsida*), or ferns;
- the *Sphenopsida*, or horsetails;
- the *Lycopsida*, or clubmosses, spikemosses and quillworts.

During the last century consensus arose that the whisk ferns, being a very primitive group, justify a fourth class on its own, the *Psilotopsida*. To these four classes the term 'ferns and fern allies' is applied in colloquial speech. Although united in the *Pteridophyta*-division, it should be noted that this grouping is based on similarities of the life cycles rather than common ancestry. Their origins go back in geologic time to the Devonian and Carboniferous eras and their inclusion in the *Pteridophyta* is a matter of convenience, although a few recent authors have chosen to raise the four classes to the level of division (e.g.

McCarthy, 1998). It is often suggested that the *Pteropsida* in this sense are polyphyletic still and that the *Ophioglossales* (represented in this subvolume by *Ophioglossum* L. and *Helminthostachys* Kaulf.) and *Marattiales* (represented in this volume by *Angiopteris* Hoffm.) may be not correctly placed here. Cladistic methods, using a great number of morphological and biochemical characters, are currently being deployed to resolve these relationships (e.g. Pryer et al., 2001), but have not yet resulted in a definitive classification scheme.

Pteropsida

The ferns are a diverse group, but they are easily distinguished from the other classes by their large leaves with a more or less complex pattern of venation. The sporangia grow on the leaves, but these may be modified into highly specialized organs. Six orders constitute this class, of which five have circinate leaves.

Lycopsida

These are plants with solid, herbaceous stems and numerous small, moss-like leaves (or rush-like, in *Isoëtes* L.). The sporangia reside solitarily in the axils of the fertile leaves, which can be very different from the sterile leaves and form a terminal strobilus. The quillwort family (*Isoëtaceae*) is essentially aquatic and very rare in South-East Asia. The clubmosses (*Lycopodiaceae*) are firm-herbaceous plants, either dichotomously branched or with a creeping main axis. All species of spikemosses (*Selaginellaceae*) within the area of this book have dorsi-ventral flattened branches with the lateral leaves the largest. Like the quillworts but unlike the clubmosses they are heterosporous, so some of the sporangia contain megaspores that are large enough to be discerned by the naked eye. The plants are generally soft herbaceous.

Sphenopsida

The horsetails have hollow, articulated stems built of clearly distinct joints. The leaves have been reduced to scales that stand in whorls around the joints, forming a sheath that encloses the next internode. The stems can be branched; the branches are built like the stem but much smaller and stand in whorls around the sheaths. The sporangia grow under peltate sporangiophores, forming a terminal strobilus (spike). The spores are green with four hygroscopic ribbon-like appendages called elaters. The elaters quickly coil up when moistened, thus reducing the wind resistance near suitable habitats for germination. Although the spores come in one size, the gametophytes are unisexual, the male ones remaining smaller than the female ones.

Psilotopsida

The whisk ferns are the only free-living vascular land plants without true roots. The stems are dichotomously branched and bear few leaves or only green scales. The sporangia are fused in groups of three that stand solitary on the

branches. There is one family represented by two living genera, *Psilotum* Sw. and *Tmesipteris* Bernh. The aerial shoot of *Psilotum* is a very simple green structure consisting of a dichotomously branching axis without leaves but with exceedingly small scale-like appendages called prophylls, which are mere flaps of tissue. Trilobed synangia are borne on short lateral branches. The underground rhizome is irregularly branched and is covered with fine, long, brown rhizoids. *Tmesipteris* differs morphologically from *Psilotum* by its well-developed foliage leaves supported by a single vein, and the bilobed synangium.

Families

Fossil *Pteropsida* have been found from the Lower Carboniferous. All six families known from the end of the Carboniferous became extinct by the Lower Permian. In a second major filicalean evolutionary radiation during the Permian, Triassic and Jurassic several families arose which still have extant representatives (*Cyatheaceae*, *Dicksoniaceae*, *Dipteridaceae*, *Matoniaceae*, *Osmundaceae* and *Schizaeaceae*). A subsequent radiation among the polypodiaceous ferns began in the Upper Cretaceous while flowering plants already had gained dominance over much of the land surface.
In the 19th Century most pteridologists classified the ferns into families based on a few characters only. Especially, analogous to the importance of reproductive organs in flowering plants, the position, the shape and morphology of the sori determined the family to which a genus should belong. The resulting families were often very large and, as understood today, not in accordance with the presumed lines of evolution, or on the other hand segregated on the base of characters that vary between related genera. In the course of the 20th Century new classifications were accepted that take more characters into account, such as the venation pattern, the anatomy of the petioles, and, in the second half of the century, the number of chromosomes. Especially the *Polypodiaceae*, or the 'modern' ferns, have long persisted as an extremely large and heterogeneous family. Various authors though, have proposed regrouping the ferns into families in varying combinations. One of the most comprehensive classifications published (Kramer & Green, 1990) reflects best the present state of general consensus. This synthesis was based on similarities between genera rather than differences, thus reflecting their relationships more explicitly. As several relationships still need to be revealed this classification will also be worked over in time, alternative views even coexist at present. For the time being, however, this is a good standard to go by, if one has to be chosen. In this Prosea subvolume the nomenclature of families and genera is in accordance with this classification, even when it diverges from prevailing literature of the region.

1.4.2 Morphology

The most commonly used descriptive terminology is illustrated in the Figures 2a and 2b.

Rhizome

The leaves (fronds) of a fern are formed at or near the apex of its main axis or

stem, the rhizome. The rhizome can, depending on the species, attain different growth forms. In many ferns the stem is erect and radially symmetric. It is then called a 'caudex', which may also be prostrate or ascending. The fronds grow in a crown-like bundle on top of the caudex, radiating in all directions and roots grow downwards from all sides. The majority of species with a caudex gain little height and the leaves are based at or somewhat below soil level, but some of the most conspicuous species exhibit a potent heigth growth resulting in an appreciable stem of sometimes more then 20 m tall.

The creeping rhizomes produce their leaves at regular distances though they still may be crowded when the intervals are short. This kind of rhizome can be dorsiventrally differentiated with leaves arising in two or more rows from the upper surface and roots growing from the side that is appressed against the substratum. Most epiphytic ferns have creeping rhizomes, but they are not uncommon in terrestrial species either.

Creeping rhizomes often branch either in an irregular fashion or dichotomously; the caudices as a rule do not branch though ramifications may be induced by damage to the growing apex. The vast majority of ferns with a caudex are terrestrial; most epiphytes have a creeping rhizome though frequently a short one.

In few cases, the rhizome is green and photosynthetically active but generally it is well protected and covered with scales. Very rarely the rhizome is naked. Usually there is at least some form of indumentum, at least on the growing tips, to protect these vulnerable parts from physical damage, herbivory, or desiccation. The same indumentum is formed around the young unrolling fronds and usually the remains on the petiole base of full-grown leaves constitute a helpful character in identifying the species, but with time they may fall off. The indumentum is often of considerable diagnostic importance and may comprise scales, wax excretions, hairs, bristles and remainders of leaves, in any combination. The shape, colour, types of apex and base and the presence of marginal hairs and glands are important characters. Many advanced families of ferns have flat scales with a darker central area on a broad base. Sometimes four of the walls of the cells are very prominent whereas the two remaining ones are thin and translucent or clear. Seen with a hand lens this looks like lace or lattice work; this kind of scales is called clathrate and their presence is a helpful character.

The rhizomes normally do not increase in diameter, but in some cases the structure is reinforced by hairs, fibres, or mats of adventitious roots and remains of leaves. The anatomical structure of the stem is of considerable taxonomic importance. The stele or central vascular cylinder of the axis may be:

- solid, the primitive protostele (as in most *Gleicheniaceae*);
- a central vascular cylinder with a core of non-vascular tissue, the medullated protostele or siphonostele (e.g. *Dipterus* and most members of the *Ophioglossaceae*);
- slightly more complex and feature a hollow cylinder with leaf gaps from which the vascular strands to the fronds develop; the most simple form is a solenostele, e.g. as in *Davallia* where the leaf gaps are widely separated and do not overlap; more complex is a dictyostele, e.g. as in the *Thelypteridaceae*, where the leaf gaps overlap and form an elaborate network.

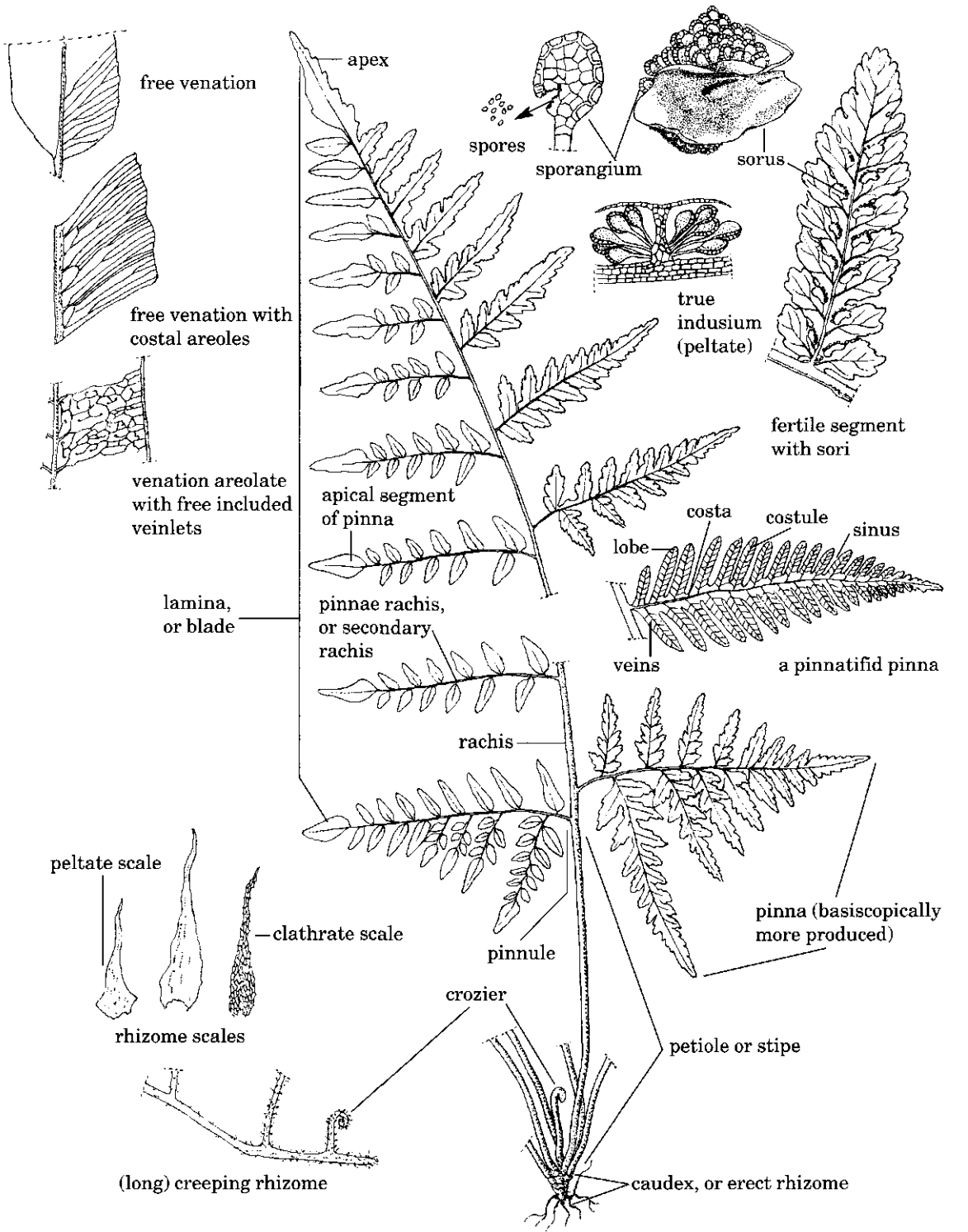


Figure 2a. Illustration of some terms used in the descriptions.

Roots

Only adventitious roots occur in ferns. In tree ferns such as *Cyathea* J.E. Smith and *Dicksonia* L'Hér., numerous roots are found near the base of the caudices, providing stability. Primitive fern allies of the genera *Psilotum* and *Tmesipteris* are entirely rootless. In the floating aquatic fern *Salvinia molesta* D.S. Mitch., the submerged leaf is modified to form root-like structures, but true roots are absent.

Petiole

The stipe of the fern frond is also known as the petiole. Well-developed petioles are only found in the true ferns and are absent or extremely short in the fern allies. Normally, the petiole is continuous from the rhizome to the lamina, but in some species it is articulated. This means that the precise location where the old leaf will be severed from the plant is predetermined. Fallen leaves leave behind a neat scar (abscission mark), either directly on the rhizome, or at a small distance above the petiole base. In some groups the rhizomes form modified outgrowths (phyllopodia), usually densely clothed with scales, onto which the petiole articulates. Phyllopodia are found in the families *Davalliaceae*, *Polypodiaceae*, and the genera *Arthropteris* J. Sm., *Elaphoglossum* J. Sm. and *Oleandra* Cav. Leaves with non-articulated petioles leave behind remaining petiole bases of varying length and with roughly cut off upper ends. In most families the petiole is not articulated to the rhizome.
The colour of the petioles is not a constant character of a family or a genus since it varies and overlaps between species of a genus, or between genera in a family. The colour varies from green, stramineous to brown or purple. Green petioles are observed in nearly all families but such petioles usually turn brownish or stramineous as they mature. The colour character may be useful in distinguishing species.
The petiole may be winged (alate) and grooved (sulcate), whereas those that are circular in transverse section are called terete. The shape, number and arrangement of the vascular bundles and the configuration of the xylem strand are characteristics of several families, but these characters are rarely used in the descriptions.

Rachis

The (primary) rachis is the continuation of the petiole into the lamina or blade. However, when the lamina is not completely divided up to its central axis, but embedded within leaf tissue for its entire length beyond the stalk, the central axis is called the costa rather than rachis. Likewise the pinnae can have pinnae-rachises when the leaf is at least 2-pinnate. The main vein of the pinna is also called the costa when the leaf is 1-pinnate only. It should be noted though, that in some literature these terms are used with a different meaning: there the rachis is the main axis of the lamina, whereas the costa is the main axis of the pinna, or lower order segments. Details of the rachis, such as indumentum and grooves, are frequently used as distinguishing characters in the identification of ferns.

Typically the rachis is pinnately branched, that is, the primary rachis continues more or less in a straight line to the basis, branching off at regular intervals, alternating on the left side and the right side like a fish bone. In some cases, the rachis is dichotomously branched: at each node the rachis splits into two equal branches. When the apical branch of a pinnately divided leaf does not develop, only the two pinnae grow sideways, which apparently also results in a dichotomous branching. This is referred to as pseudodichotomous, although the apical bud remains visible in the fork, thus giving away the underlying pinnate nature of this pattern.

Lamina

The flattened, leaf-like blade of the fern frond is called the lamina and it varies from simple to highly dissected. Most ferns have a number of leaves that are more or less uniform. In a considerable number of species, however, the fertile leaves are different from the sterile ones. Generally, the fertile leaves are more erect than the sterile leaves and also narrower, longer, or more constricted. Some large epiphytes, such as *Platycerium* Desv. and *Drynaria* (Bory) J. Smith, form specialized sterile leaves, closely appressed to the substratum, which protect the rhizome, conserve moisture and collect litter and humus.
The venation patterns of ferns are of great taxonomic significance. Basically the venation can be free or areolate. When the venation is free, the veinlets, once they have branched off, run towards the margin without ever connecting again to another vein. When the venation is areolate (also 'reticulate' or 'anastomosing'), the veins do meet again with other veins, and by doing so they form closed cells, the areoles. Combinations of the two patterns can be found. Quite often there are a few rows of areoles along the costa whereas the outer veins run free towards the margin. Also areoles may contain free veinlets, often short and little branched. When the lamina is very thick and coriaceous the veins may be concealed. In these cases it can be helpful to view the lamina against a powerful light source. The vein-endings may be enlarged and club-shaped, often of a somewhat different colour or translucency than the surrounding leaf tissue. These are called hydathodes, organs which have an excretory function.

Sori

In most ferns the sporangia are produced on the back side of the lamina. Usually the sporangia are clustered together into heaps or pouches with a characteristic shape, position and protection. These clusters are called sori. Sometimes the sori become confluent and can no longer be separated by eye. In several species the sporangia cover considerable parts of the leaf surface, so no sori can be distinguished. This condition is called 'acrostichoid'. In many genera the sori are protected by a special flap-like membranous structure termed the indusium. This structure is essentially an outgrowth from the leaf epidermis and may be attached laterally or centrally. The indusium may be linear, rounded or reniform, oblong, or double and borne back to back. In most cases it roughly follows the shape of the sorus. Some ferns have a false indusium, a soral protection formed by the reflexed margin of the lamina. The sporangia are sometimes

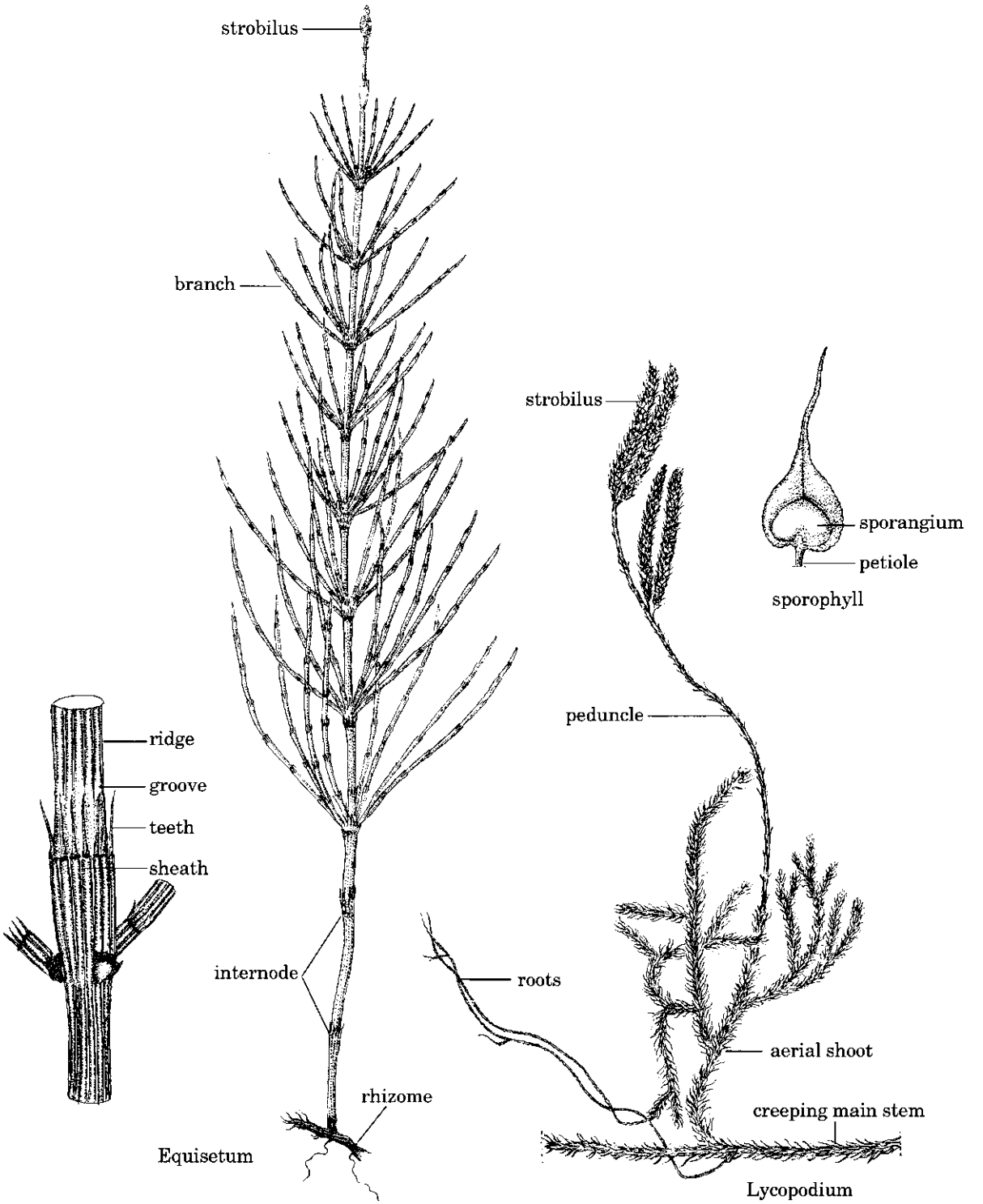


Figure 2b. Illustration of some terms used in the descriptions.

additionally protected, especially when immature, by modified hairs or scales known as paraphyses.

Sporangia

The spores are formed within specialized organs, the sporangia. At the higher taxonomic subdivisions (above family level) the shape and construction of the sporangia are characteristic. In its simplest form, the sporangium is a solid walled hollow sphere containing thousands of spores. This kind of sporangium may be found in spikes (e.g. *Helminthostachys*, *Ophioglossum*), branch ends, or, as in clubmosses, in the axils of specialized leaves.
In most ferns the sporangium is thin-walled, stalked and small. Running completely or partially around the sporangium body is a ring or group of specialized cells, called the annulus. The cells of the annulus have their inner cell walls thickened in such a way, that when the cells become dehydrated, the whole annulus bends outward, acting as a spring that forcibly ruptures the sporangial wall and releases the spores. In most families the annulus runs vertically, but in others it runs horizontally or forms a closed circle at top of the sporangium (e.g. *Lygodium*) Inside the sporangium there are 16 cells that act as spore mother cells by undergoing meiosis and forming tetrads of haploid spores. The sporangia of the *Marattiaceae* (*Angiopteris*) are borne on the abaxial surface, either free or aggregated in synangia. They are large, sessile and either lack or have a rudimentary annulus.

Spores

Spores are single-celled structures that are tiny and light enough to be dispersed by wind. The haploid spores in a tetrad have an exceedingly resistant outer protective coat which is generally composed of a thin inner layer called the intine, and an outer layer, the exine. Some spores have a covering outside the exine, called the perispore, derived from the periplasm around the spores. The perispore may be ornamented with ridges, spines, warts or balloon-like wings. The ornamentation and the ultrastructure of the spore wall are taxonomically important and are best observed using electron microscopic visualization. For a comprehensive study with superb photographs, see Tryon and Lugardon (1991).
Commonly, a spore has a proximal surface, which faces the centre of the tetrad, and a distal surface that faces the periphery of the tetrad. On the proximal surface is a mark called the laesura which is an 'aperture' in the exine.
Spores may be trilete, radially symmetric, tetrahedral to globose, with a triradiate aperture, or monolete, i.e. of bilateral symmetry, more or less bean-shaped, with a linear aperture. Monolete spores are the most common since they predominate in some large groups (e.g. *Asplenium* L., *Cyclosorus* Link and the *Polypodiaceae*). Trilete spores are considered to be the less advanced type as they are found earlier in the fossil record and are dominant in more primitive families. It is assumed that monolete spores have been derived from a trilete ancestor. This appears to have occurred on several occasions, since both types of spore occur in 12 distantly related genera.
Most pteridophytes produce one kind of spore only, thus they are homosporous.

Four families (*Azollaceae*, *Marsiliaceae*, *Salviniaceae* and *Selaginellaceae*) are heterosporous and produce two kinds: small (10–60 μm) microspores and large (up to more than 1 mm) megaspores. Consequently, the gametophytes of the heterosporous families are either male or female, as opposed to the monoecious gametophytes of the homosporous ferns.

Gametophytes

Gametophytes have been little used to identify species. They exhibit relatively few macromorphological characters, that in addition do not show much variation on the species level. Consequently, they have not received much attention by taxonomists, although micromorphology (e.g. of the gametangia) and isozyme patterns may include more information than hitherto exploited (Raine et al., 1996).

At a higher taxonomic level the type of gametophyte can be very characteristic. The prothallus of leptopsporangiate ferns is often typically membranaceous, heart-shaped and commonly less than 1 cm in size (Fig. 3(1). It has chlorophyll and is dark green, and near the sinus of the heart it is attached to the substrate by root-like hairs arising from the lower surface, the rhizoids. It is amongst these rhizoids that the passive or female sex cells develop. The egg cells are hidden within flask-like female organs, the archegonia. At some distance other organs are formed (the antheridia) that will produce the active or male sex cells. Gametophytes of homosporous ferns normally produce both male and female sex cells and are capable of self fertilization. However, mechanisms exist, such as asynchronous maturation, that enhance the probability of outbreeding. Heterosporous ferns produce either male (from the microspores) or female prothalli (from the megaspores – Fig. 3(6, 7). Different shapes are found in other groups. Several kinds of marginal outgrowths occur (Fig. 3(3), while others are basically filamentous (Fig. 3(2). *Ophioglossaceae* (Fig. 3(4), *Lycopodiaceae* (Fig. 3(5) and *Psilotaceae* have pale, lumpy, subterranean gametophytes that spend a long time living saprophytically in association with a mycorrhizal fungus, before giving rise to the green sporophyte.

1.4.3 Reproduction

The dominant stage in the life history of the pteridophytes is the generation that produces the spores and therefore is called the sporophyte. The ferns, horsetails and clubmosses as commonly known are in the sporophyte generation and the descriptions in the following chapter apply to this generation. The sporophyte forms spores by meiosis, the type of cell division that reduces the number of chromosomes to half the number that are in the nuclei of the sporophyte cells.

The spores commonly have very hard outer walls, often with intricate decorations of points and ridges. They grow in specialized organs called sporangia. Different groups within the *Pteridophyta* have their own types of sporangia. Many of those have mechanisms to assist the mature spores to leave the thin layer of slack air immediately around the sporophyte so they can be taken away by the wind and effectively dispersed. Many pteridophytes grow erect spikes or specialized upright fertile leaves to promote effective dispersion of the

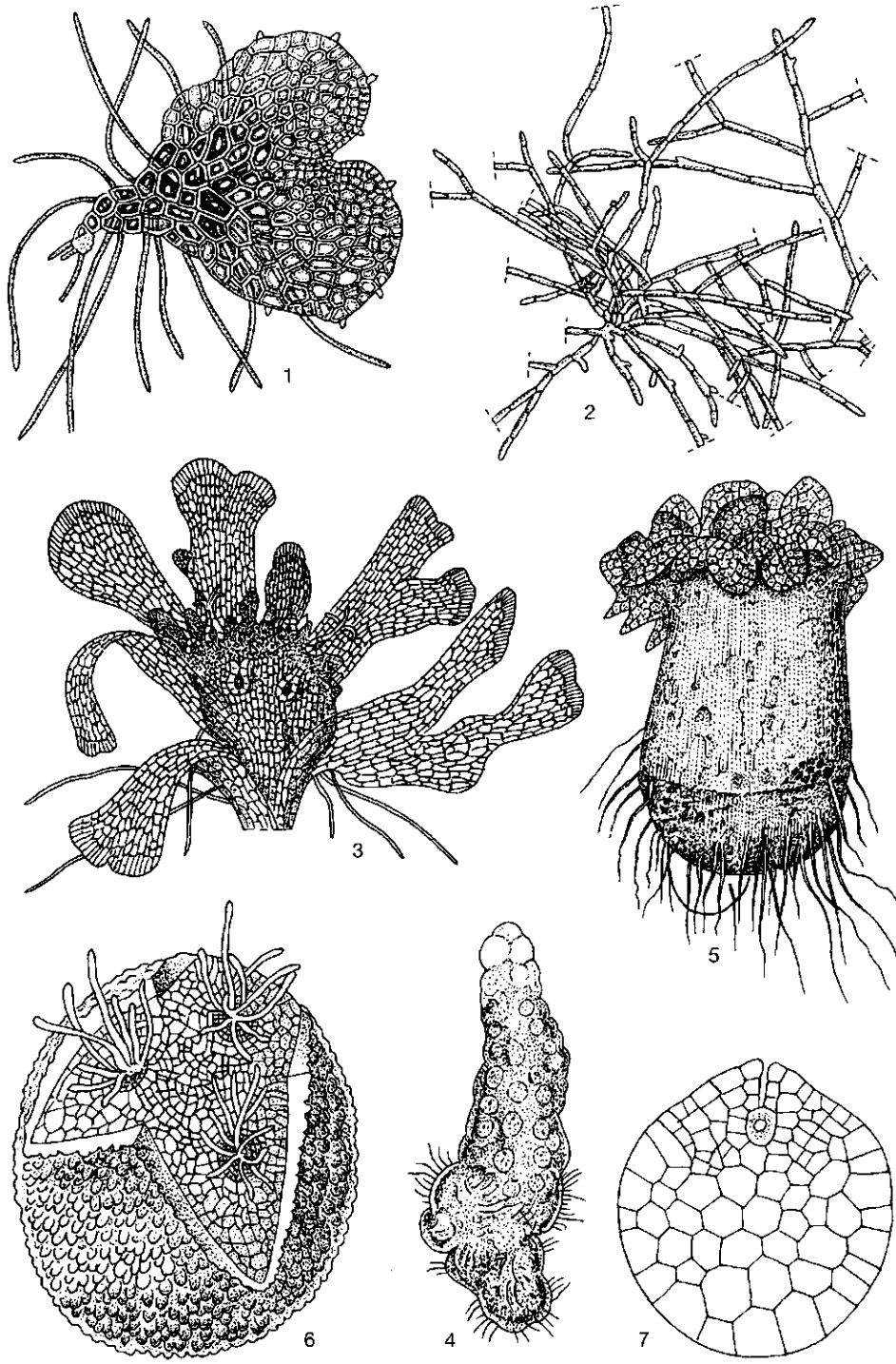


Figure 3. Prothalli of various shape (not to scale) – 1, *Polypodium*; 2, *Trichomanes*; 3, *Equisetum*; 4, *Helminthostachys*; 5, *Lycopodiella*; 6, *Selaginella* (female); 7, *Isoëtes* (female).

spores. The large megaspores of the heterosporous ferns impose an extra challenge to the dispersion process. The megaspores are frequently transported by water, but launching of the spores by hydrostatic pressure may also occur. The hard outer shell of the spores helps them to survive the unfavourable conditions as they are blown through the air and after they have been deposited and are awaiting a chance to germinate. Some spores remain dormant in soil spore banks for several years. A few groups though, have green, non-resting spores that will stay viable only for a few days or weeks and perish if no suitable conditions for germination are met within that time.

Upon germination the spore shell breaks along a predetermined opening and the alternate generation starts to grow out. At first, this is a simple uniseriate thread of cells; soon afterwards it develops into a more specific shape. Note that since the spore was formed by meiosis, this plantlet has a haploid chromosome count. Later in its development it will produce sex cells or gametes and therefore this generation is called the gametophyte, as opposed to sporophyte. Another name often used for the gametophyte is prothallus. The motile male gametes need a film of water to swim actively to the female gametes. This need for a period of free water poses a severe constraint on whether a habitat can be colonized by ferns. The tender construction of most gametophytes also limits the possible environments to sites that are suitable for both the sporophyte and the gametophyte. However, despite their fragility, gametophytes may be surprisingly resilient to desiccation, reviving multiple centres of growth even after months of dehydration.

A striking difference in the cytology of ferns compared to other plants is the high chromosome numbers. The sporophyte (diploid) counts range from less than 20 to over 1200. Many fern genera have existed for several hundreds of million years and these high numbers have resulted from repeated polyploidization during their history. There is, however, no unequivocal relation between the age of a genus and its chromosome count. Although the driving forces are not yet understood, at present the process can be observed and induced. Polyploidization follows from fertilization and nuclear fusion of a diploid gametophyte (apospory). Diploid gametophytes can originate from somatic sporophyte tissue that anomalously develops into a prothallus, or from an aberrant sporogenesis in which the meiotic process is rendered ineffectual (Manton, 1950).

A special case of polyploidy is alloploidy, where part of the genome descends from a different species. Alloploidy originates from hybridization, followed by a chromosome doubling. Hybridization between related pteridophyte species is rather frequent. This type of hybrid has, instead of a double set of analogous chromosomes, two single sets of chromosomes, one from each of the parents. While hybrid sporophytes can develop well, indeed often grow more vigorously than either of the parent species, they are sterile, as the two different chromosome sets do not allow a regular pairing of the analogues during the meiosis. However, when the number of chromosomes are doubled by apospory, normal meiosis can proceed and fertile spores can be formed. From cytological analyses it appears that alloploidy is a common phenomenon. In some fern floras a high percentage is of alloploid origin. It is assumed that alloploidy is especially common in unstable environments (on a geological time scale), where new genetic combinations can rapidly take advantage of the newly created niches.

Various causes, such as hybridization, can impose a sterility barrier by preventing regular meiosis during spore development. One strategy described above, is to double the chromosome number to enable meiosis with a doubled genome. Another strategy is to skip the reduction phase altogether and to produce spores with the somatic chromosome count. To prevent inadvertent genome doubling at each transition from gametophyte to sporophyte, the omission of the meiosis must be counterbalanced by not fusing the nuclei of sex cells on the gametophyte. The sporophyte develops directly from the tissue of the gametophyte and both phases therefore have the same chromosome count. This process is called apogamy, and it enables even triploid species to disperse by spores. The consequence is that outbreeding has become impossible.
Whereas reproduction by spores offers great advantages such as long-distance dispersion and the exchange of genetic variation, it is not always the most effective strategy to rapidly spread over the suitable habitat of an established parent plant. The gametophyte phase is easily influenced by less than optimal environmental conditions, and it may take a long time before the young sporophyte is strong enough to stand up to the competition of other plants. Therefore, many fern species have evolved ways to reproduce asexually. The most common approach is by long-creeping rhizomes, that may conquer a large area with considerable speed. Given time, a single clone may cover many hectares. Some aquatic ferns improve this process by fragmenting the rhizome, thus realizing an almost exponential growth. Also young plantlets in a more or less reduced state (bulbils) may be formed on the leaves, which, after disconnection or even before that, give rise to new sporophytes. When these young plants grow at the drooping apices of the leaves, a series of clonal individuals may 'walk' a path through the forest.

1.5 Ecology

During millions of years of evolution pteridophyte species have adapted to a wide range of environments, from the poles to the equatorial forests, from deserts to lake bottoms, from the seashore to high mountains. Only a submerged existence in salt water seems to be beyond their adaptive possibilities. Consequently, they exhibit a range of habits and life forms to cope successfully with this variety of habitats. The sporophytes vary in size from moss-like and a few mm long to tree-like and 20 m tall, including terrestrial, scrambling, climbing, epiphytic, epilithic, xerophytic, amphibious, aquatic, halophytic, floating and sub-arboreal forms.
The environment and substrate in which they grow are reflected in their habit and often their appearance. Frequently they are classified on the basis of their substrate into classes as epiphytes, terrestrial and aquatic plants. However, as they vary in their degree of specialization, many species do not keep to their class. Lower epiphytes are also found on the forest floor, aquatic species survive extended periods of complete emersion (or reverse) and terrestrial ones may extend into the trunks of trees. Especially fallen logs form a transient environment where both remaining and newly settling species mix with invading terrestrial ferns and deadwood specialists.
In spite of these transgressions, major families of pteridophytes are predominantly terrestrial, epiphytic or aquatic respectively, several morphological cha-

racters being correlated with the growing habit defined in this manner. A better understanding is obtained by taking the (micro-)climate into account together with their growing habit. Several classifications of the tropical environment from a pteridological point of view have been used (Holttum, 1938; Page, 1979; Tindale, 1998). Here a simplified classification is presented to give some insight into the morphological adaptations commonly seen in ferns.

1.5.1 Rain forests

The rain forests are characterized by a per-humid climate. They are found at lower altitudes, generally below 1000 m. The temperature is fairly constant and neither water supply nor water loss are problematic, though leaching of nutrients from the leaves by excess rainfall may be a factor that needs to be taken into account. The forest floor offers a sheltered habitat, usually with good drainage although marsh forests with permanently or seasonally waterlogged soils are not rare. The most important limiting abiotic factor is light. As it is intercepted by many layers of leaves, only a tiny fraction of the radiant tropical sunlight reaches the lowest strata. As an adaptation to this, ferns of the forest floor mostly have thin textured leaves and seem capable to maintain photosynthesis at remarkably low levels of light. The individual plants are typically well spaced, avoiding competition for light, nutrients, or other resources. There is little air movement in the rain forest, and so that the spores are better dispersed the fertile leaves are frequently narrower and more elevated than the barren trophic leaves.

Another strategy to reach higher is to climb the trees. Quite a number of ferns start on the forest floor, but send their long creeping rhizomes up along the trunks of trees. Some of them climb as high as the canopy and thus effectively escape the sheltered, moist environment near the forest floor into the dry epyphytic habitat of section 1.5.3. The low-climbers adhere to the bark with many fine roots from the tightly appressed rhizome. When the roots penetrate the superficial layers of the bark, they are able to extract water and nutrients. In these cases the terrestrial origin of a plant may perish and the plant will become truly epiphytic. True epiphytes depend on the rain and water draining off for their water supply.

Often there is no strict division between epiphytes and ferns of epilithic habit (i.e. growing on rocks). Especially small ferns may effectively root in the moss-layer, regardless of whether the moss grows on living or dead trunks or on stone. Many have membranaceous leaves with only two layers of cells (e.g. *Trichomanes* L.) and the adult sizes may be as little as 2 cm or less. Nevertheless, rocks and cliffs in the forest provide a range of habitats that specialized species can take advantage of. Since they are always sloping and often steeply so, waterlogged substrates requiring special adaptations for the oxygen supply of the roots hardly occur. On the other hand, the water supply varies from very constant in the crevices of larger cliffs to complete dependence on airborne moisture on exposed surfaces. Often the canopy is open to some extent, allowing more light to penetrate. The weathering of the stone could provide the epilithic ferns with a much richer nutrient supply than elsewhere in the rain forest, but the mineral sediment can also be biologically inert. Generally though, it is a favourable habitat for many fern species. In fact, ferns are better

adapted to exploit this habitat than many seed plants, as they lack a thick taproot but have filamentous rhizomes capable of creeping into the smallest fissures. Due to the nature of the cracks and fissures in rock, a few deep clefts offer an extremely strong anchorage, but the surfaces in between may be smooth, or hard and inhospitable. Under these circumstances small ferns with erect (non-creeping) rhizomes are favoured. However, other species follow crevices with their creeping rhizomes for a considerable distance.
Where streams break open the canopy, the aspect of the vegetation changes as the terrestrial plants grow larger and more vigorous. There is heavy competition for light as there is at the forest edge and in temporary clearings. Ferns seen here often grow to large sizes with finely divided leaves, often developing a scrambling habit or a tall, trunk-like stem. Smaller ferns growing where they could be washed over by the variable water levels, adopt a habit of surviving extended periods of submersion undamaged by the current (e.g. *Microsorum pteropus* (Blume) Copel.).

1.5.2 Montane habitat

In montane forests at around 2000 m mist and condensate may become the prime source of water. As the presence of the clouds is so constant, reaching from the forest floor to well above the canopy, the high-epiphytes do not need any special adaptation to prevent too much water loss and to protect them from intense radiation. The trees are shorter than in the lowland forests and the canopies less dense, so the forest floor receives more light. It is hardly surprising that this is where the richest fern floras are found.
At higher altitudes the trees become really dwarfed and finally are replaced by shrubs. Mosses become a dominant factor in the vegetation. The soil may also be partly unprotected by vegetation. When the welkin breaks open the sunlight is rich in ultraviolet radiation. Like the angiosperms, ferns living here therefore have leathery leaves covered by scales or a dense hairy indumentum, unless growing in well-protected sites. Often the leaf margins curl inward to further reduce the exposed surface. Reddish pigments may also be present. At even higher altitudes of over 3500 m the shrubs also disappear, leaving nothing but the protection of boulders and rock to shelter the remaining plants from radiation and wind. During the frequent showers and at night temperatures may drop to around freezing point.

1.5.3 Dry epiphytic habitat

The lower strata of the rain forest are well insulated from many direct climatic influences by several layers of vegetation. Many epiphytes, however, escape these lower reaches in search of light or nutrients and settle for less protected positions higher up in the trees. The more abundant light and earlier access to the nutrient chain come at a price, as the epiphyte has no access to water reservoirs. It is directly dependent on precipitation while at the same time being more vulnerable to desiccation due to sun and wind. The bright sunlight may also cause damage to the living tissues of the leaves. Similar conditions are found out of the rain forest reaches, in savannas and solitary trees in cultured land. Common adaptations to withstand the low relative humidity and high in-

solation include leathery leaves and protection of the leaves by hairs or scales. Especially in areas with a marked dry season, these environmental effects are aggravated as relative scarcity of water is accompanied by the hosting trees shedding their leaves. Under these conditions the ferns may bide their time in dormancy, with or without becoming deciduous.
Another remarkable adaptation, especially seen in some polypodiaceous ferns (e.g. *Drynaria*, *Platycerium*), is the formation of special fronds that are closely appressed to the substrate. In this way they protect the roots and centres of growth, but their shelter also provides a milder microclimate which favours the decomposition and recycling of nutrients. These shield fronds are frequently shaped in a way that facilitates the funnelling of falling litter towards the roots of the plant.

1.5.4 Exposed habitats

The habitats where ferns are exposed without protection to the elements of the tropical climate are varied and deserve a further classification. However, this is beyond the scope of this introduction. They include open rock faces, temporarily exposed soils, such as road cuttings, plantations and disaster sites, fresh- and salt-water marshlands, deserts and open water. The ample (or even excess) availability of light is here the common factor, whereas precipitation, desiccation and water stress vary to a great degree. As a general rule, ferns are not very competitive and under favourable conditions the struggle for resources is often lost against angiosperms. However, in more extreme conditions they still do well as is proved by their large species diversity and virtually ubiquitous distribution.
Time is sometimes also on their side, as under disturbed circumstances such as clearings and plantations where a rapid clonal growth enables some species to establish and maintain a dense, competitive stand for many years, until they are finally outcompeted by specialists of the more stable conditions. However, when the environment continues to be disturbed, as often occurs in plantations, they may behave like a weed that is hard to eradicate. Their easily dispersed spores also enable the pteridophytes to rapidly colonize barren areas, such as after forest fires or volcanic eruptions.
In arid habitats pteridophytes can grow as well as any xerophyte, but at least once during their lifetime they need free water as the male gametes need a film of water on the surface of the gametophyte to swim to the egg-cells. A little dew, though, will do for this.

1.6 Propagation

1.6.1 Division

Most pteridophytes with creeping rhizomes are easily propagated vegetatively by divisions of rhizome branches. The divisions should have an active growing tip, which can be recognized by the fresh colour and the young leaves arising at short distances behind the tip. The development of growing tips from side buds on thick rhizomes may be stimulated by partly cutting through the buds. All cuts should be made with a sharp, clean knife. Care must be taken not to injure

the growing tips and to keep as much soil to the roots as possible, but damaged leaves and old roots should be removed.
The cutting should be planted as deep in the soil as it was before, or slightly deeper if the roots remain uncovered. If the cutting does not bear roots, it may be placed half of its diameter within the soil and secured with bent wire, or, length allowing, diagonally with the growing tip emerging from the soil. The divisions should be kept moist, but not wet, and in light but not exposed to the sun. To keep the relative humidity high, thin-leaved species may require glass or plastic sheet covering, which can gradually be removed when the plants grow up. Inorganic fertilizer is applied after 15–20 days, but organic fertilizer should be avoided at this early stage as the bacteria and fungi it contains may turn against the vulnerable explants.
Some species produce vegetative reproduction organs such as runners, bulbils, or even buds developing into young plantlets whilst still attached to the parent leaves. When available these organs are better suited for vegetative reproduction than rhizome divisions. To reduce the risks during their early life stages, the organs are left to root and to grow well before detaching them, allowing them to profit from nutrients and water supplied by the parent plant.

1.6.2 Tissue culture

A technically more advanced means of vegetative propagation is tissue culture (also: meristem culture) which allows for mass multiplication under well-controlled conditions, though starting with tiny bits of parent material. For commercial use, this technique offers significant advantages: the product is free of diseases, the quality is high and constant, the application is not dependent on parent plants to form spores and it is much faster.
To start, apical meristems are taken from parent plants. The meristems consist of actively dividing cells that are not yet infected by germs. They are cleaned and externally sterilized and then transferred to a sterile, often fluid growing medium where they are kept under controlled conditions for several weeks to let them start multiplying by dividing. Part of the produced cell-clumps is explanted to a solid artificial growing medium to grow young plantlets, while the rest is kept in stock for a new production cycle. Many variations in medium composition and treatments (e.g. with plant hormones) exist to stimulate the growth of the meristems and the development into plantlets.

1.6.3 Spore propagation

Spores are the natural means of reproduction of all pteridophytes and growing ferns from spores can be as simple as shedding the spores over a container with moist soil and waiting. However, various techniques have been developed to obtain a more reliable production. The following just provides some examples, for details see Hoshizaki (2000).
Leaves should be selected that have light brown sori. A 10× hand lens should be used to check whether the sporangia are not still green or are empty pockets that have shed the spores already. The leaf could also be placed with the sori down on a sheet of white paper and gently tapped with the fingernail. Mature sporangia will then shed the spores as a fine greyish-brown dust. To harvest

the spores the leaf can also be left on a paper sheet for a day or two. The spores will precipitate on the paper when the sporangia dry and dehisce. Tapping the leaf speeds up the process, but also increases the amount of contamination. Non-sporal debris should be removed as much as possible as it promotes the growth of algae, fungi and mosses. Various minute-mesh devices have been applied to sieve the fluff from the spores. The spores are normally stored dry in paper envelopes, but good results have also been obtained with wet storage in the fridge.

For commercial use, the spores are normally not sterilized. However, it is strongly advised that the growing media and containers be sterilized. A semi-natural growing medium, a mixture of fine sand and one to two parts of finely screened peat moss is most often used commercially. Alternatively, a fluid nutrient solution (e.g. Knop's, Hoagland's, or Turtox) can be used. The medium should cover the bottom of the container permanently, which means a layer of about 7.5 mm depth. Agar media offer few advantages over fluid media unless the plants have to remain sterilized. After dusting the media-surface with spores, the containers are entirely or partly closed to prevent water loss and contamination with fungi.

The containers should receive low to medium intensity light. In about two weeks germination becomes visible by a thin green mat of threads on the medium surface. Gradually these threads develop into recognizable prothalli about 1 cm in diameter. When the prothalli are large enough they may be manipulated to ensure or avoid cross-fertilization. Fertilization will not occur when the prothalli are not covered with a thin film of water. It may be necessary to apply misting to obtain this condition. Other overhead watering should not be applied and likewise dripping from overhead condensation on the container lid should be avoided, as this promotes fungal growth. Moulds that develop nonetheless should be killed as soon as they become visible, by isolating the patch and applying a fungicide. After fertilization, the young sporophytes soon emerge. Once they are large enough to handle, they may be carefully transplanted.

1.7 Genetic resources and breeding

Many pteridophytes are fastidious habitat discriminators and thus vulnerable to loss of genetic diversity. At least 700 species are globally endangered (Dyer & Lindsay, 1996). Extinction or drastic reduction in genetic variation is a negative development because of the intrinsic value of the disappearing taxa, the impoverishment of the ecosystem, but also because of the decline of the chemical potential of bioactive substances, most of which have yet to be discovered. One example is the clubmosses of the genus *Huperzia* Bernh., from which valuable alkaloids and terpenoids have been extracted that are raw materials for the development of new medicines against serious diseases such as dementia (e.g. see the treatment of *Huperzia serrata* (Thunb. ex Murray) Trevis.). Some of the constituents occur in a wide range of related species, but others are specific to a single species or even to a taxon of lower rank. Many of these have a restricted distribution and logging, collecting and exploitation for personal or commercial purposes lead to a rapid decline of populations. It is feared that a number of species will become extinct in the future.

Ex-situ conservation can be achieved by maintaining living plants, but also by collections of viable spores. The viability of spores decreases over time, with rates varying from weeks to tens of years until none of the spores of a batch will germinate when sown. The common practice of storing dry, either at room temperature or cold, may be inferior to wet storage in retaining the germination capacity of the spores (Lindsay et al., 1992). In-situ conservation of pteridophytes and their ecosystems must always be the ideal. No environment is better suited to allow the subsistence of a species than its own. At present, however, ex-situ approaches must accompany in-situ measures to maintain the integrity of the gene pool for threatened species until in-situ conservation is practised (Page et al., 1992). Botanic gardens play an important role in ex-situ conservation and worldwide coordination of activities is being initiated. However, the conservation of tropical pteridophytes is lagging behind the temperate species due to lack of funding and organization and the number of species involved. The task of conservation of plant diversity has up to now mainly been shouldered by governmental and non-governmental organizations, but seen in the light of the vast research budgets of pharmacological companies, these companies should also be urged to shoulder responsibility in safeguarding future plant resources both for the general interest and for themselves.

As ferns are not horticultural crops, breeding is not normally done. Two exceptions exist, being *Azolla* Lamk and ornamentals. During the last decades, races of the mosquito fern *Azolla* have been selected towards a maximized nitrogen output under various cropping conditions. *Azolla* species have been hybridized and various genotypes of the symbiotic cyanobacterium were tried. The various selections and cultivars are still available from the International Rice Research Institute (IRRI).

Breeding ferns for ornamental purposes has a long tradition. As long as ferns have been kept as ornamentals, plants with aberrant leaves or variegated colours have received special attention and their offspring or clones were distributed amongst other fern lovers. Especially 19th Century England, during the Victorian 'fern craze' or 'pteridomania', saw the origin of many cultivars and hybrids. Nowadays a large part of the market for ornamentals is still occupied by cultivars with misshapen leaves and breeders are continuously trying to create new cultivars that appeal to fashion sensitive customers.

1.8 Prospects

With the ever-growing importance of the urban lifestyle at the expense of rural life, the distance between man and nature tends to increase. Younger generations achieve valuable skills for making their living in the city rather than to survive in remote areas where one has to depend on what nature can provide. It is therefore to be expected that botanical knowledge for daily use will disappear in the South-East Asian countries, as it has virtually disappeared in industrialized countries. Yet today, in rural areas, there is still a living tradition of using plants found in the wild for food, medicine, construction and other purposes. It is a living tradition in the sense that, with modern transport and communication, new ideas about plant use in other areas reach the erstwhile isolated communities. These are tried and, when found to be valuable, find a place in the tradition, or lead to experiments to explore new possibilities. Scientific

research thus can play a two-way role, both as recorder of remaining ethnobotanical knowledge and as mediator of ideas between remote areas.
Ferns as food do have a future. The young leaves of most ferns can be eaten as a vegetable, but not all are of equal quality. From the ferns treated in the next chapter, it may become clear that several of them have been selected for food by availability rather than palatability. However, as qualitatively adequate nutrition is not yet secured in all parts of the world, they may remain important as an additional food source. Other species though, have a good taste and feel by absolute standards and these could be developed into more important products. In New England (United States) and Japan small high-value markets already exist with young fern croziers as delicacies and opportunities exist for the export of other species. To guarantee a steady supply of constant quality, cultivation of these ferns might be taken up.
Ferns as fibres only play a role in artisanal production. Some of these products, such as fishing gear, are expected to disappear once they cannot compete with industrial products. For others a small market will remain in the tourist industry and traditional production. Nowadays in most areas, tree ferns are only used incidentally or casually as construction material. They are very well suited for the construction of makeshift bridges as they hardly rot or get slippery, but further development is not foreseen. A better opportunity lies in the production of high-quality horticultural materials. In deforested middle-elevation areas tree ferns grow and reproduce very well. Tree-fern farming for pots and fibres could generate access to a capital market. Care must be taken not to deplete the spontaneously grown stands of tree ferns, to comply with international regulations (required for export), to prevent erosion and to save future resources.
The future of ferns as medicine could proceed in several ways, and which one it will be, if not a combination, is hard to predict. Most medicinal uses of ferns in South-East Asia refer to traditional applications. In western Europe traditional knowledge about medicinal herbs disappeared as pharmacological medicines became widely available. In China, on the other hand, herbal medicine persists and is solidly rooted in society and the medical community. Other Asian countries occupy an intermediate position. Many people in South-East Asia do not yet have access to pharmacological medicines, either for logistic or economic reasons. When this situation changes, their traditional medicine will be relatively well documented and partly backed up by scientific research. Marketing by representatives of pharmacological medicine or herbal medicine also will exert influence.
Scientific knowledge about the pharmacological properties of medicinal ferns is by no means complete, although an increasing number of publications is filling in this gap. Ferns that have a recorded medicinal use are always more or less common species. It is rather worrying to think of the potential of the less accessible species that remain undiscovered by traditional medicine. With the ongoing threat to the tropical environment and its species diversity, this potential may be lost forever.

1.9 Recommended literature

The identification of South-East Asian pteridophytes is often hampered by the lack of accessible literature. The Flora Malesiana project caters for this need by

publishing a separate series on the Pteridophyta (van Steenis & Holttum, 1959–1981; Holttum, 1991; Kalkman & Nooteboom, 1998). The parts that have been published offer up-to-date revisions of the treated genera found in Malaysia, Singapore, Brunei, Indonesia, the Philippines and Papua New Guinea. Regrettably, the series, that was initiated in 1959, progresses slowly and a number of families have still not been covered yet. Therefore, other identification works dedicated to smaller areas are still necessary. For Peninsular Malaysia the Flora of Malaya (Holttum, 1968) provides an excellent entry, although it only treats the ferns, leaving lycopods and selaginellas to pose a problem. Piggott (1996) gives a colour photograph for most of the species described in Holttum. The Philippine pteridophyte flora has been described completely but the publication is hard to obtain and taxonomically outdated (Copeland, 1960). For Indonesia, fern floras are old and not all in English (Backer & Posthumus, 1939). For Indo-China the fern flora is old and in French (Tardieu-Blot, et al., 1939–1951). The Thai fern flora is well covered by the Flora of Thailand (Tagawa & Iwatsuki, 1979–1989). Finally, from neighbouring regions, the Flora of Taiwan (Huang, 1994) and Flora of Australia (McCarthy, 1998) prove very useful additional sources.

The morphology and biology of ferns and fern allies is usually poorly covered in general text books, which concentrate on spermatophytes. A good introduction in a palaeobotanical context is found in Sporne (1975); exhaustive descriptions of the anatomy, morphology and development are given by Parihar (1989). In relation to the spore-morphology, the atlas of Tryon & Lugardon (1991) provides thousands of detailed scanning electron microscope micrographs of spores of all pteridophyte genera, revealing intricate details.

Accounts of the ecology of ferns are more commonly found. However, most of them are limited to not very profound habitat descriptions. A more systematic approach to the classification of tropical fern habitats is given by Holttum (1938) and Page (1979). Page (2002) presents a thorough reflection on the ecology of ferns, including their intrinsic biological possibilities and limitations.

2 Alphabetical treatment of genera and species

Acrostichum aureum L.

Sp. pl.: 1069 (1753).
PTERIDACEAE
$2n = 60$ (diploid), 120 (tetraploid)
Synonyms *Chrysodium vulgare* Fée (1845), *C. aureum* (L.) Mett. (1856).

Vernacular names Leather fern, golden mangrove fern (En). Indonesia: paku laut (general), paku cai (Sundanese), krakas (Javanese). Malaysia: piai raya, paku piai, larat. Philippines: lagolo, pakong-laut, pagaypay. Thailand: prong thale (general), pee-yo (Malay-Satun). Vietnam: r[as]ng d[aj]i, c[aa]y r[as]ng.

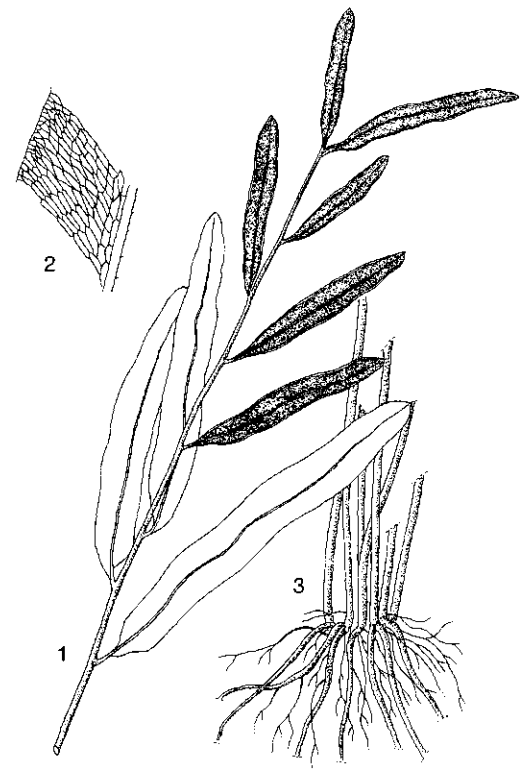
Origin and geographic distribution *A. aureum* is pantropical, occurring along the coasts of Asia, America and Africa. It is abundant in mangrove vegetation all over South-East Asia.

Uses In Malaysia, Indonesia (Kalimantan, northern Sulawesi, Kangean and Timor) and the Philippines, young shoots of *A. aureum* are eaten as a vegetable. In Vietnam and the Pacific, the firm, dried, parchment-like leaves are stitched together and used as thatching material in the place of straw-thatch. In this way the roof lasts longer and there is much less risk of fire. Should the roof catch fire the leaves burn rapidly and leave very little ash, thus reducing the risk of the rest of the habitation and its furniture catching fire. Medicinally, the pounded or grated leaves and rhizomes are applied as a paste to wounds, ulcers and boils all over South-East Asia. In China the rhizome is used against worms. *A. aureum* also has potential as an ornamental because of its handsome leathery leaves and the plant can be grown in pots.

Production and international trade *A. aureum* is neither cultivated commercially nor traded internationally. The fern is collected from the wild and is commonly sold on local markets for vegetable or medicinal use. In Vietnam leaves are locally traded as roof material.

Properties In the aboveground parts of *A. aureum* the following compounds have been found: amygdalin, arbutin, formic acid, oxalic acid, tannin and saponin. *A. aureum* spores are potential causative agents for patients with allergenic rhinitis. In a fertility test in female albino rats, ethanolic and acetone extracts of *A. aureum* showed 60–70% anti-implantation activity.

Description Large fern (up to 4 m tall) with leathery leaves, rhizomes often forming tussocks in mangrove swamps. Rhizome erect to procumbent, up to 6 mm in diameter, amply scaly at the apex; scales linear to lanceolate to broadly ovate



Acrostichum aureum L. – 1, leaf; 2, venation; 3, rhizome with petioles.

near the petiole base, (0.5–)1–2(–4) cm × 0.8 cm, attenuate, margin entire or erose, lustrous brown or bicolorous pale with a blackish central stripe. Leaves tufted, erect or arching, up to 4 m long; petiole up to 1 m long, at the base up to 20 mm in diameter, lustrous, stramineous to grey-brown, glabrous, bearing on upper portion small spine-like remains of reduced glandular pinnae; lamina pinnate, narrowly oblong to elliptical, up to 3 m long, subcoriaceous to coriaceous, glabrous, bright red when young; sterile pinnae simple, ascending, stalk up to 2.5 cm long, lamina narrowly oblong, 8–50 cm × 1–7 cm, base cuneate to rounded and more or less unequal, margin entire, cartilaginous, apex rounded to obtuse and shortly mucronate; midrib grooved above, distinctly raised below; veins raised below, hardly visible on upper surface, close, forming somewhat regularly arranged areoles up to 2 mm × 0.5 mm. Fertile pinnae only on upper portion, like the sterile ones but smaller, 10–15 cm × 1–2.5 cm; sporangia covering the whole underside surface of pinnae except for the midrib; paraphyses minute, capitate, with small multi-lobed apical cells, deep castaneous.

Spores trilete, anisopolar with radiosymmetry, rounded triangular, subtriangular or triquete, 40–50(–70) µm × 32–40(–52) µm, the side concave or convex, the angle rounded, the proximal pole flat or conical, the distal pole subhemispherical.

Growth and development *A. aureum* often grows in terrestrial clusters in a tidal water environment with salinity of 0–13 parts per thousand. Individual growth of *A. aureum* in its natural habitat shows that there is an increase of coverage when it grows farther inland. Like other mangrove plants they transpire freely and stomata occupy 30% of the lower surface. It prefers open areas; its growth is inhibited under a dense mangrove forest canopy, but where there is a dense *A. aureum* cover, mangrove forest recovers badly. In mangrove reforestation programmes, *A. aureum* can be a noxious weed.

Other botanical information *A. aureum* may be confused with *A. speciosum* Willd. *A. speciosum*, however, can be distinguished by its smaller size (up to 1.5 m tall), its brownish-green young leaves, its acuminate sterile pinnae, and the dark brown lower surface of fertile pinnae. In the Bogor Botanical Garden (Indonesia), *A. speciosum* has been grown successfully in fresh water for more than 10 years. There are 3 species in the genus, the third one (*A. daneifolium* Langsd. & Fischer) is neotropical. *Acrostichum* L. is also classified as belonging to the family *Adiantaceae*.

Ecology *A. aureum* is a facultative halophyte, commonly found in coastal areas, in open mud flats in brackish swamps, in disturbed or clear cut mangrove forests and along tidal streams. In Muara Pasir, East Kalimantan (Indonesia) it tends to be a noxious weed in the mangrove forest, which is dominated by *Avicennia officinalis* L. Dense growth of *A. aureum* interferes with the natural regeneration of mangrove species. *A. aureum* does not tolerate as much inundation by seawater as does *A. speciosum*; it prefers the drier parts of the mangrove areas and it continues to grow inland, surviving also in fresh water at altitudes up to 100(–300) m. There is one extraordinary record of *A. aureum* growing at 550 m, 400 km inland on highly saline, mineral rich soil next to hot springs. Young plants are often found in sheltered locations on rocky shores, but in such positions they rarely attain any size.

Propagation and planting Natural propagation and regeneration of *A. aureum* is by spores. Vegetative propagation is possible by clump division and by rhizome cuttings.

Husbandry *A. aureum* is not cultivated commercially. Large plants are generally intolerant of disturbance, whereas small specimens will adapt to cultivation readily. Full sunlight and plenty of moisture are required throughout its growth. It is also possible to grow *A. aureum* in pots. A recommended potting mix is a ratio of 1-1-2 of vegetable mould, sand and leaf mould respectively with pH 5.5–6.5.

Genetic resources and breeding No germplasm collections nor breeding programmes are known to exist for *A. aureum*. Because it is a pantropical fern species, often occurring as a weed, there is up to now no danger of extinction.

Prospects *A. aureum* has proved to be useful as a vegetable, for roofing and in traditional medicine. The natural habitats of this fern are facing serious destruction due to the accelerated exploitation of mangrove areas for timber and firewood or conversion of the land for other purposes. Further research towards its domestication, as a means for its conservation, deserves more attention.

Literature |1| Amoroso, V.B., 1990. Ten edible economic ferns of Mindanao. The Philippine Journal of Science 119 (4): 295–313. |2| Bunnag, C., Dhorranintra, B., Limsuvan, S. & Jareoncharsri, P., 1989. Ferns and their allergenic importance: skin and nasal provocation tests to fern spore extract in allergic and non-allergic patients. Annals of Allergy 62(6): 554–558. |3| Holttum, R.E., 1966. A revised flora of Malaya. 2nd Edition. Vol. 2. Ferns of Malaya. Government Printing Office, Singapore. pp. 409–410. |4| Prakash, A.O., Saxena, V., Shukla, S., Tewari, R.K., Mathur, S., Gupta, A., Sharma, S. & Mathur, R., 1985. Anti-implantation activity of some indigenous plants in rats. Acta Europaea Fertilitatis 16(6): 441–448. |5| Sukardjo, S., 1988. Komunitas Acrostichum aureum L. di hutan mangove Avicennia officinalis L. Muara Pasir, Sungai Kandilo, Kalimantan Timur [Community of Acrostichum aureum L. in the Avicennia officinalis L. mangrove forest of Muara Pasir, Sungai Kandilo, East Kalimantan]. Rimba Indonesia 22 (1–2): 59–74.

Dedy Darnaedi & Titien Ngatinem Praptosuwiryo

Adiantum L.

Sp. pl.: 1094 (1753); Gen. pl., ed. 5: 485 (1754).

PTERIDACEAE

$x = 30$ (many aneuploids and polyploids exist); *A. capillus-veneris*: $2n = 60, 120$; *A. caudatum*: $2n = 60, 90, 120$; *A. philippense*: $2n = 60$

Major species and synonyms

- *Adiantum capillus-veneris* L., Sp. pl.: 1096 (1753).
- *Adiantum caudatum* L., Mant. pl.: 308 (1771), synonyms: *A. hirsutum* Bory (1804), *A. ciliatum* Blume (1828), *A. malesianum* Ghatak (1963).
- *Adiantum flabellulatum* L., Sp. pl.: 1095 (1753), synonym: *A. bonii* Christ. (1894).
- *Adiantum philippense* L., Sp. pl.: 1094 (1753), synonym: *A. lunulatum* Burm.f. (1768).

Vernacular names General: maidenhair ferns (En). Chevelure, sieplier (Fr). Indonesia: suplir. Vietnam: chi t[os]c v[eej] n[uwx].

- *A. capillus-veneris*. Venus hair fern, common maidenhair fern (En). Southern maidenhair (Am). Philippines: kulantrillo de Alambre, lettuce de Alambre. Thailand: foen kan dam (central), kut pha (northern), phak waen han (eastern). Vietnam: c[aa]y r[as]ng.
- *A. caudatum*. Slender maidenhair (Am). Indonesia: suplir berekor. Philippines: alambrilong, gubat. Thailand: hang nak bok, tin tukkae (central), kut namkhao (northern). Vietnam: c[aa]y r[ows] den.
- *A. flabellulatum*. Indonesia: paku angin-angin. Vietnam: c[aa]y v[os]t, t[os]c v[eej] n[uwx].
- *A. philippense*. Indonesia: kamuding. Malaysia: paku sisek, paku mega. Philippines: kaikai, kulantrillo, palsik. Thailand: hang chingcha (peninsular), kut hu khwak, hua khwak (southeastern).

Origin and geographic distribution The most primitive representatives of *Adiantum* occur in the Old World tropics but most species are present in the American tropics. It is distributed pantropically with extensions to the subtropics and even temperate regions. The total number of species is disputed, but is in the range of 150–200. In South-East Asia 10–20 species are present. *A. capillus-veneris* is found all over the world in warm temperate and subtropical climates; in the tropics it is less common but is often found cultivated as an ornamental. *A. caudatum* is widely distributed in the Old World tropics from Sri Lanka throughout tropical Asia to the Pacific islands. *A. flabellulatum* occurs from India and southern China throughout South-East Asia to Taiwan and southern Japan. *A. philippense* is distributed throughout the tropics from the Old World. Many *Adiantum* species, including the major species mentioned here, are also widely cultivated as indoor and outdoor ornamentals.

Uses The beautiful habit of *Adiantum* species makes them attractive for indoor (cool climates) and outdoor (warm climates) decorative ornamentals; *A. caudatum* and *A. philippense* particularly are also used in hanging baskets or pots. Most species are also used medicinally. In many European pharmacopoeias the rhizome and leaves of *A. capillus-veneris* are considered antiparasitic, antitussive, expectorant, demulcent, febrifuge, haemostatic, refrigerant, tonic and mildly astringent, and infusions or syrups are recommended in chest disorders, bronchitis, nasal catarrh, laryngitis and to aid detoxification for alcoholics. In Colombia it is used as diaphoretic and emollient as well as for problems of the urinary tract. Externally, it is applied to alleviate insect stings and snake bites. An infusion serves as shampoo against dandruff and other skin problems and is said to promote hair growth. Very young shoots, when still tightly coiled, are eaten as a vegetable. The petioles and rachises of the leaves are sometimes used to make baskets. In South-East Asia *A. caudatum* and *A. philippense* have the same medicinal uses as *A. capillus-veneris* in Europe and a number of *Adiantum* species are used likewise in South America. In the Philippines, the leaves of *A. caudatum* are also used internally against diabetes, cough and fever. Pounded leaves of *A. philippense* are applied for poulticing swellings, whereas a decoction is used to alleviate stomach-ache, colic, dysentry and is considered to be a uterine tonic after childbirth.

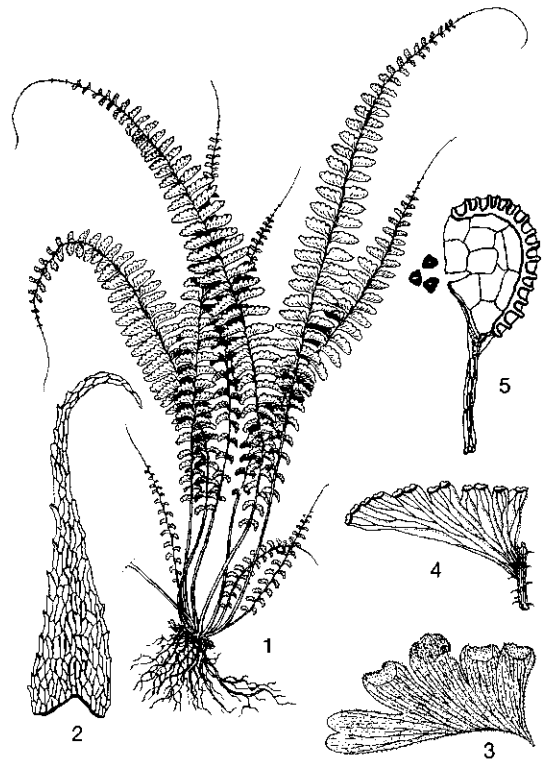
Production and international trade Maidenhair ferns are commonly cultivated commercially and non-commercially all over the world. Trade in northern America, Europe and Australia is believed to reach impressive quantities, but statistics are lacking. In South-East Asia production and trade are on a much smaller scale, mostly locally, both for medicinal and ornamental uses.

Properties In general the Old World species of *Adiantum* are richer in proanthocyanins, simple flavonoids and simple cinnamic acid esters when compared to New World species, which might mean that the New World species are more advanced. *A. capillus-veneris* has an aromatic lily fragrance; some of its constituents (present in all parts) include filicine, filicinal, fernene, β-sitosterol, stigmasterol, gallic acid, capillarine (bitter principle), terpenoids (adiantone), flavonoids (kaempferol, rutin, quercetin), cinnamic esters, amygdalin, saponin, mucilage and tannin. In Europe, the use of *Adiantum* as a drug has been well known since antiquity. It is used to treat various illnesses of the respiratory tract and is taken in the form of tea (infusion) or syrup (extract). Be-

cause of the similarity of the glossy blackish petiole and rachis to pubic hair, the drug was used to promote pubic hair growth and dark hair colour. There are reports of dried maidenhair (used as a herbal medicine) being made impure by the addition of leaves of *Pteridium aquilinum* (L.) Kuhn. Extracts of *A. capillus-veneris* show antimicrobial activity at a concentration of 2 mg/ml against *Bacillus subtilis*, *Candida albicans*, *Candida pseudotropicalis* (synonym: *Candida kefyr*), *Escherichia coli*, *Proteus vulgaris*, *Pseudomonas aeruginosa* and *Staphylococcus aureus*. In *A. capillus-veneris* a volatile oil is present of which both aqueous and alcoholic extracts of 0.02 mg/ml inhibited the growth of *Aspergillus flavus*, *Aspergillus niger*, *Aspergillus fumigatus*, *Bacillus subtilis*, *Corynebacterium ovis*, *Streptococcus pyogenes* and *Trichophyton mentagrophytes*. Wounds created surgically in the thigh of guinea pigs and infected with *Streptococcus pyogenes* healed in 10–14 days when treated with aqueous or alcoholic extracts of the oil; healing took 8 days when the wound was treated with terramycin. The inhibitory effect of the extracts is directly proportional to the concentration of the applied oil. A hypoglycaemic activity of the extract was demonstrated to improve glucose tolerance. The aqueous extract of an unspecified *Adiantum* species significantly inhibited aflatoxin production by *Aspergillus parasiticus* on agricultural commodities such as rice, wheat, maize and groundnuts. Extracts of *A. caudatum* reduced growth and germination of *Alternaria brassicicola* and *Aspergillus niger*. Rhizome extracts were more toxic than leaf extracts. Two triterpenoid constituents of *A. monochlamys* Eaton, neohop-12-ene and adiantane, greatly inhibited Epstein-Barr virus activation induced by the tumour promoter TPA.

Description Terrestrial (rupestral) ferns with shiny black rachises and flabellate ultimate segments. Rhizome creeping to erect, scaly. Leaves monomorphic or nearly so; petiole usually adaxially sulcate, not jointed to the rachis; lamina very variable, simple to pinnately decompound, leaflets dimidiate (half subcircular) or flabellate, herbaceous to papyraceous, glabrous or hirsute, veins usually free. Sori along veins on inner face of reflexed marginal flaps (which thus serve as indusia and also bear the sporangia); annulus of 13–30 thickened cells. Spores trilete, smooth, tetrahedral-globose and with prominent angles, 25–50 µm in diameter.

- *A. capillus-veneris*. Rhizome short, creeping, densely covered with narrow scales 3 mm long, brown. Petiole 3–8 cm long, lustrous blackish-purple as is the rachis; lamina bipinnate, in outline oblong-subdeltoid, 5–20 cm × 3–5 cm, with an apical leaflet, 3–4 pairs of lobed upper pinnae and usually 2–4 pairs of basal pinnate pinnae; basal pinnate pinnae 3–4 cm long, also with a terminal and 1–4 pairs of smaller, sometimes fan-shaped, stalked pinnules; lobed upper pinnae petiolate, subquadrangular, up to 1.5 cm × 1 cm, basal margins meeting at about a right angle, distal margin lobed up to halfway into 4 or 5 lobes which again are shallowly lobed; veins dichotomous, distinct, transparent but basal ones blackish. Sori round or a little elongate, occupying less than the full width of the lobe.
- *A. caudatum*. Rhizome short, erect, scaly, bearing a dense tuft of leaves; scales sublinear, 4–5 mm long, brown with pale edges. Petiole 4–15 cm long, glossy purplish-black, densely covered with stiff, spreading, dark reddish hairs; lamina simply pinnate, linear-lanceolate in outline, 10–35 cm × 2–4 cm, apex without pinnae and long flagellate (flagellum may start rooting),



Adianthum caudatum L. – 1, habit; 2, rhizome scale (much enlarged); 3, leaflet with false indusia; 4, venation of leaflet; 5, sporangium and spores.

usually densely hairy, middle pinnae largest, lower ones usually slightly smaller, upper ones gradually becoming much smaller; pinnae subsessile, parallelogram-shaped, up to 2 cm × 1 cm, distal and lateral margins deeply lobed, lobes lobed again; veins conspicuous on the upper surface, radiating from the very short stalk. Sori on the apices of the lobes, the reflexed flaps almost circular or somewhat elongate, hairy.

- *A. flabellulatum*. Rhizome short, erect or ascending (rarely creeping), scaly, bearing a dense tuft of leaves; scales sublinear, about 8 mm long, shiny yellow-brown. Petiole 10–30(–50) cm long, blackish; lamina pedate or tripinnate with a few pairs of bipinnate pinnae, in outline up to 20 cm × 25 cm; upper pinnae and pinnules of the large pinnae similar, pinnate with more than 10 pairs of leaflets, linear, about 10 cm × 2 cm; leaflets fan-shaped, distinctly stalked, 2 basal margins forming a broad cuneate base, up to 15 mm × 13 mm, distal margin round, serrate, glabrous, veins not raised; fertile leaflets usually not longer than 1 cm. Sori round to elongate, up to 5 mm long.
- *A. philippense*. Rhizome short, suberect, scaly at the apex; scales sublinear, up to 3 mm long, brownish-black. Petiole up to 10(–25) cm long, bright brown to black; lamina simply pinnate, in outline 15–30 cm × 10 cm, usually bearing 8–15 alternate pinnae and an abnormal terminal leaflet or with prolonged, leafless rachis that may start rooting at the tip when in contact with soil; stalks of pinnae up to 2 cm long; leaflets crescent-shaped, 1–5 cm × 0.5–1.5 cm, base subcuneate, outer margin an almost even curve, entire, crispate or lobed, thin, glabrous, veins fine and slightly raised, many times forked. Sori with reflexed, elongate soral flaps 5–8(–15) mm long; sporangia small, annulus about 18 thickened cells. Spores tetrahedral.

Growth and development About 3 months after sowing, the spores of *Adiantum* germinate into prothalli. The gametophyte is cordate, symmetrical, with a thickened central cushion and thin borders. Antheridia are mostly in the basal region among rhizoids, the archegonia more apical on the thickened portion. After fertilization, young sporophytes develop in 4–6 months and the fern fully grown by about 12 months. After 2–3 years the fern starts producing spores.

Other botanical information *Adiantum* ferns are easily recognized by the dark polished petioles, the absence of a conspicuous midvein on the leaflets or segments and the false indusium formed by a fold of the leaf margin bearing the sporangia on its underside. *Adiantum* is an old and morphologically isolated genus. It has been variously classified, e.g. in *Adiantaceae* (Holttum and many authors), *Parkeriaceae* (Flora of Thailand), *Polypodiaceae* (Fern flora of Java), *Pteridaceae* (Kubitzki, followed here). In the *Pteridaceae*, it is classified in the subfamily *Adiantoideae* with *Adiantum* as the only genus. Within the genus various groupings have been proposed (based on anatomy, morphology, and chemistry), but a thorough, up-to-date, worldwide revision, incorporating all findings, is missing.

- *A. capillus-veneris*. Because of its wide distribution, numerous forms have developed, with variations in leaf form, size and even chemical content. Many cultivars have been distinguished for ornamental use, particularly in the United States and Great Britain. Some well-known cultivars are: 'Fimbriatum', Imbricatum', 'Magnificum', 'Mairisii' and 'Scintilla'. The North American *A. pedatum* L. is often used as a substitute for its medicinal uses.
- *A. caudatum*. This species is for tropical South-East Asia what *A. capillus-veneris* is for the non-tropics. In the past *A. caudatum* was considered a very variable species; variations were sometimes distinguished as varieties and cultivars were developed for ornamental use. In a narrower species concept, the *A. caudatum* complex is subdivided into 4 species, which can be distinguished as follows (the distribution and ecological requirements are similar for all):
  - *A. caudatum*: pinnae sessile, rachis hairy, pinnae hairy, lobed more than halfway towards the costa; veins prominent with white setose hairs; indusial flaps almost circular;
  - *A. zollingeri* Mett. ex Kuhn (synonym: *A. caudatum* var. *subglabrum* Holttum): pinnae sessile, rachis hairy, pinnae glabrous, lobed less than halfway towards the costa; veins not prominent, brown hairy; indusial flaps broader than long;
  - *A. edgeworthii* Hook. (synonym: *A. caudatum* var. *edgeworthii* (Hook.) Bedd.): pinnae sessile with completely glabrous rachis;
  - *A. soboliferum* Wall. ex Hook. (synonym: *A. caudatum* var. *soboliferum* Bedd.): pinnae stalked, glabrous, crescent-shaped, longer than 2 cm, petiole and rachis distinctly winged.
- *A. flabellulatum*. It is closely related to the more common South-East Asian *A. stenochlamys* Bak. which has distinctly pinnate leaves with more widely spaced leaflets that are almost symmetrical.

– *A. philippense*. Owing to its wide range this species is very variable; in deep shade leaflets become larger and thinner, in exposed situations plants can become dwarfed. It is closely related to *A. soboliferum*, which has a distinctly winged petiole and rachis. Specimens from China ($2n$ = 60) have (16) 32 spores in each sporangium instead of the usual 64 and may be agamosporous diploids.

A. tenerum Swartz (brittle maidenhair) is one of the non-indigenous *Adiantum* species most commonly cultivated (that often escapes) in South-East Asia as an ornamental with numerous attractive cultivars. In tropical America, where it originates, it is also used medicinally.

In the American continent *A. raddianum* Presl is the most important ornamental species of which numerous cultivars have been developed. In India, China and Nepal *A. venustum* D. Don is an important ornamental.

Ecology All maidenhair ferns prefer light shade and ample moisture. *A. capillus-veneris* prefers a subtropical and warm temperate climate and often grows near streams in spray and in light shade at low altitudes. It is not well suited for per-humid tropical climates, where it can survive in exposed but moist locations on walls but where it does not reproduce freely. It can survive temperatures as low as –2°C, but growth is then completely seasonal. Of the cultivated species *A. capillus-veneris* is perhaps the most adaptable, with cultivars for different ecological circumstances. *A. caudatum* is most suited to drier and more seasonal climates, on well-drained soils such as limestone, from sea-level up to 1200 m altitude. The pinnae are sometimes deciduous and in very dry conditions the leaves curl up. *A. flabellulatum* prefers humus-rich soils in rather open forest up to 1500 m altitude. *A. philippense* grows in almost the same habitat as *A. caudatum*, but is more delicate. It grows from sea-level up to 1000(–1400) m on rather dry slopes or on muddy crevices of rocks in light shade or sometimes on the humus-rich floor of dense montane forest. Aboveground parts disappear in the dry months.

Propagation and planting *Adiantum* can be propagated by spores, rhizome parts and clump division. When sowing spores, the planting medium and container should be sterilized before use. Moist fine compost or sphagnum alternated with layers of wet crushed brick or gravel are suitable. The container is covered with glass or polythene sheeting, kept in the shade with a temperature between 18–24°C, and regularly sprayed with water. Often evaporation from the container itself is sufficient for germination. After 3 months the container will have become very crowded with prothalli. The prothalli should be moved to another container with the same medium at a spacing of about 2.5 cm. After 4–6 months young ferns will be 5–10 cm tall and should be transplanted to another container. By 10–12 months the ferns are fully developed. Propagation by clump division is easier and faster. The clump is taken out of the container, cut with a sharp knife and the new sections can be grown as separate plants. *Adiantum* grows well on soils rich in organic matter, such as peat moss or leaf mould mixed with coarse sand or loam, with pH 6.5–7.

Husbandry *Adiantum* grows well on sites free from wind and drying drafts since the foliage is easily desiccated or damaged by air movement. A relative humidity of 50–80% is preferred. A fine spray or mist of water applied on warm dry days will help to protect the leaves against burning but good drainage is important as *Adiantum* ferns do not withstand waterlogging. Regular fertilizer application is recommended (for example every 2–3 weeks with a balanced NPK mixture). Old leaves should be removed regularly to provide space for new ones and to allow some light to penetrate the inner part of the clump. During winter or the resting season all leaves can be cut back and the plants enter a resting period until the new growing season.

Diseases and pests *Adiantum* is particularly susceptible to attacks by snails, slugs, pill bugs and sow bugs. Persistent use of baits and poisons offers protection.

Harvesting For ornamental use, *Adiantum* plants grown from spores can be traded about one year after sowing. Plant parts are harvested in the growing season whenever needed for medicinal uses.

Handling after harvest For medicinal use harvested leaves and rhizomes of *Adiantum* can be dried and stored.

Genetic resources and breeding There are no known germplasm collections of *Adiantum*, but commercial growers keep their stock of cultivars and various interesting forms. Some breeding for improved ornamental cultivars is carried out in the United States.

Prospects *Adiantum* is a popular ornamental all over the world. It is worthwhile investigating the possibilities for large-scale cultivation of locally available species and cultivars in South-East Asia. The medicinal properties of the South-East

Asian *Adiantum* need further research.

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J.J. Afriastini

Ampelopteris prolifera (Retz.) Copel.

Gen. fil.: 144 (1947).
THELYPTERIDACEAE
$2n = 72$

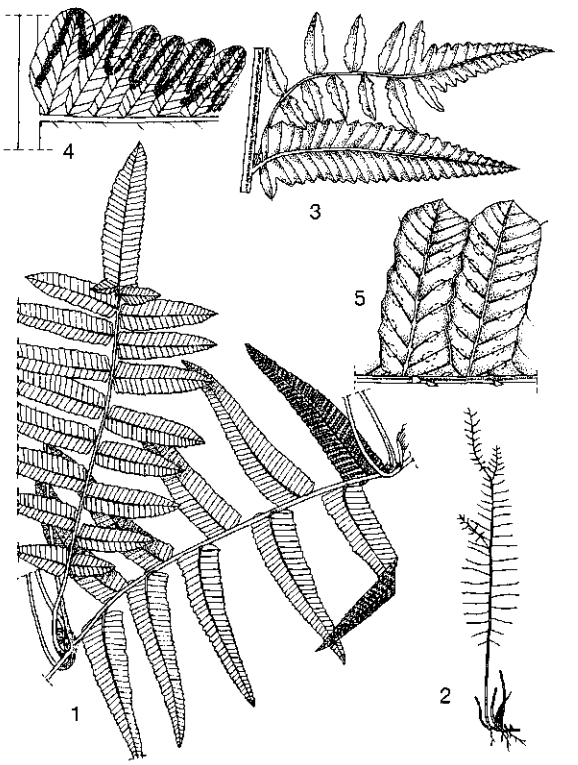
Synonyms *Hemionitis prolifera* Retz. (1791), *Goniopteris prolifera* (Retz.) Presl (1836), *Ampelopteris elegans* Kunze (1848).

Origin and geographic distribution *A. prolifera* is widely distributed in the Old World tropics, from West Africa and tropical mainland Asia to north-eastern Australia (to 30°S) and New Caledonia. It occurs throughout South-East Asia, but has not often been collected; it is absent in southern Peninsular Malaysia.

Uses Although not often collected, young leaves of *A. prolifera* are eaten as a raw or cooked vegetable, especially in India, where they are considered inferior in taste to those of the more commonly eaten *Diplazium esculentum* (Retz.) Swartz. In traditional medicine in India, the leaves of *A. prolifera* are used as a laxative and in Tanzania the leaf-sap is added to a mixture which is drunk to treat meningitis and encephalitis.

Properties A leaf extract of *A. prolifera* showed antiviral activity against cucumber mosaic virus.

Description A large, scrambling (2–4 m long), usually sterile fern with proliferous buds scattered along the leaf rachis which develop into new plants. Rhizome short-creeping, 4–10 mm in diameter. Leaves approximate, arching; proliferous buds common in the axils of the pinnae; petiole 12–50 cm long, pale brown, glabrous; lamina narrowly lanceolate to narrowly elliptical, 27–150 cm × 9–26 cm, pinnate, apex indeterminate, papery, both surfaces glabrous; leaves from plants formed by proliferation from buds much smaller, usually



Ampelopteris prolifera (Retz.) Copel. – 1, habit of a leaf part; 2, schematic view habit plant; 3, young plant proliferating from axil of pinna; 4, pinna-lobes with sori; 5, pinna-lobes showing venation.

with pinna-like terminal lamina; pinnae numerous, the basal pairs distant, the distal ones more closely spaced and smaller, the basal 3–4 pairs gradually reducing in size; rachis with forked hairs or glabrous; midrib above with short hairs, beneath likewise veins very sparsely set with minute hairs, becoming glabrous in older leaves, midrib also bearing a few ovate or peltate, ciliate scales; buds producing long secondary leaves common in the axils of the pinnae; pinnae oblong, 10–15(–20) cm × 1.5–2 cm, sometimes fertile from a size of 3.5 cm × 0.8 cm, base truncate to subcordate, subsessile, the basal lobe often overlapping the rachis, margin crenate, often very shallowly and irregularly so, lobed to a depth of 2 mm, apex acute to acuminate, rather evenly attenuate; secondary veins numerous, 3–4 mm apart, tertiairy veins per pinna lobe up to 12 pairs, 4–7 pairs of anastomosing veins below the shallow sinus uniting alternately to form a zigzag intermediate excurrent vein. Sori circular to elongate, 4–12 on each side of the primary veins, on apical parts of the veins, without indusium, with orange capitate paraphyses, at maturity uniting with adjacent sori. Spores closely and irregularly spinulose.

Other botanical information There is no generally accepted scientific name for this fern because specialists disagree about the delimitation of genera within the large family *Thelypteridaceae*. In addition to those mentioned under the synonyms, the species has also been named in the genera *Cyclosorus* Link, *Dryopteris* Adans., *Meniscium* Schreb., *Phegopteris* (Presl) Fée, *Polypodium* L. and *Thelypteris* Schmid. Sometimes the monotypic genus *Ampelopteris* Kunze is considered as a subgenus in the larger genera *Cyclosorus* or *Dryopteris*. *A. prolifera* is distinguished from other species with similar venation pattern by its adventitious leaf buds able to produce new plants (as reflected in the specific name) and its elongate sori without indusium.

Ecology *A. prolifera* grows mostly in full sunlight in freshwater swamps at low altitudes, usually below 300 m but occurring as high as 1000 m, or close to the edge of rivers where the rhizomes often root in the water. The proliferous stems may grow in the water. The freely proliferating buds result in effective local spread and it is significant that fertile leaves are rarely recorded (only in dry climates). It has been suggested that the plant spreads along river systems by flood waters breaking off leaves and depositing them on the river banks further downstream.

Genetic resources and breeding Neither germplasm collections nor breeding programmes are known to exist for *A. prolifera*. Since it is widespread and rather common, it does not seem in danger of extinction.

Prospects The use of the leaves of *A. prolifera* as a vegetable would justifies research on the nutritional value and cultivation requirements. The cultivation of the fern does not seem to present big problems because the proliferous buds make vegetative propagation easy.

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W. P. de Winter

Amphineuron terminans (Hook.) Holttum

Amer. Fern Journ. 63: 82 (1973).

THELYPTERIDACEAE

$2n = 144$ (tetraploid)

Synonyms *Nephrodium terminans* Hook. (1862), *Cyclosorus interruptus* sensu Holttum (1955), *Thelypteris terminans* (Hook.) Tagawa & K. Iwatsuki (1975).

Vernacular names Philippines: lokdo.

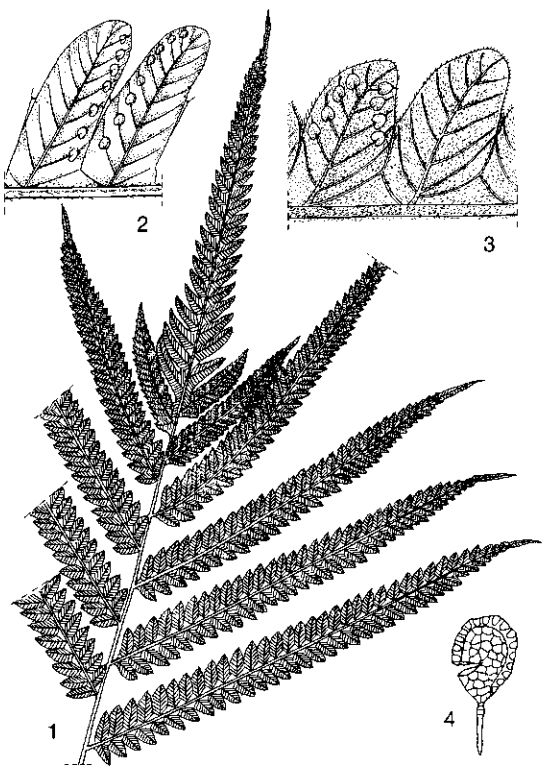
Origin and geographic distribution *A. terminans* is distributed from southern India, Sri Lanka and southern China (Hainan, Macao) throughout South-East Asia to Australia (Queensland to 18°S). Sporadically, it has also been found in Central Africa and Fernando Poo.

Uses In some parts of the Philippines, the stems of *A. terminans* are crushed and the vascular

strands extracted for use as decorative weaves in baskets.

Properties The vascular strands of *A. terminans* which are used for decorative weaves in baskets are of inferior quality and are not strong.

Description Rhizome long-creeping, 5 mm in diameter (dry); scales narrow, setiferous, up to 6 mm long, brown. Leaves tufted, pinnately compound; petiole up to 50 cm long, flushed dull reddish, minutely hairy, glabrescent abaxially, basal scales about 8 mm long; lamina subelliptical in outline, up to about 80 cm × 40 cm, pinnate, apex similar to the lateral pinnae or somewhat broadened and few lobed at the base; abaxial surface of costae, costules and veins bearing short acicular hairs, longer hairs usually lacking; subsessile, almost spherical, rather pale glandular hairs abundant on distal veins, usually few and smaller on lower veins; very short acicular hairs often present between veins; adaxial surface of costae bearing antrorse pale acicular hairs, similar hairs scattered on costules and veins, some hairs also on surfaces in exposed plants; copious, small, yellow glands present along veins near segment margins; up to 25 pairs of pinnae; rachis bearing short acicular hairs; pinnae oblique, always distinctly narrowed at their bases, 17–20(–29) cm × 1.7 cm, if longer not more than 2 cm wide; basal pair somewhat reduced, rarely very small; base of middle pinnae broadly cuneate to truncate, lobed 1/3 towards costa or less deeply, apex acuminate; lobes as wide as long or wider with forward pointing tip, apex broad asymmetrical; venation costules 4–5 mm apart, usually at a less than 60° angle to costa; veins 6–9 pairs, basal pairs spreading at a broad angle to their costules and always anastomosing, uniting to form a rather long excurrent vein to the sinus; next veins very oblique; 1 or 2 ending beside the sinus-membrane. Sori orbicular, supramedial, confined to the upper veins, thus occupying only the lobes of the pinnae leaving a broad sterile zone on either side of the costa; indusium reniform, persistent, setulose , large, thin, often with some short acicular hairs and a few small, yellow, glandular hairs which are not marginal. Spores dark, irregularly rugose or with irregular thick and more or less branched ridges.



Amphineuron terminans (Hook.) Holttum – 1, habit leaf part; 2, 3, pinnae-lobes; 4, sporangium.

Growth and development The gametophyte of *A. terminans* is symmetrically cordate, with on all parts unicellular chlorophyllous hairs with swollen, rounded tips that become wax-encrusted.

Other botanical information The family *Thelypteridaceae* has no close living relatives and its affinities are not known for certain. Some authors have argued that the family is closest to the genus *Cyathea* J.E. Smith because of several common characters. Others, however, have pointed to other contradictory characteristics. Cladistic research based on morphological as well as molecular characters strongly support the relationship with the polypodioid ferns. The taxonomy of the family is confusing because there are many different opinions about the number and delimitation of genera. Here the Flora Malesiana (Holttum) view is followed, in which the family is subdivided into 25 genera (for the Old World species). Often the differences between genera are vague and include characters of minute glands and hairs, requiring 30 × magnification or greater for observation. Moreover, hybrids between genera seem to exist (having intermediate characters of the genera), which would favour a much wider genus concept. *Amphineuron* Holttum comprises about 12 species, all occurring in South-East Asia; other authors include *Amphineuron* in *Cyclosorus* Link or in *Thelypteris* Schmidel. *Amphineuron* is closely related to the genus *Christella* Léveillé (about 50 species, distributed in tropical Asia and Africa).

The two most widely distributed *Amphineuron* species, *A. terminans* and *A. opulentum* (Kaulf.) Holttum, are both variable and have a complex nomenclatural and taxonomic history. They probably also hybridize (possible examples have been found in Thailand). *A. opulentum* seems to be adapted to semi-exposed locations among rocks, especially in areas with a dry season; it can be distinguished from *A. terminans* by its shorter creeping rhizome and its pinnae that are lobed more than halfway to the costa.

Ecology *A. terminans* is a terrestrial fern, common in thickets on hillsides, in localized wet patches along river banks and in valleys at low and medium altitudes. It occurs abundantly in areas with a distinct dry season, in rather open but not too dry locations.

Propagation and planting Although *A. terminans* is hardly cultivated commercially, it can be propagated by spores, and more easily by rhizome cuttings. In natural habitats it spreads quickly due to its long creeping rhizomes. The plants can be grown in large pots but are best suited to culture in the field.

Genetic resources and breeding Its wide distribution and abundance in certain habitats more or less guarantees the survival of *A. terminans*, for which neither germplasm collections nor breeding programmes are known to exist.

Prospects It is not expected that *A. terminans* will become more important in the future; possibly its ornamental value deserves better investigation.

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W. P. de Winter

Angiopteris evecta (G. Forst.) Hoffm.

Commentat. Soc. Regiae Sci. Gott. 12: 29, t. 5 (1796).

MARATTIACEAE

$2n = 80, 160$

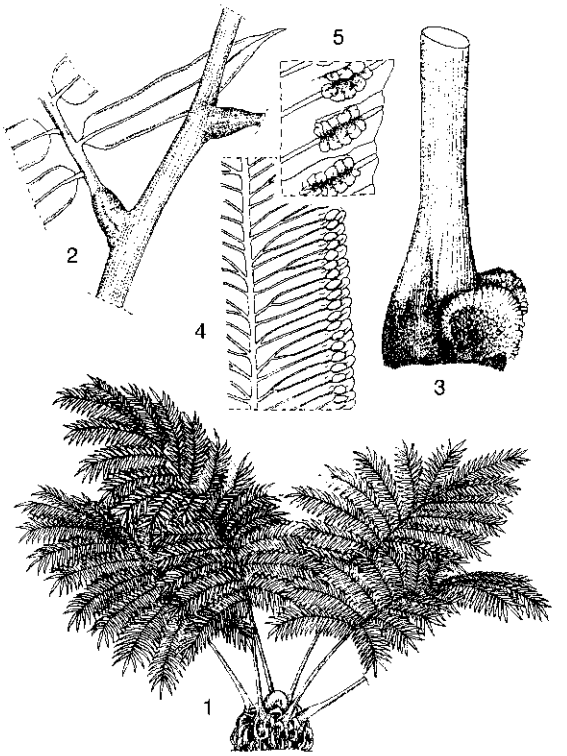
Synonyms *Polypodium evectum* G. Forst. (1786), *Angiopteris palmiformis* (Cav.) C. Chr. (1937).

Vernacular names King fern, giant fern, elephant fern (En, Am). Indonesia: paku gajah (general), sibakkat-laggai (Siberut). Malaysia: paku gajah. Papua New Guinea: faflako (Wantipi, Sepik), sagonefos. Philippines: pakong kalabaw (Tagalog), salagisog, andawigay (Binukid). Singapore: paku gajah. Thailand: wan kip raet (general), wan kip ma, kip ma lom (northern).

Origin and geographic distribution *A. evecta* is widespread in the Old World tropics from Madagascar and tropical Asia, throughout South-East Asia, to Australia and Polynesia. Elsewhere it is sometimes naturalized, e.g. in Jamaica and Hawaii.

Uses The starchy stipules of *A. evecta* have been eaten in times of starvation in Papua New Guinea and have been used for brewing alcohol, the young leaves are eaten in Ambon and croziers as an ingredient of stew in the Philippines. Many traditional medicinal uses are known: a decoction of the rhizome has been used to arrest the discharge of blood after a miscarriage and rhizome boiled with green beans to treat beriberi. In Siberut (Indonesia) a decoction of the leaves of *A. evecta* and *Diplazium esculentum* (Retz.) Swartz is given to pregnant women to treat backache, but to treat heavy backache a concoction is made of the root of *A. evecta*, the inflorescence of *Etlingera punicea* (Roxb.) R.M. Smith and *Hedychium coronarium* Koenig, and the leaves of *Kaempferia galanga* L. The rhizome is chewed together with ginger and betel to treat spitting blood, especially if caused by poisoning. The pounded stem is used as an ingredient for cough medicine and the stipules as a poultice for abdominal pain. In Papua New Guinea, leaves are bound to fractured limbs to aid healing and the mucilage from the leaves is also applied to the body to reduce high fevers; fresh leaves are used as a poultice for stomachache. In the Philippines pulverized young tender leaves are used as a poultice for swellings. *A. evecta* is cultivated as an ornamental in South-East Asia.

Production and international trade *A. evecta* is not cultivated commercially and no interna-



Angiopteris evecta (G. Forst.) Hoffm. – 1, habit; 2, main rachis with swollen bases of the pinnae; 3, petiole base with stipules; 4, part of pinnule showing venation and recurrent veins; 5, sori.

tional trade exists. Plants grow wild or as an ornamental in domestic gardens.

Properties No nutritional analysis of *A. evecta* is known; the stipules contain starch grains.

Description A fleshy, robust, terrestrial fern, developing a stout stem and tall bipinnate leaves (up to 6 m long). Rhizome short, fleshy, massive, erect, forming a clump up to 1 m tall and 0.5(–1) m in diameter, partly concealed by persistent fleshy stipules of previous and present leaves. Leaves clustered at rhizome apex; petiole about 1/3 of the leaf length, 1–1.5 m × 5 cm or more, base swollen, with a pair of fleshy, rounded stipules 5 cm long and 7 cm wide, dark green with scattered whitish streaks, glabrous but when young more or less covered with appressed, soft, brown, linear scales and hairs that are soon deciduous; blade arching, up to 6 m × 2 m, usually bipinnate, upper side dark green, slightly paler at underside; rachis green, sparsely and deciduously scaly like the petiole, especially on the underside; smaller rachides narrowly alate distally; stipes of pinnae and pinnules swollen at the base; pinnae oblong-oblanceolate in outline, 1 m long or longer, midrib with 3 grooves above, terete below; pinnules usually 30–36 on a side, 2–3 cm apart, linear-oblong, up to 20 cm × 2.5 cm, inequilateral at the base, margin serrate with a small, blunt tooth at each vein, apex acuminate-attenuate and serrulate; veins simple or forked, raised and translucent; recurrent veins slender, usually conspicuous between and parallel with main lateral veins. Sori short, submarginal in an irregular line 0.5–1.5 mm from the edge, on lateral veins, composed of a double row of 3–7 sporangia that dehisce by vertical slits to release several thousands of spores per sporangium; receptacular hairs branched, usually conspicuous. Spores trilete, globose, the surface low tuberculate to rugate.

Growth and development A germinating spore of *A. evecta* produces a flat, large, glabrous, dark green gametophyte (prothallus) up to several cm long and resembling an anthocerotoid liverwort. The gametophyte is mycorrhizal and assumed to be as slow growing and long-lived in the wild as it is in cultivation. The young fern embryo (sporophyte) emerges through the dorsal surface of the gametophyte. The first leaves borne by the sporophyte are fan-shaped, later ones are pinnate, mature leaves are bipinnate. The leaves are long-lived. The degree of pinnation may be affected by environmental factors and varies within a leaf or between leaves. Immature leaves often bear sporangia. Plants are long-lived, e.g. one individual cultivated in the Bogor Botanical Garden (Indonesia) is over 50 years old.

Other botanical information For *Angiopteris* Hoffm. about 200 species have been described (including for example in South-East Asia, *A. amboinensis* de Vriese, *A. angustifolia* C. Presl, *A. ceracea* Alderw., *A. lygodiifolia* Rosenst., *A. palmiformis* (Cav.) C. Chr.), but the specific classification is still in confusion. Some authors consider all described species as variations of only one species *A. evecta*. The general characters of all so-called species are very much alike but they differ in details. The original *A. evecta* was found in Tahiti. In South-East Asia most specimens belong to *A. evecta*, with pinnules usually 2.5 cm wide and the recurrent veins not translucent beyond the sori. Specimens with pinnules about 1.5 cm wide and recurrent veins translucent almost to the midrib of the pinnule have been classified as *A. angustifolia* Presl which is commonly considered as a distinct species growing particularly in mountainous regions of over 1200 m altitude. The 'recurrent

veins' are lines which run from the margin between the true veins, starting in the sinus between two marginal teeth; they are often translucent; their structure is the same as that of the edge of the leaflet and possibly they indicate that once *Angiopteris* had more finely divided leaves but the finer divisions have joined together, the edge-characters persisting in the junctions. Plants with dense scales borne on podia on the petiole, or with simply pinnate leaves, or much broader pinnules, are referred to other species. Sterile plants of the closely related genus *Marattia* Swartz may be confused with *Angiopteris*.

Ecology *A. evecta* is a plant of wet tropical and subtropical primary and secondary forests. It often occurs on shady stream and river banks or steep clay slopes, along trails and edges of open areas in the forest, from sea-level up to 1200 m altitude. Introduced in gardens outside its natural distribution area, *A. evecta* is known to escape easily and grows from spores transported over large distances (over 50 km) when the climate is favourable. On the Hawaiian island Maui, the spores were dispersed by wind to several nature reserves and it is feared that the fern may soon spread to new areas and occupy niches formerly occupied by endemic Hawaiian ferns on all the islands.

Propagation and planting Propagation of *A. evecta* from spores is slow. Vegetative propagation through the growth of adventitious buds on the stipules is very effective and may be seen in wild plants whose stipules have been damaged by foraging pigs. Plantlets developing from the swollen leaf bases can be removed and planted separately in loamy soil, rich in humus. Portions of the stipule placed with the cut side down on soil or compost and kept damp, will eventually sprout.

Husbandry *A. evecta* is not cultivated commercially, but it is a handsome and impressive garden ornamental. It tolerates warm to cool conditions, but should not be exposed directly to the sun. Leaves droop dramatically under drought stress and the fern does not tolerate dry conditions. Adequate water and humidity appear more important than shade.

Diseases and pests *A. evecta* grown in a greenhouse sometimes suffers from southern blight by *Corticium rolffsii*. A gall mite causes a kind of erineum of a callus nature on the underside of the leaves.

Genetic resources and breeding Neither germplasm collections nor breeding programmes are known for *A. evecta*.

Prospects The medicinal value of parts of *A. evecta* that are used in traditional medicine may merit further pharmaceutical investigation. The use of the starch in the stipules for famine food or brewing alcohol has apparently been superseded by the availability of better sources of starch. The prospects for ornamental use of *A. evecta* are good.

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W. P. de Winter & P.C.M. Jansen

Asplenium L.

Sp. pl.: 1078 (1753); Gen. pl., ed. 5: 485 (1754).
ASPLENIACEAE
$x = 36$; ploidy level of species varies from diploid to 16-ploid

Major species and synonyms

– *Asplenium nidus* L., Sp. pl.: 1079 (1753), synonyms: *Neottopteris nidus* (L.) J. Smith (1842), *Thamnopteris nidus* (L.) Presl (1849), *A. musifolium* J. Smith ex Mett. (1859).

Vernacular names General: spleenwort (En). Doradille (Fr).

– *A. nidus*. Bird's nest fern (En). Indonesia: pakis sarang burung (Indonesian), lokot (Kalimantan), kadaka (Sundanese). Malaysia: daun semun, paku langsuyar, paku pandan. Singapore: rumah langsuyar (Malay). Philippines: pugad-lauin, pakpak-lauin (Tagalog), dapong babae. Thailand: kaprok hang sing, kaprok hua long (south-eastern), katae tai hin (north-eastern). Vietnam: rang be, t[oor] chim.

Origin and geographic distribution There are more than 700 known species of *Asplenium* and the total number is increasing steadily. They are distributed all over the world but the majority are found in the tropics and warm temperate regions (about 30% in the neotropics, 22% in Africa, 33% in Asia, 10% in the Pacific and Australia, 5% in Europe). In South-East Asia 40–50 species occur (e.g. about 25 in Java, 25 in Peninsular Malaysia, 35 in Borneo, 40 in the Philippines, 40 in Indo-China and 35 in Thailand). *A. nidus* occurs throughout the Old World tropics, from East Africa through India, Sri Lanka, throughout South-East Asia to Taiwan, Australia, Tahiti and Hawaii.

Uses Many *Asplenium* ferns are used mainly as ornamentals. Particularly well known are the bird's nest ferns:

- *A. antiquum* Makino in Okinawa and Ryukyu Islands;
- *A. australasicum* (J. Smith) Hook. in Australia and New Zealand;
- *A. nidus* pantropically and
- *A. phyllitidis* D. Don in South-East Asia.

Many more species are used or have potential as ornamentals, e.g.:

- *A. bulbiferum* Forst. f., mother fern, a viviparous fern of Australia and New Zealand with finely dissected leaves;
- *A. ceterach* L. (synonym: *Ceterach officinarum* Willd.), the rust-back fern of the northern and western Mediterranean;
- *A. longissimum* Blume from Indo-China to western Malesia;
- *A. macrophyllum* Swartz from East Africa to Polynesia, including South-East Asia;
- *A. marinum* L., known as sea spleenwort in Europe;
- *A. scolopendrium* L. (synonym: *Phyllitis scolopendrium* (L.) Newman) known as hart's-tongue fern in Europe and the United States and of which numerous cultivars exist;
- *A. trichomanes* L., the maidenhair spleenwort, a temperate-climate species with numerous cultivars;
- *A. viviparum* C.B. Presl from Mauritius.

In the Philippines, *A. nidus*, in addition to being an important ornamental, is also used for orchid potting.

Many *Asplenium* species are also used medicinally. The Latin name 'asplenium' and the English vernacular 'spleenwort' refer to their supposed curative properties for spleen complaints. In Malaysia *A. nidus* is traditionally used to improve hair growth by frequent washing of the hair with a decoction of a mixture of ground leaves and coconut milk; Sakai women take a decoction or infusion of the plant in northern Pahang to ease labour pain and in northern Perak against fever. In Malaysia *A. nidus* is also believed to be the home of the ghosts of women who died during childbirth ('langsuyar'). In the Philippines *A. nidus* is thought to have depurative and sedative properties. In Vanuatu young *A. nidus* leaves are used as a contraceptive; two young, still curled leaves (croziers) are eaten in the morning just after menstruation. To reverse sterility, 300 ml juice of leaves of *Hemigraphis reptans* (G. Forst.) T. Anderson ex Hemsley (*Acanthaceae*) should be drunk for 2 days. Modern herbalists recommend *A. scolopendrium* as a diuretic and expectorant, and to treat obstructions of the liver and spleen. Several other medicinal species are *A. adiantum-nigrum* L., *A. ceterach* L., *A. falcatum* Lamk, *A. macrophyllum* Swartz, *A. polyodon* Forst.f. and *A. trichomanes* L. (anthelmintic, emetic, diuretic, laxative and to treat ophthalmia, jaundice and diseases of the spleen). In India *A. trichomanes* is smoked to get rid of head cold whereas *A. ruta-muraria* L. is used to cure rickets. *A. monanthes* L. is reported as a diaphoretic in Peru and Colombia. In North Africa and India (Madras), the rhizome of *A. falcatum* is used to treat prolonged malaria and in Venezuela *A. auritum* Swartz and other aspleniums are used to alleviate fevers. *A. serratum* L. is used in Colombia to treat liver problems. Several species are used in Chinese medicine: *A. adiantoides* L., *A. incisum* Thunb., *A. nidus*, *A. sampsoni* Hance, *A. scolopendrium*, and *A. yoshinagae* Makino.

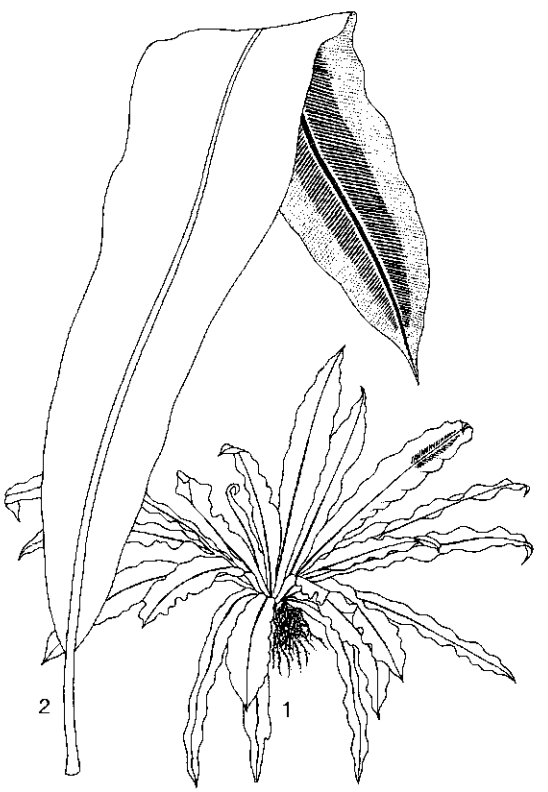
The young curled leaves (croziers) of *A. nidus* and several other *Asplenium* species are eaten as a vegetable (e.g. *A. affine* Swartz in Papua New Guinea). In the inland areas of New Guinea *A. acrobryum* Christ is used as a source of salt and is known as the 'New Guinea salt fern'. In certain hill regions of Uttar Pradesh (India), *A. polypodioides*, known as 'lingura' or 'kothira', is eaten as a rainy season vegetable. *Asplenium* leaves are chewed in Peru as a substitute for coca. The midrib of *A. nidus* was used in Hawaii to decorate woven mats.

Production and international trade Most *Asplenium* ferns are only locally used. The cultivated ornamental species probably account worldwide for a considerable amount of production and trade, but statistics are not available.

Properties In-vitro tests of *A. nidus* extracts at

concentrations of 2.5 mg/ml demonstrated oxytoxic activity on isolated rat uterus. In the Philippines histochemical tests showed the presence of alkaloids, tannin and oxalic acid in the leaves of *A. nidus*. In older literature *A. nidus* is mentioned as a source of salt in inland areas of Papua New Guinea. Later investigations made it clear that the source is not *A. nidus* but a closely related group of other ferns, collectively named the *A. acrobryum* complex. There seems to be no obvious chemical reason why only this complex is used in preference to *A. nidus*, as the salt productions are comparable, consisting mainly of potassium, calcium and chloride.

Description Terrestrial, climbing or epiphytic ferns; rhizome creeping or erect, scales usually small, clathrate, dark. Leaves simple, pinnate or more finely dissected, mostly less then 1 m long; petiole often shiny black, grooved above, with 2 vascular strands at the base which unite upwards into a single 4-armed strand; lamina usually with grooved rachis and free veins. Sori usually rather long, along and on one side of the veins, protected by a narrow indusium, opening normally towards the midrib of the leaflet; sometimes double sori or sori of irregular orientation occur. Spores are bilateral with perispore.



Asplenium nidus L. – 1, habit plant; 2, leaf, with sori at underside upper part.

- *A. nidus*. Rhizome short, stout, erect or ascending, epiphytic, bearing a rosette of leaves at the apex (forming the nest) and below the leaves usually with a large mass of roots which bear copious, persistent, brown root hairs; apex of rhizome clothed with thin clathrate scales up to 2 cm × 3 mm, margins amply ciliate, black to purple-brown. Leaves simple, coriaceous; petiole up to 5 cm long, pale yellow to black; lamina narrowly elliptical, 1–1.5 m × 6–30 cm, gradually narrowed towards both ends, margin entire, grass-green; midrib strongly raised above, flat below, dark brown in old leaves, veins prominent and close, once (sometimes twice) forked near the midrib and then running parallel to unite again near the margin to form submarginal veins about 0.5 mm inside the margin. Sori elongate along veins in the upper half of the lamina underside, extending as close (about 1 mm apart), parallel, brown lines from near the midrib up to halfway (sometimes more) the margin; indusium about 0.5 mm wide, reflexed at maturity; sporangium small, stalked, annulus with 20–28 thickened cells. Spores with irregular, thickened wing, translucent light brown when fresh, turning darker brown.

Growth and development *Asplenium* spores germinate in shaded and moist soils, on rocks or on tree trunks. The prothallus is of the common cordate or elongate-cordate type, sometimes naked, sometimes bearing papillae or hairs. The nest-shaped rosette of leaves of *A. nidus* catches and firmly retains dead leaves; this dead material starts rotting and forms a most effective sponge together with the roots, capable of holding much water after rains. The sponge thus provides water and food for the development of the fern.

Other botanical information Although several subclassifications of *Asplenium* exist, they are all highly artificial and often based on superficial resemblances. *Asplenium* is still extremely poorly known and thus recognition of natural infrageneric groups such as subgenera, sections or groups is not easily possible. *Asplenium* is thought to be closely related to *Athyriaceae, Blechnaceae* or *Thelypteridaceae*, but the similarities are few and may be due to convergence. Confusion of *Asplenium* with *Diplazium* and *Athyrium* is common but these genera are not thought to be closely related. Holttum classified *Asplenium* in the family *Denn-*

staedtiaceae, subfamily *Asplenioideae*, and he believed that the original *Asplenium* has tripinnate leaves from which species with simple leaves evolved. Although *A. nidus* is a common species, it has often been neglected by collectors and its variability is little known. *A. nidus* plants with very wide leaf blades, up to 30 cm, have sometimes been considered a separate species (*A. musifolium* J. Smith ex Mett.) or a variety (var. *musifolia* (J. Smith ex Mett.) Bedd.), but are considered here as falling within the species variability. On the other hand evidence exists that *A. nidus* consists of a number of morphologically indistinguishable cryptospecies which do not intercross and have different allozyme patterns and habitat preferences. In addition to *A. acrobryum* Christ, also *Leptochilus macrophyllus* (Blume) Noot. (synonym: *Colysis macrophylla* (Blume) C. Presl, *Polypodiaceae*, widely distributed in South-East Asia) is used as a source of salt in New Guinea.

Ecology *Asplenium* has adapted to a wide range of habitats. In the tropics it is often epiphytic or epipetric and particularly abundant in cloud forest of medium elevation. In temperate zones *Asplenium* ferns often grow epipetrically on acid or alkaline soils, but for example *A. scolopendrium* favours terrestrial sites in woodlands. In Malesia *A. nidus* is by far the commonest and the only epiphytic *Asplenium* growing in open locations in the lowlands. *A tenerum* Forst., also with a nest habit but with pinnate leaves, is the commonest lowland forest species, growing as an epiphyte near the ground and on rocks; on the mountains *A. robustum* Blume is the commonest epiphytic species. The epiphyte *A. nidus* with its enormous spongy mass of roots, affords shelter for many other ferns and epiphytes. Fallen leaves are caught in its capacious nest and each successive crop of leaves hold the accumulating mass securely between their bases, which the roots of the fern also penetrate. In this way gigantic masses of roots and humus are developed over a long period of years, continuing until their weight breaks the branch or the tree itself. These 'hanging soils' provide a habitat for a rich meiofauna and a specific mycoflora. Also harems of the larger dog-faced fruit bat (*Cynopterus horsfieldi*) seek shelter to roost between the marcescent leaves. The aptness of the name of *A. nidus* (bird's nest fern) appears on Madagascar, where the critically endangered, endemic Madagascar serpent-eagles (*Eutriochis astur*) build their nests in the fern. Only few species of *Asplenium* are frost resistant, e.g. cultivars of *A. scolopendrium* and *A. trichomanes* tolerate temperatures as low as –30°C.

Propagation and planting *Asplenium* normally propagates by spores. Many species, however, produce side crowns which can be separated. Separation of new plants is easiest in species with a creeping rhizome. Although *A. nidus* grows naturally as an epiphyte, it can thrive terrestrially. In addition to spore propagation, *A. nidus* can also be propagated through in-vitro culture of rhizome segments and through planting out dissected leaf-bases (up to 13 per leaf) in vermiculite, each with a small portion of the rhizome attached. Micropropagation through tissue culture of both the gametophyte and the sporophyte has been successful as well. A good potting material for *Asplenium* consists of equal parts of rich soil and leaf mould or peat.

Husbandry *A. nidus* grown in pots does not positively react to N and P applications, but K doses of up to 160 mg/pot increased plant growth and reduced the number of necrotic leaves. Plants should be kept in a very lightly shaded position.

Diseases and pests In potted *A. nidus* for ornamental use, a leaf spot and blight caused by *Pseudomonas gladioli* and *P. asplenii* are serious diseases . The impatiens necrotic spot virus causes ring spots and necrotic lesions. Because of its rather fleshy foliage, damage caused by slugs can also be serious. In the rainy season *A. scolopendrium* suffers from a troublesome rust disease caused by *Melesina scolopendrii*.

Genetic resources and breeding Germplasm collections of *Asplenium* species occurring in Peninsular Malaysia are available at the Fernarium of the Universiti Kebangsaan Malaysia in Bangi. Breeding in *Asplenium* is directed towards new ornamental cultivars.

Prospects The ornamental value of most *Asplenium* species warrants more research on propagation, cultivation requirements and marketing possibilities. Cultivation of these ferns may reduce the collection of plants from the wild. It is recommended that germplasm be collected from all *Asplenium* species. The traditional medicinal value of several *Asplenium* ferns seems interesting and deserves more pharmacological research.

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G. Rusea

Azolla pinnata R. Br.

Prodr. fl. Nov. Holl.: 167 (1810).
AZOLLACEAE
$2n = 44$ (diploid), 66 (triploid), 88 (tetraploid)

Synonyms *Salvinia imbricata* Roxb. ex Griff. (1844), *Azolla decomposita* Zoll. (1854), *A. imbricata* (Roxb. ex Griff.) Nakai (1925).

Vernacular names Azolla, ferny azolla, mosquito fern (En). Indonesia: mata lele (Javanese), kayu apu dadak, kakarewoan (Sundanese). Malaysia: mān chiang húng (Chinese). Thailand: nae daeng (central). Vietnam: beo dau.

Origin and geographic distribution The exact origin of *A. pinnata* is unknown. It is found throughout tropical Asia (including South-East Asia), in southern and eastern China, in southern Japan, northern Australia and in tropical and southern Africa (Madagascar included). In maritime locations in China (Wenzhou district) and Vietnam (La Van village) *A. pinnata* is known to have been cultivated since the 7th Century.

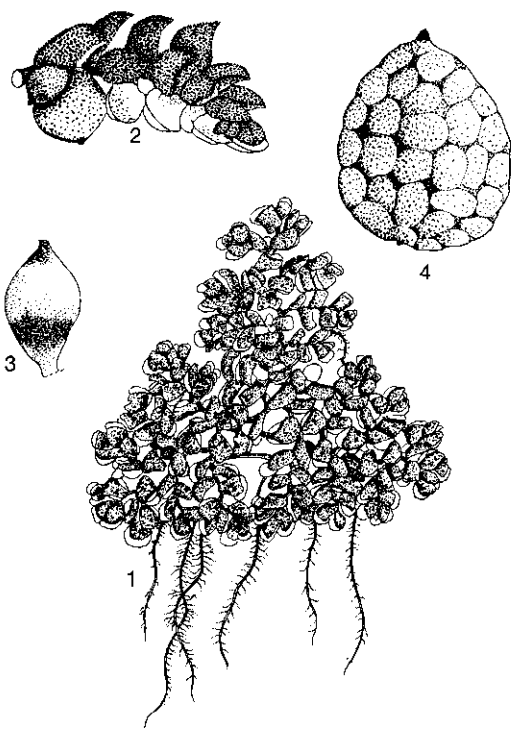
Uses *A. pinnata* has become important as an organic fertilizer in tropical lowland rice production in South-East Asia. It can be grown in dual culture with wet rice, or as a cover crop grown during the fallow season of rice and incorporated into the soil as a green manure. It maintains a symbiotic association with the blue-green alga *Anabaena azollae* Strasb. ex Wittr., Nordst. & Lagerh. which is able to fix atmospheric nitrogen. Other crops where *A. pinnata* is applied as mulch or as green manure include taro (*Colocasia esculenta* (L.) Schott), Manchurian wild rice (*Zizania latifolia* (Griseb.) Turcz. ex Stapf) and arrowhead (*Sagittaria trifolia* L.). Commercial production of azolla compost has been realized; the quality is good and the decomposition time may be reduced by 50%. *A. pinnata* is also used as fodder crop for pigs, rabbits, chicken, ducks and fish, mainly in China. Another use in rice cultivation is to control weeds and good results have been obtained in controlling e.g. *Cyperus difformis* L., *Echinochloa glabrescens* Munro ex Hook.f., *Monochoria vaginalis* (Burm.f.) Presl and *Paspalum* sp. A dense cover of *A. pinnata* on water is also quite effective as a means of mosquito control. Waste material of *A. pinnata* is used as a substrate for cultivating edible mushrooms, e.g. *Pleurotus* sp. In China small-scale biogas production units are exploited using azolla as biomass. Philippine farmers have used azolla for human consumption in various dishes such as salads, pinangat, mungo and omelette. The meal can be added to flour to increase the fibre content.

Production and international trade *A. pinnata* is only produced and traded locally. In the first half of the 20th Century in North Vietnam, where this fern was widely used as green manure for spring rice, villages specialized in propagating and selling it with good profit as a source of inoculum for rice paddy. In the United States *A. pinnata* cultivation is prohibited by federal law because of the risk of inadvertent break outs. In South Africa *A. pinnata* is not considered harmful.

Properties Per 100 g (dry weight basis) *A. pinnata* contains approximately: protein 13–30 g, fat 4–6 g, carbohydrates 41–45 g, fibre 39 g, cellulose 5–15 g, hemicellulose 9–18 g, lignin 9–35 g, ash 10–24 g (ranges of the elements N 2–5%, P 0.1–1.6%, K 0.3–6%, Ca 0.4–1.7%, Mg 0.2–0.6%, S 0.2–0.7%, Si 0.1–3.5%, Na 0.1-1.3%, Cl 0.6–0.9%, Al 0.04–0.6%, Fe 0.04–0.6%, Mn 0.06–0.3%, Cu 0–0.03% and Zn 0.002–0.1%). The N, K and Si contents are reasonably high. Deficiencies in methio-

nine, histidine and fibre make *A. pinnata* unfit to be the sole feed source for animals, but the amino acid composition compares well with reference protein sources and although the methionine content is low, the lysine content is more than twice that of maize. In the tropics 60–75% of the N will be released as ammonia within 6 weeks after the onset of mineralization in the soil in a flooded field without rice.

Description A small, free-floating, aquatic fern, triangular to trapezoidal in outline, about 2–4 cm × 1 cm, with branched, floating stem (rhizome) bearing roots and leaves. Roots solitary, growing from stem branching points, hanging down in the water, plumose, 1–5 cm long, with obliquely arranged groups of 3–6 root hairs. Leaves small, alternately in two rows, variably imbricate, sessile, bilobed with a dorsal lobe held above the water surface and a floating (resting on water surface) ventral lobe; dorsal lobe subelliptical, up to 1.5 mm × 1 mm, fleshy, chlorophyllous and photosynthetic, margin hyaline and (2–)3(–4) cells wide, apex obtuse, with 1–2-celled trichomes and papillae, inside on lower surface with a cavity containing mucilage and filaments of the blue-green alga *Anabaena azollae*, green but turning red under adverse environmental conditions; ventral lobe thin (one cell thick), flat, translucent, without chlorophyll, glabrous. Sporocarps borne in pairs or fours at base of branches (reduced ventral leaf lobe), initially covered by involucre of dorsal leaf lobe, each containing one megasporangium (containing a single megaspore) or many microsporangia (each containing 64 microspores). Spores trilete, of two kinds; megaspore bearing on the proximal side a columella, hair-like filaments and 9 apical massulae (called floats); microspores of one sporangium released as one mass (called a massula) which floats, its inner surface bearing 2–4 small, simple, spiniform trichomes without hooked apices; microspores germinate within the massula.



Azolla pinnata R. Br. – 1, habit; 2, branch with basal sporocarp; 3, megasporocarp (female); 4, microsporocarp (male).

Growth and development The sporophyte of *A. pinnata* reproduces vegetatively through fragmentation, made easy by an abscission layer present at the base of each branch. Secondary branches extending from older lateral branches bend the lateral branch and put pressure on its abscission layer, contributing to its separation. Lateral branches then drift away independently from their parent. Exponential growth may continue under optimum conditions for fragmentation and dispersal and consequently *A. pinnata* can become a troublesome weed. Initiation of the gametophytic cycle in most *Azolla* species seems to be stimulated by environmental stress, which also affects the ratio of micro- to macro-sporocarps. When a plant becomes fertile, sporocarps are formed in pairs after a few divisions by a fertile ventral lobe initial of the first leaf of a branch. The dorsal lobe of the fertile leaf retains its normal shape and function. Leptosporangiate development of the sporangial initials eventually gives rise to two megasporangia, each containing 32 megaspore initials produced by meiotic division. If a megaspore is to develop within the megasporangium, all but one of the 32 megaspore initials abort. If all of the megaspore initials abort, microsporangia initials arise from basal outgrowths on the stalk of the megasporangium. The resulting pair of sporocarps may be all of one sex or any mix. Sporocarps mature on the plant in a week or more. Microsporocarps contain up to 130 stalked microsporangia with 64 microspores. The microspores are not released directly into the water, but as cluster held together by hardened mucilage (massula). The massulae bear trichomes that facilitate coupling to the hairs of the megasporan-

gia. The microspores germinate and release antherozoids to fertilize an archegonium produced by the megaspore gametophyte. When after successful fertilization the new sporophyte ruptures the megasporangium wall, *Anabaena* strands located there become entrapped in the shoot apex. As the funnel-shaped first leaf emerges, it dislodges the *Anabaena* and establishes a colony around an apical trichome that is incorporated into the dorsal leaf cavity.

Other botanical information Within *A. pinnata* three subspecies are distinguished of which only one is found in South-East Asia, subsp. *asiatica* R.M.K. Saunders & K. Fowler. This has lax to slightly imbricate dorsal leaf lobes with narrow (width about 1/10 of leaf width) hyaline margins, ventral leaf lobes shorter and wider than dorsal ones, surface of megaspore with prostrate or erect elongate outgrowths. The other 2 subspecies are found in Australia and New Caledonia (subsp. *pinnata*) and in Africa (subsp. *africana* (Desv.) R.M.K. Saunders & K. Fowler). Although many species have been described in the genus *Azolla* Lamk, only 6 or 7 are currently recognized. *A. pinnata*, together with *A. nilotica* Decne. ex Mett. (leaves up to 40 cm long, never red, restricted to tropical Africa) are classified in section *Rhizosperma* of the genus *Azolla*. Several other *Azolla* species, e.g. *A. filiculoides* Lamk, *A. mexicana* Presl and *A. microphylla* Kaulfuss (all in section *Azolla*), have been introduced into South-East Asia and are used experimentally and in breeding.

Ecology The geographical distribution of *Azolla* indicates that it is adapted to a wide range of climatic conditions. The primary requirement of *Azolla* is an aquatic habitat, since it is very sensitive to dryness. It dies within a few hours under dry conditions. Most of the *Azolla* species are widely distributed in temperate regions as they are generally sensitive to the higher temperature of the tropics. The optimum temperature range in which most of them grow well is 20–25°C. The most favourable temperature for growth and nitrogen fixation of *A. pinnata* is 20–30°C, it perishes below 5°C and above 45°C. Light intensity interacts with the effect of temperature. The optimum temperature for *A. pinnata* grown under 15 klux artificial light is 30°C. The growth rate is reduced under light intensities that fall outside the range of 15–60 klux. The optimum relative humidity needed for normal growth of azolla is 85–90%; values below 60% cause the leaves to dry up. High relative humidity causes a longer dew period, resulting in susceptibility of the plant to disease and pest infestation. In the tropics direct sunlight at midday suppresses the growth of the fern, while light exposure on cloudy days is more favourable. Wind tends to push all the leaves together so they collect on the same part of the water surface. A slightly acidic to neutral pH (4.5–7) has been found to be suitable, the optimum being pH 5.5–6.0. Wilting occurs where salt concentrations surpass 1.5 g/l during the summer. Azolla may suffer from competition from other floating water plants such as algae, *Pistia* L., *Lemna* L., and *Salvinia molesta* D.S. Mitchell. Because of its rapid vegetative reproduction, however, azolla often also becomes a troublesome water weed, clogging waterways and drainage systems, forming dense surface mats which interfere with boating, fishing and recreational activities and degrade water quality by reducing oxygen levels.

Ferns of the genus *Azolla* share a mutually beneficial symbiotic relationship with the nitrogen-fixing blue-green alga *Anabaena azollae*. The fern provides nutrients and a protective leaf cavity for *Anabaena*, which in turn provides ammonia to the fern. The *Anabaena* symbiont occupies a specialized cavity in aerial dorsal leaf lobes. Specialized trichomes are involved in the metabolite exchange. More of the alga is found in the apical meristem and some filaments penetrate beneath the megasporangial indusium where they inoculate new leaves and young sporophytes, respectively. Natural *Azolla* populations are rarely free of *Anabaena*. *Arthrobacter* bacteria also constitute a third partner in the *Azolla-Anabaena* symbiosis, but their role is not yet understood. Nitrogen fixation occurs only in specialized *Anabaena* cells called heterocysts. Most of the energy is supplied by metabolites produced by the photosynthesis of *Azolla*. Characteristically low levels of ammonium-assimilating enzymes in *Anabaena azollae* make the nitrogen fixation process very efficient. The fixed nitrogen is transported to the host, which incorporates it into amino acids. Part of the amino acids probably then go back to *Anabaena*. Because *Anabaena azollae* is associated with *Azolla* throughout its life cycle, a free-living stage of the symbiont is not needed. The frequency of heterocysts inside the leaf cavity is 3–10 times that found on free-living blue-green algae. The taxonomy of *Anabaena azollae* and its relation to free-living *Anabaena* species is still subject to discussion. Also it has been questioned whether the laboratory grown isolates match the genuine endosymbiont.

Propagation and planting At present vegeta-

tive material of *A. pinnata* is generally used as planting material. In order to maintain the fern throughout the year, special multiplication nurseries are prepared to produce sufficient quantities of planting material as inoculant for further propagation. These nurseries require shade, an ample supply of water, plant nutrients, disease and pest control and some measures to protect the fern from extreme weather conditions. The field for the fern nursery should be thoroughly prepared. Super phosphate is applied, usually in three gifts at 4 day intervals. About 7 days after inoculation a systemic insecticide is applied to provide protection against insect pests (e.g. carbofuran granules). By repeated inoculation and harvesting in the nursery a sufficient amount of azolla inoculants can be obtained for the main rice field. Vegetative reproduction can be promoted by fragmenting the plants, e.g. by tapping them with a broomstick. Storage of harvested azolla is difficult and hence special care is necessary for long distance transport. Desiccation should be prevented and fresh azolla can be shipped packed in sealed polythene bags or petri dishes, surviving at least 2–3 weeks when kept at 5–10°C.

Propagation can also be done by spores, which allows large quantities of inoculum to be produced and transported. To encourage the azolla to produce spores, the plants have to occupy the available space completely, making vegetative reproduction no longer possible. After about a week some 70% of the plants will have produced spores. Then, about two thirds of the azolla mat is harvested. Under favourable conditions the remaining plants will produce spores again in about three weeks. A production field of 10 m × 25 m can be inoculated with 100 g dry spores. Spores start germinating after 7 days. After two weeks the young plants can be transplanted.

Husbandry Under favourable conditions, a layer of *A. pinnata* covering a rice field of one ha releases 20–30 kg organic N. The economic return from azolla adoption is more than 10% of the total non-land cost for rice production in areas where conditions favour azolla growth. Constraints for its use include the phosphorus content of the soil, insect and pest control and labour requirements. The need for additional phosphorus fertilizer may not be a problem in its adoption because azolla normally grows when only 0.06 ppm P is available, though 30 ppm or more is advised. However, if more than 200 g/ha of a systemic insecticide such as carbofuran is necessary the economic benefits are eliminated. Labour costs of azolla application can become critical where wages are high. In some areas *Azolla* species that lack heat tolerance are taken advantage of by letting the ferns die in summer, thus freeing the nutrients and allowing the light to penetrate through the water to the submerged rice plants. Sometimes azolla fertilization is used in addition to inorganic N-fertilizer. In general, however, the average nitrogen fixation rate of azolla amounts to 1–2 kg N per ha per day which is sufficient to meet the nitrogen demand of the rice crop. The azolla-rice culture can be augmented with fish production (e.g. *Tilapia nilotica*) and with ducks.

Diseases and pests A serious disease of *A. pinnata* in rice fields is caused by the fungus *Myrothecium verrucaria*, characterized by white spots of mycelium and a rapid rot and death of azolla. *A. pinnata* is also highly susceptible to rice sheath blight, caused by *Sclerotinia sclerotiorum* and to black rot disease caused by *Rhizoctonia solani*. Disease severity is higher when the leaves are also attacked by snails. Numerous other fungal genera have been isolated from diseased azolla. Crude garlic extract was found to be very effective against fungal pathogens.

In South-East Asia pests are considered the major limiting factor in azolla cultivation. In the Philippines, the most important pests are the webworm (causing yield losses of 6–74%), the lepidopteran spinningworm (*Ephestiopsis vishnu*) and the caseworm complex (*Elophila* (*Nymphula*) *enixalis*, *E. nigralbalis*, *E. responsalis*). In Thailand, *Chironomus glauciventris*, *Cryptoblabes* sp., *Polypedilum johannseni* and *Elophila enixalis* are the main pests. In Thailand, azolla is also damaged by high temperatures in April and by competition from blue-green algae. The best insect control and the highest yield was obtained by spraying 0.5 kg/ha monocrotophos, applied 1 and 10 days after inoculation. Foliar sprays of carbosulfan or chlorpyrifos applied after field inoculation also gave good results. Treatment with these or with monocrotophos resulted in 3-fold increases in yield. A preparation (Bactospeine) containing *Bacillus thuringiensis*, applied after inoculation, provided some insect control and significantly increased the yield. To reduce application costs, it is recommended that the azolla stock culture be sprayed 2–3 days before it is transferred to the propagation field. Another application is necessary 7 days later. Because azolla cultivation should begin after transplanting rice, insecticide applications also have some effect on rice pests. Destruction by snails is an obstacle to azolla-breeding in India.

Snails primarily responsible are *Lymnaea luteola*, *Bellamya bengalensis*, and *Pila globosa*. The golden apple snail, *Pomacea canaliculata*, originating from South America, was introduced as a promising export industry in South-East Asia but it has also escaped to rice fields in Taiwan, Japan and the Philippines (here *Pomacea cuprina* and *Pomacea gigas* have also been introduced) and azolla and young rice seedlings are preferred hosts. Control is possible by manual removal, draining of rice fields, releasing carp (prey on young snails), application of pesticides such as triphenyltin-acetate ('brestan', effective but highly toxic to Nile tilapia), clonitralid ('bayluscid', effective but toxic to fish), metaldehyde ('namekil', effective with low fish toxicity).

In southern China, the azolla midge (*Polypedilum ivinoense*), which is aquatic at larval instar stage, can devastate an azolla stand in 3–5 days. It is light red, 2–3 mm long, and makes its nest on the underside of azolla, eating roots and young leaves. In summer it is able to complete its life cycle in 12 days, building in a short time populations of 90 000 per m^2. Methods to prevent damage by azolla midge include protecting the *Dytiscidae* which are natural enemies, applying maceration extract of cake of tea oil and insecticides such as deltamethrin, carbofuran, carbaryl, and temephos. Pesticides and herbicides can have effects on the growth and nitrogen assimilation of the *Azolla-Anabaena* symbiosis. Most rice herbicides (e.g. bipyridylium and phenolic herbicides, chloramben, dicamba, simazine, benzoic, triazine, dinitroaniline and urea herbicides) are deleterious to azolla but delaying inoculation with azolla until after herbicide application reduces or eliminates the problem. The symbiosis is also severely damaged by atmospheric SO_2 even at low concentrations, with significant reductions in growth, assimilation, protein synthesis and heterocyst development. Propanil is highly toxic, sinking the floating fern in about five days after inoculation.

Harvesting Since *A. pinnata* floats on the surface of the water, the easiest way of collection is by using nets and transport in big baskets. For green manuring of rice a full cover of azolla mat can be directly incorporated into the soil using simple tools or rotary tillers.

Yield Under optimum conditions *A. pinnata* can double in weight every 3–5 days. In an open field under tropical conditions, a full cover of azolla can yield about 20 t/ha fresh weight. When intercropped with rice the growth rate decreases with the development of the rice canopy, but repeated inoculation and harvest of the fern can give an annual yield of up to 40–50 t/ha fresh weight. Rice yields may increase by 0.4–1.5 t/ ha when thus fertilized.

Handling after harvest To mix dried azolla as supplement to commercial layer or broiler rations, the freshly harvested azolla should be washed thoroughly to remove soil and pesticide residues. Then it is dried in the sun for 3–7 days, until it crumbles when squeezed. Subsequently, it is ground, either using a commercial grinder, or by crushing the dried plants in bags with the feet. The azolla meal is mixed with the layer/broiler rations 1:10 by weight or 1:5 by volume. To harvest the spores, the harvested plants are placed in a 50 cm deep, well-drained pit. The plants are left to decay for two weeks during summer or up to one month in the rainy season. The decayed plants are collected and dried in the sun and open air for 24 hours. The dried mass is sieved through a coarse screen (1 mm mesh). The particles that pass through are immersed in water and left to soak overnight. The floating spores are finally scooped from the water.

Genetic resources Living *A. pinnata* germplasm collections are maintained at the International Rice Research Institute (IRRI) in the Philippines, the Azolla Research Centre, Hanoi, Vietnam, the Azolla Research Center, Fujian Academy of Agricultural Science, Fuzhou, Fujian, China, in the United States at the Washington State University and the University of California, Davis, in Africa at research stations of the Office de la Recherche Scientifique et Technique Outre-Mer (ORSTOM) and the West Africa Rice Development Association (WARDA) in Ivory Coast, and at the Université Catholique de Louvain, Belgium (UCL). In 1997 about 550 accessions were maintained at IRRI, covering all extant species (about 150 accessions of *A. pinnata*) collected worldwide in cooperation with many researchers, including also unique material which cannot be obtained from natural habitats, such as sexual hybrids (79 accessions), *Anabaena*-free azolla (20), azolla with heterologous symbiotic cyanobacteria (6) and putative mutants (16). The IRRI collection is now maintained as shoot-tip agar cultures, which are renewed every 3–6 months. Most cultures of the section *Azolla* are duplicated at the Azolla Research Center of the Fujian Academy of Agricultural Science (Fuzhou, Fujian, China).

Breeding At several azolla research stations, selection and breeding programmes are in progress to obtain more efficient, more pest resistant

and more shade- and salt-tolerant genotypes. Interspecific hybrids have been tried but so far they have all proved sterile. Given the isolated position of *A. pinnata* in *Azolla*, fertile interspecific hybrids are not to be expected. Other *Azolla* species hybridize more easily and several promising hybrids have been bred in the Philippines, Thailand and China.

Prospects The great expectations of *A. pinnata* as a natural source of nitrogen and weed control peaked around 1980–1990, but have declined since. Nevertheless, many promising initiatives aimed at the utilization of azolla are being developed especially in China and South-East Asia, and also in other parts of the world. Unfortunately, in most environments azolla is not a cost-effective substitute for inorganic nitrogen. Limiting factors to the use of azolla include the need for water, high phosphorus requirements, susceptibility to pests and limited temperature tolerance. High labour costs (for maintenance, transport, inoculation and burying), high opportunity costs of land and poor water control are major constraints to the economic feasibility of green manure. Improvements in azolla technology that increase nitrogen yield and pest resistance or reduce the opportunity costs of labour and land could make azolla economically feasible in a wider range of environments. Integrated production systems with azolla are promising. In the laboratory the symbiotic *Anabaena* cyanobacterium can be induced to produce free hydrogen. So far this has not led to commercial-scale hydrogen production of plants. Azolla is capable of extracting phosphates from eutrophicated water, acting as a decontaminant in sewage treatment. In Israel, biological processes for the removal of heavy metals from effluents by means of azolla have been developed. The process is suitable for uranium, cadmium, nickel, copper and chromium and the recovery of silver. These processes are superior to traditional methods of metal removal from effluents when environmental and ecological constraints exist and the concentrations of metals are low (1–20 ppm). At such low concentrations, no effective chemical means of metal removal are presently available. In tests the heavy metals were concentrated 500–1000 fold in the azolla biomass within 2–7 days of growth, and the content of metal in azolla was about 1% Cu, Cd, Zn, U and Ag, and 0.3% hexavalent Cr and Ti. Some 40–60% of the heavy metal was removed from the water body. The total content of metal in the azolla ash was 5%. Filters made of dried azolla were found to bind a high percentage of the metal in solution.

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Soetjipto Partohardjono & P. Swatdee

Blechnum L.

Sp. pl.: 1077 (1753), Gen. pl.: 560 (1754).

BLECHNACEAE

x = 28–40 (diploids, triploids and tetraploids occur); *B. indicum*: $2n$ = ca. 74; *B. orientale*: $2n$ = ca. 64–66

Major species and synonyms

- *Blechnum egregium* Copel., Perkins, Fragm. fl. Philipp. 3: 187 (1905), synonym: *B. nitidum* C. Presl var. *contracta* Hook. (1860). Note: The name *B. insigne* Copel. has been used formerly, but it is a nomen nudum.

- *Blechnum indicum* Burm.f., Fl. Indica: 231 (1768), synonyms: *B. striatum* R. Br. (1810), *B. moluccanum* Desv. (1811), *B. malaccense* (C. Presl) Fée (1852).
- *Blechnum orientale* L., Sp. pl.: 1077 (1753) (erroneously as *B. occidentale* L., corrected in 2nd ed.: 1535 (1763), synonyms: *B. javanicum* Blume (1828), *B. adnatum* Reinw. ex De Vriese (1846), *Blechnopsis orientalis* (L.) C. Presl (1849).
- *Blechnum vittatum* Brack., U.S. expl. exped. 16: 131 (1854), synonyms: *B. dentatum* (Kuhn) Diels (1901), *B. bamlerianum* Rosenst. (1912), *Lomaria bamleriana* (Rosenst.) Alderw. (1917).
- *Blechnum vulcanicum* (Blume) Kuhn, Ann. Mus. Bot. Lugd.-Bat. 4: 284 (1869), synonyms: *Lomaria vulcanica* Blume (1828), *L. villosa* Fée (1852), *Spicanta vulcanica* (Blume) Kuntze (1891).

Vernacular names

- *B. egregium*. Papua New Guinea: hariga (Orokaiva). Philippines: patugo (Manobo).
- *B. indicum*. Indonesia: bacai, paku paci besar (Kalimantan), kadu (Irian Jaya).
- *B. orientale*. Indonesia: paku leucir, paku lipan, paku lubang. Malaysia: paku lipan, paku ikan (Malay), kelindang (Sarawak). Papua New Guinea: aduba, zani (Orokaiva). Philippines: pakong alagdan (Tagalog). Thailand: kut khang fan (northern), kut doi (central), mahasadam (south-eastern). Vietnam: r[as]ng d[uwf]a d[oo]ng, c[aa]y r[aw]ng d[ee] l[as] d[uwf]a.
- *B. vulcanicum*. Indonesia: paku gunung.

Origin and geographic distribution *Blechnum* is an early group of ferns, probably originating from late Cretaceous, with a radiate distribution pattern centred on Gondwanaland with distinctive but overlapping lines of speciation extending northwards from Antarctica. At present it is a widespread genus comprising about 180 species, most of which occur in the southern hemisphere; in South-East Asia about 20 species are present. *B. egregium* is widespread throughout the Philippines and it occurs also in some isolated localities in Sabah (Malaysia) and Papua New Guinea. *B. indicum* is distributed from continental South-East Asia through Sumatra, (not found in Java), Borneo and New Guinea to New Caledonia and northern and eastern Australia. *B. orientale* is the most abundant and most widespread species and is found from India, Nepal and southern China throughout South-East Asia to southern Japan, Australia and Polynesia. *B. vittatum* occurs from eastern Papua New Guinea and the Solomon Islands to the Santa Cruz Islands. *B. vulcanicum* is rarely common and occurs from non-continental South-East Asia and Australia to New Zealand, through the Pacific as far east as the Cook Islands and north to the Marquesas.

Uses Tender portions of young leaves of all *Blechnum* species are eaten as a vegetable in the Philippines and Papua New Guinea. They are also cultivated as an ornamental because they are elegant and beautiful with brilliant scarlet young leaves and dark green upper and paler lower surfaces in mature leaves. In some places the croziers are considered a delicacy, somewhat resembling asparagus in flavour and texture. On Frederik Hendrik Island off the coast of Irian Jaya (Indonesia), a coarse edible flour is prepared from the rhizome. In Australia the rhizome is washed, roasted, ground or pounded, sclerotic leaf and root traces removed and the resultant flour made into a kind of unleavened bread. In the Philippines, *B. orientale* is used as an ingredient in stews. In Papua New Guinea young leaves are eaten as a wild food supplement, but they are also used to induce sterility in women. Total sterility can be achieved by eating new leaves for three successive days, waiting a fortnight and repeating the treatment. In Malaysia and the Philippines the rhizome is also consumed for food whereas in the Philippines it is used as a diaphoretic, aromatic, aperative, and a poultice made from the leaves is a recommended treatment for boils (also in Peninsular Malaysia). In India and Polynesia the rhizome is used against intestinal worms and bladder complaints. In Chinese pharmacies the rhizome is prescribed in relation to urinary complaints. In Malaysia *B. orientale* is a magical application for dropsy, along with the leaves of *Elephantopus scaber* L. (prickly-leaved elephant's foot, a tropical weed of *Compositae* (see Prosea 12(1), which possesses numerous interesting medicinal properties, including being useful against dropsy). On Waya Island (Fiji) new brightly coloured leaves are used as necklaces.

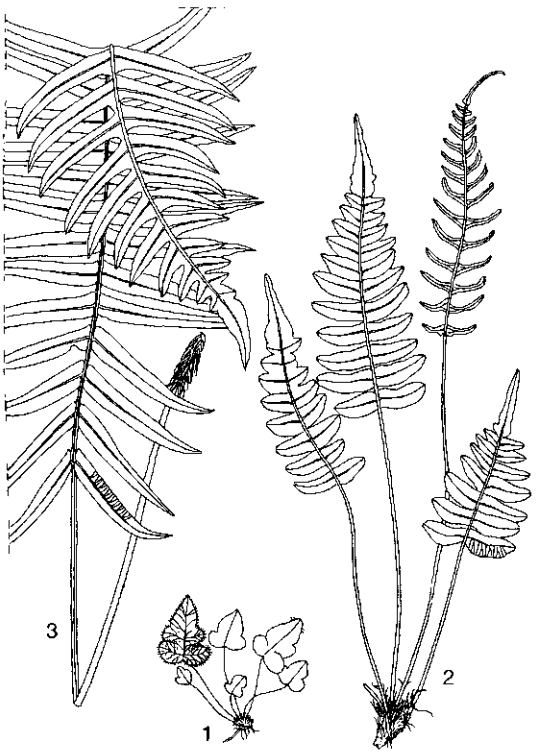
Production and international trade *Blechnum* plants are not cultivated commercially but they are locally important. Fresh croziers and young leaves of *B. indicum* are sold in bunches on many local South-East Asian markets and in some countries the croziers are canned and sold as a delicacy.

Properties In the Philippines, per 100 g edible portion, the young, unexpanded leaves of *B. orientale* and *B. vulcanicum* contained respectively: total N 1.36 g and 1.33 g, P 156 mg and 181mg, K 625 mg and 475 mg, Ca 206 mg and 343 mg, Fe 16

mg and 45 mg, Mg 290 mg and 842 mg. Flavonoid glycosides and the four lignans blechnic acid, 7-epiblechnic acid, 8-epiblechnic acid and brainic acid were isolated from a number of fern species including *B. orientale*. Tests in the Philippines showed that water extracts of *B. orientale* possessed antifungal properties against *Bacillus subtilis, Candida utilis, Escherichia coli, Micrococcus luteus, Pseudomonas aeruginosa* and *Staphylococcus aureus*.

Description Rhizome or caudex ascending to erect, thick, densely covered with narrow, dark brown, lustrous scales; some species eventually forming a short trunk up to 2 m tall, usually forming extensive colonies interconnected in the early stages of development by rhizomes or stolons. Leaves all similar or fertile leaves different, pinnate, pinnatifid or pinnatisect, rarely simple, bipinnate or multipinnate; sterile leaf subcoriaceous, glabrous, pinnae linear, entire to dentate, veins free; fertile leaf similar to the sterile leaf or with much narrower pinnae. Sori at the underside of the pinnae, linear, closely aligned to the midrib, in reduced pinnae covering the entire surface; indusium narrow, opening towards the midrib. Spores monolete, bilateral, reniform to subglobulose, with various decoration patterns.

- *B. egregium*. Caudex up to 100 cm long, 5–10 cm or more in diameter; scales linear triangular with a finely acuminate apex, up to 3 cm × 2 mm, entire, shiny dark brown to black. Leaves dimorphous, pinnate; petiole 3.5–31 cm long, brown, darker at the base, densely and persistently scaly; sterile lamina narrowly elliptical or ovate to narrowly elliptical in outline, 20–120 cm × 9–30 cm, gradually narrowed towards the base, apex acute, rachis and veins dark to reddish-brown, or paler, at underside with two lateral grooves, sometimes at upperside persistently scaly; pinnae narrowly triangular, middle ones 2.5–15 cm × 0.8–2 cm, base adnate to the rachis, margins crenate to serrulate, dentate near the apex, apex acuminate to attenuate; fertile lamina of the same size as the sterile ones or somewhat larger; fertile pinnae restricted in width or not, widening a little towards the rachis becoming broadly adnate and decurrent. Sori in narrow pinnae occupying the whole undersurface, in normal pinnae restricted to either side of the midrib. Spores 48 µm × 36 µm, smooth to granulose.
- *B. indicum*. Rhizome very variable, from slender and creeping to an erect caudex, covered with old leaf bases and adventitious roots or with small scales; scales 3–4 mm × 1 mm. Leaves all similar, pinnate; petiole 6–50(–83) cm long, very dark at the base to brown or stramineous towards the top, scales persistent only at the very base; lamina ovate to narrowly elliptical in outline, up to 50(–100) cm × 6–15(–28) cm, base acute, apex acuminate, rachis stramineous, usually glabrous and lustrous; pinnae in 16–52 pairs, oblong to narrowly elliptical, 4–16.6 cm × 0.5–1.6 cm, base cordate, sessile or shortly petiolate, articulate to the rachis with a characteristic socket joint, margins serrate, gradually narrowing into the acuminate apex, veins up to twice forked, very fine and close, 3–4 per mm. Sori close to and often covering the midrib, usually extending to the pinna base but not to the apex, indusium nearly 1 mm wide. Spores 36 µm × 28 µm, light brown, minutely papillate.
- *B. orientale*. Rhizome forming a stout suberect caudex, 6–20(–300) cm long and 4–5 cm in diameter, densely covered with scales; scales linear-elliptical, up to 2 cm × 2 mm, dark brown with pale margins. Leaves all similar, pinnately di-



Blechnum vulcanicum (Blume) Kuhn – 1, habit juvenile plant; 2, habit typical fertile small plant; 3, large mature sterile leaf.

vided (in juvenile plants pinnatifid), rarely bipinnate or multipinnate; petiole up to 70 cm long, stramineous or purplish when young, densely scaly at the base, bearing small auricles (also considered as reduced pinnae and then petiole only 5 cm long) throughout about 3 cm apart; lamina lanceolate to ovate in outline, up to 200 cm × 54 cm, rachis pale pinkish-brown, glabrous or with a few hairs and slender, brown scales; pinnae 6–70 or more pairs, 2–5 cm apart, sessile, linear, 30 cm × 1.2–2 cm, base truncate or broadly cuneate, the upper ones decurrent, entire, gradually narrowing into the acuminate apex, veins simple or forked, distinct, spreading at a broad angle to the midrib and up to 0.5 mm apart at the midrib. Sori closely parallel to and on either side of the midrib, 1–2 mm wide, often enlarged to overlap or cover the midrib, indusium usually broken before maturity. Spores 47 µm × 37 µm, pale translucent with a clear, rather narrow median wing, smooth to scabrous.

– *B. vittatum*. Caudex erect or suberect, up to 1 m long and 3–5 cm in diameter, densely scaly at the apex; scales linear-acuminate, 1–4 cm × 0.2–1.5 mm, black or very dark brown, frequently with paler margins. Leaves usually dimorphous, pinnate; petiole 12–58 cm long, dark at the base, stramineous upwards, densely and persistently scaly at the base, few scales persistent elsewhere, petiole and rachis at underside often with conspicuous black lines on the ridges on either side of the groove; lamina in outline ovate to narrowly elliptical in smaller (50 cm long) leaves, linear to narrowly elliptical in larger (100 cm) ones, up to 100 cm × 40 cm, base more or less truncate, gradually widening towards the middle, apex acute; rachis stramineous to pale brown, glabrous or with a few scales; sterile pinnae oblong to narrowly elliptical, 6–21 cm × 1–2 cm, base adnate and often decurrent (middle region of the lamina), often slightly auriculate, in larger leaves several basal pairs may be petiolate and deflexed, margins crenate to denticulate, increasingly toothed towards the sharply acute apex; fertile pinnae similar to the sterile ones, or narrower and linear, 15(–20) cm × 2.5–3.5 mm, with veins simple or forked, distinct, ending in a gland. Sori covering the whole surface when the fertile pinnae are narrow, in normal pinnae sori not covering the whole undersurface, often somewhat discontinuous. Spores 46 µm × 33 µm, smooth to scabrous.

– *B. vulcanicum*. Rhizome creeping or erect, often forming a caudex up to 20 cm long and 3 cm in diameter, clothed with densely scaly bases of old petioles; scales linear to narrow triangular, up to 2.5 cm × 3 mm, entire, shiny red-brown. Leaves dimorphous, erect or pendulous, narrowly to broadly elliptical in outline, 10–70 cm × 3–30 cm, fertile leaves usually longest, but size of leaves (and whole plants) varies considerably; petiole 5–40 cm long, slender, yellowish-brown, usually pilose with fine straight uniseriate hairs, at base densely persistently scaly; lamina pinnatisect to pinnate with 6–30 pairs of pinnae, rachis and veins with persistent whitish hairs; sterile pinnae oblong to narrowly triangular, often slightly falcate, 4–8 cm × 0.7–1.5 cm, sessile and adnate to rachis (except basal pair which is semi-adnate); fertile pinnae 4–8 cm × 4–6 mm wide, spaced on the rachis, margin often with hairs. Sori covering whole undersurface, indusium sometimes bearing hairs. Spores 42 µm × 33 µm, smooth to granulose.

Growth and development After germination of a spore of *Blechnum*, a gametophyte is developed. The prothallus is cordate or elongate with a distinct firm midrib and often bearing simple chlorophyllous hairs. The gametangia are of the common, advanced leptosporangiate type. After fertilization the sporophyte starts growing and the first leaves are small and differ from the leaves in mature plants. Some species produce a caudex (stem) sufficiently tall for the plants to be regarded as small tree-ferns (e.g. most species mentioned here). Other species form a slender creeping rhizome which may be either aboveground or subterranean giving rise to colonies from one individual (e.g. sometimes *B. indicum*), whereas other species produce a massive subterranean rhizome. In *B. egregium* the fertile leaves are seasonal in their development and usually occur in the central part of the leaves. In *B. orientale* the growth form varies from small leathery fertile plants on dry exposed soil banks to large harsh ferns of open spaces on the margins of lowland.

Other botanical information In 1753 Linnaeus mixed up collections and described the most widespread species of the New World, *B. occidentale* L., as occurring in the Old World, and the most widespread species in the Old World, *B. orientale* L., as occurring in the New World. In 1763 he corrected the error and it has been generally accepted to have the correction effectuated starting 1753. Taxonomically, *Blechnum* is very incompletely known. It is classified in the *Blechnaceae* which comprises 9 genera (including *Woodwardia* J.E. Smith, mostly distributed in the northern

hemisphere). The leaf pattern is a very important characteristic for identifying species in *Blechnum*, but sometimes characteristics of petiole, rachis, scales on the midrib, spores and hairs are also needed. *B. egregium* and *B. vittatum* are closely related; they can be distinguished by their basal pinnae: sessile or shortly petiolate but of normal size in *B. vittatum*, reduced to small, (semi)adnate lobes in *B. egregium*. *B. indicum* is closely related to the American *B. serrulatum* Rich. with broader and oblong pinnae that do not taper evenly from the base to the apex. *B. orientale* occupies a very wide range of habitats resulting in extremely varying plants, from 20 cm up to over 3 m tall. Sometimes confusion with *B. finlaysonianum* Wall. is possible, but the latter always grows in the shade, having pinnae up to 4 cm wide and not tapering towards the apex. *B. vulcanicum* plants are very variable in leaf size and hairiness; in Malesia plants are usually densely brown pilose but plants with paler, often silvery white hairs also occur. It is possible that what is known as *B. vulcanicum* from outside Malesia, is a complex of several species. *B. gibbum* (Labill.) Mett. (dwarf tree fern) is raised in nurseries and sold as a pot plant in West Java.

Ecology The greatest diversity of *Blechnum* species is to be found in almost perpetually humid regions. In South-East Asia all species are primarily terrestrial, although in very humid habitats some individuals might grow on fallen logs. *B. egregium* is mostly found in humid jungle areas on stream banks and protected cliffs, from the lowland up to over 1500 m altitude. *B. indicum* grows in brackish swampy areas and river margins, usually near the coast but sometimes inland and up to 1900 m altitude, often forming extensive dense stands on sandy or peaty soils in open, sunny locations, usually along with grasses. *B. orientale* is often a primary colonizer after forest clearing and fire and it sometimes becomes a dominant species after repeatedly being burnt. It is a fern of open places which never grows in the shade. On very exposed sites the plants may be stunted with often unusually wide sori. It is found from the low hills up to 1500 m altitude. *B. vittatum* is a forest fern and a common undergrowth species from the primary and secondary lowland rain forest up to 600 m altitude in Fiji and up to 1200 m in Papua New Guinea. It may invade volcanic slopes within two years after an eruption. *B. vulcanicum* grows in cool, moist, partly shaded locations, usually in forest, more rarely in exposed tall grasslands. It is certainly not restricted to volcano sides.

Propagation and planting *B. orientale* grows easily from spores. In culture, 95% of the spores germinated 30 days after sowing. No information is available on commercial cultivation.

Husbandry When *B. orientale* is planted in gardens, the soil should be well drained. Provided the plants are well watered, they can be exposed to the full sun. Plants can be grown within the temperature range 8–40°C.

Diseases and pests The fungus *Stenella australiensis* was found to attack *B. indicum* in Australia.

Genetic resources and breeding Germplasm collections or breeding programmes are not known to exist for *Blechnum*.

Prospects *Blechnum* comprises a range of interesting species with variable uses including edible young leaves and rhizomes as well as medicinal applications. The ornamental value of several species may have commercial potential. More research is needed to evaluate the possibilities for domestication and to determine the food value of the edible species and the active principles of the medicinal species.

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F.X. Inawati

Cephalomanes javanicum (Blume) van den Bosch

Hymenophyll. javan. 30, pl. 22 (1861).
HYMENOPHYLLACEAE
$2n$ = ca. 64

Synonyms *Trichomanes javanicum* Blume (1828), *T. laciniatum* Roxb. (1844).

Vernacular names Indonesia: pakis kartam (general), taimalaulau, sikai'kai'batak (Siberut).

Origin and geographic distribution *C. javanicum* is distributed throughout South-East Asia.

Uses In Peninsular Malaysia, *C. javanicum*, dried and mixed with garlic and onions, was smoked like tobacco to cure headache. In northern Siberut (Indonesia), it is one of the ingredients of a medicine used to treat wounds caused by snake bites. *C. javanicum* has also gained some popularity as an aquarium plant.

Production and international trade *C. javanicum* plants produced as aquatic ornamental are traded on a very small scale.

Properties *C. javanicum* contains flavonoids.

Description Rhizome erect, bearing many rather thick roots and with the leaves in dense tufts. Leaves monomorphous, pinnate; petiole 1.5–15 cm long, not winged, densely setose when young, glabrescent; lamina odd-pinnate, lanceolate, 5–25 cm × 1.5–5 cm, base obtuse, apex acuminate, lustrous dark green, stiff membranaceous, glabrous; rachis narrowly alate, setose but glabrescent; pinnae lanceolate-oblong, up to 0.8 cm × 2.5 cm, gradually shorter towards the leaf apex, subsessile, base cuneate, margin serrate, apex acute; venation anadromous. Sori on the acroscopic lobes, placed on a receptacle with a long protuberance from a tubular involucre that is immersed within the leaf-tissue; involucre 2 mm × 1 mm, truncate at the apex.

Growth and development The spores of *Hymenophyllaceae* contain chloroplasts that start to divide within the spore coat and are short-lived. The development of the filamentous or ribbon-like prothallium is slow, often taking a few years until it is mature.

Cephalomanes javanicum (Blume) Bosch – 1, habit; 2, part of leaf with sori.

Other botanical information *Cephalomanes* C. Presl comprises about 60 species, distributed pantropically but with the highest concentration in the Old World tropics. *C. javanicum* is very variable in size and sometimes young plants are already fertile with only a few sori in the upper small pinnae. The sori of well-grown plants are nearly all on the middle to upper part of the acroscopic side of pinnae on the upper half of the leaf, not or only rarely reaching the apex of the pinnae. The receptacle of the sori is often very long when old and it sometimes has an enlarged tip (hence the name *Cephalomanes*).

Ecology *C. javanicum* is a terrestrial, rheophytic fern, common near streams in lowland forest, either on rocks or rooted in earth. The thick spreading roots enable it to withstand fast flowing water in floods. All *Hymenophyllaceae* have very thin leaves and need a permanently high air humidity.

Propagation and planting *C. javanicum* can be propagated by spores and by rhizome cuttings bearing at least one crozier. It is not very well suited as an aquarium plant because it is not

aquatic at all. When submerged it merely survives for a while, but hardly grows.

Harvesting For traditional medicinal use, the whole plant of *C. javanicum* is collected, cleaned, dried and stored until needed.

Genetic resources and breeding Germplasm collections are available at the fernarium of the Universiti Kebangsaan Malaysia in Bangi, Selangor, Peninsular Malaysia. No breeding programmes are known to exist.

Prospects Since *C. javanicum* is rather limited in its applications in South-East Asia, it is anticipated that it will remain a minor plant resource in the region.

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G. Rusea

Ceratopteris thalictroides (L.) Brongn.

Bull. Sci. Soc. Philom. Paris, sér. 3, 8: 186 (1821).

PTERIDACEAE

$2n$ = 154, 156 (tetraploid, two reproductively isolated cytotypes)

Synonyms *Acrostichum thalictroides* L. (1753), *A. siliquosum* L. (1753), *Ceratopteris siliquosa* (L.) Copel. (1935).

Vernacular names Floating stag's horn, pod fern, oriental water fern (En). Water sprite (Am). Indonesia: paku tespong, paku cai, pakis rawa. Malaysia: paku ruan, paku roman, sayur kodok. Philippines: makahirak-hirak, pakong sungai, pakong tubig. Laos: kok karn pu. Thailand: phak khaakhiat, phak kuutnam, phak kuut kao kwuang. Vietnam: r[as]ng g[aj]c nai, quy[ees]t g[aj]c nai, rau c[aaf]n tr[oo]i.

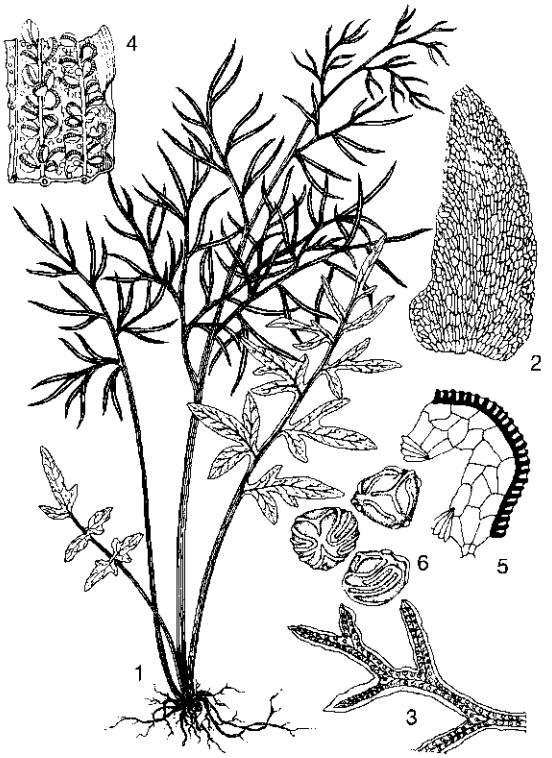
Origin and geographic distribution *C. thalictroides* is distributed worldwide in the tropics and subtropics, including South-East Asia. Because of its aquatic or semi-aquatic ecological requirements, in South-East Asia it is often a common weed in irrigated rice fields.

Uses In South-East Asia especially the young leaves of *C. thalictroides*, before they have uncurled, make excellent greens and when cooked can be eaten as a salad or as a substitute for asparagus as a vegetable. In the Philippines this is the only fern ever grown as a food crop. In Thailand, young leaves are often blanched first. Plants can be used as a green manure in rice fields. Medicinally, this fern is used in Malaysia and the Philippines as a poultice against skin complaints, in China as a styptic to stop bleeding. *Ceratopteris* species, including *C. thalictroides*, are commercially used as ornamentals in aquaria and as model plants in all kinds of plant-based research. It is extremely useful for research because it has independent haploid and diploid life phases (thus combining features of higher and lower plant systems), a short life cycle, a simple genetic system and reproduction by single-celled haploid spores allows for the screening of extremely large numbers of individuals in a small space.

Production and international trade For use as a green vegetable or as a medicine, production and trade of *C. thalictroides* in South-East Asia is limited to local markets. Worldwide it is much sold in fish hobbyist stores as a popular, easy-to-grow aquarium plant, popularly called 'water sprite'.

Properties Per 100 g edible portion, young fern leaves of *C. thalictroides* contain approximately 230 mg protein, 150 mg P_2O_5, 150 mg CaO, 120 mg Fe and 300 mg Mg. Alkaloids, arbutin and tannin have been found in the green parts.

Description A highly polymorphic, unbranched, light green, aquatic or semi-aquatic fern, usually rooted in soil, up to 1 m tall. Rhizome short, erect, sparsely scaly, bearing a rosette-like tuft of leaves; scales broadly ovate, 2 mm × 1.5 mm, base truncate or cordate, entire, apex acute terminating in a thin, glandular, translucent cell with dark lateral cell walls; roots borne on the petiole at or near the base. Leaves dimorphous, succulent; petiole thick, fleshy, sometimes inflated, filled with large air-cells, up to 50 cm long and 1 cm in diameter at base, rounded and ribbed on the underside, flattened and smooth above, sparsely scaly with broad, flaccid, appressed, often circular or reniform, light brown scales; rachis and other axes of the leaf herbaceous with tissue virtually



Ceratopteris thalictroides (L.) Brongn. – 1, habit; 2, petiole scale; 3, fertile pinnules; 4, sporangia along lateral parallel veins; 5, sporangium; 6, spores.

undifferentiated and continuous from the axes onto all the various segments; sterile laminas 1–3-pinnate, subdeltate to ovate or oblong, 2–40 cm × 2–20 cm, usually shorter and wider than in fertile leaves, glabrous, often provided with proliferous buds in the axils of pinnae or sinuses of segments; sterile segments lobed or incised, up to about 12 cm long, ultimate lobes linear, acute; fertile laminas larger, more erect and more copiously divided, 3–4-pinnate, up to 100 cm × 50 cm, pinnules divided into linear acute lobes up to 5 cm × 2 mm, the margin revolute and covering the sporangia; mature leaves turn brown and will expose the sporangia which then start releasing spores. Sporangia scattered individually along the veins on the lower lamina surface, short-stalked (appearing sessile), large, the annulus longitudinal, irregular, composed of 20–71 slightly indurated cells, sometimes interrupted at the apex as well as at the stalk. Spores 32 per sporangium, tetrahedral, 96–124 µm in diameter, pale yellow, translucent, with raised superficial lines forming a network of irregular long meshes.

Growth and development The buds present in the axils of the pinnules of *C. thalictroides* can serve as a means of vegetative propagation which is supposed to be the principal mode of reproduction. The depth of water in which spores will germinate is unknown. Old plants are always more or less submerged in water at their bases, where they also can bear roots. The length of the stipes is probably determined by the depth of the water. Young plants mainly produce sterile leaves; on well-grown mature plants leaves are usually fertile. *C. thalictroides* has a short, upright rhizome and often grows as an annual. In non-seasonal waters, however, it may live for several years and attain a considerable size. In vitro, a spore germinates in 3 days on a simple inorganic nutrient medium and a mature gametophyte develops within 6 days of germination. The gametophyte consists of a small (less than 2 mm), simple, two dimensional thallus with rhizoids, vegetative cells and sexual organs (antheridia and archegonia). Sexual differentiation is controlled by a pheromone. In the presence of water the antheridia release sperms which swim to the archegonia to fertilize eggs. After fertilization the zygote starts to grow, becoming a 5–20 cm tall sporophyte with a short upright rhizome, roots and leaves. When mature, spore production is continuous by meiosis, which occurs within the sporangia that are located on the margins of fertile leaves. Spores remain viable for many years and can be stored at room temperature. The whole cycle from spore to spore can be completed in less than 30 days. Detached juvenile leaves placed on moist soil readily produce aposporous prothalli. Older leaves produce shoot buds under these circumstances.

Other botanical information The genus *Ceratopteris* Brongn. comprises an ancient group of ferns which has been variously classified, mainly because its evolutionary relation to other genera or groups is not clear as a result of extinction. Here it is classified in the subfamily *Ceratopteridoideae* of the family *Pteridaceae*. In the literature it has been classified in, for example, *Adiantaceae, Parkeriaceae*, or in the so-called *Adiantum*-group. *Ceratopteris* comprises 3–4 species, all edible, most of them diploid ($2n = 78$) but *C. thalictroides* is tetraploid. *C. pteridoides* (Hook.) Hieron. is principally limited to Central and South America, but in South-East Asia it also occurs in Vietnam. It is easily recognized by its simple sterile leaves. *C. cornuta* (Beauv.) Le Prieur is mainly confined to tropical Africa and is nowhere common; it much resembles *C. thalictroides* and in the past the two

were often considered identical. *C. richardii* Brongn. occurs in tropical America and Africa, but it much resembles *C. thalictroides* and it is questionable whether it is a different species (diploid, 16-spored sporangia, against tetraploid and 32-spored sporangia in *C. thalictroides*).

Ecology In South-East Asia, *C. thalictroides* is commonly found in swamps, shallow water rice fields, along ditches and ponds with the greater part of its leaves exposed to air, throughout the lowlands in sunny locations. Its life cycle makes the plant well adapted to seasonal fluctuations in the water level.

Propagation and planting Propagation of *C. thalictroides* is by spores, by rhizome cuttings and by a kind of bulbil (bud) present in the axils of pinnules. Spores can float on water; they will germinate readily and produce young plants both submerged in water and on the surface of wet mud exposed to air. Submerged plants develop most quickly.

Husbandry *C. thalictroides* is sometimes cultivated for food but not commercially. Farmers harvest the plants from rice fields and swampy locations for local consumption. In the Philippines it was once cultivated in a paddy field on a larger scale, but was destroyed by a fungus.

Diseases and pests In the Philippines plants of *C. thalictroides* were completely destroyed by an unidentified fungus.

Harvesting Young leaves of *C. thalictroides* are collected for cooking while mature plants are used for green manure.

Genetic resources and breeding *C. thalictroides* is distributed pantropically and is not in danger of extinction. Germplasm collections or breeding programmes are not known to exist, also because in agriculture it is considered a weed. Its value as a model plant for plant breeding research is considerable.

Prospects In most areas the use of *C. thalictroides* as a vegetable or as a green manure is also a method of weed control in rice fields. With increasing use of herbicides its weedy occurrence will decrease and possibly also its consumption. In South-East Asia it will remain a fern of minor importance. Its use as an aquarium ornamental and as a model plant in research will guarantee a continuing interest.

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Chanpen Prakongvongs

Cheilanthes tenuifolia (Burm.f.) Swartz

Syn. fil.: 129, 332 (1806).

PTERIDACEAE

$2n = 56–60$ (diploid), 112–120 (tetraploid)

Synonyms *Cheilanthes hispidula* Kunze (1848), *Cheilanthes moluccana* Kunze (1848), *Cheilosoria tenuifolia* (Burm.f.) Trev. (1877).

Vernacular names Narrow-leaved lip fern (En). Indonesia: paku jepun (Sundanese), paku alus (Moluccas), paku resam lumut (Bangka). Malaysia: resam lumut, resam padi, paku telur belangkas. Philippines: pakong-roman (Tagalog). Thailand: chon phee (peninsular). Vietnam: th[aaf]n m[oo] l[as] m[ar]nh.

Origin and geographic distribution *C. tenuifolia* is distributed in the tropics of Asia and Oceania, from northern India, Sri Lanka, southern China and Taiwan, throughout South-East Asia to Australia and many Pacific islands.

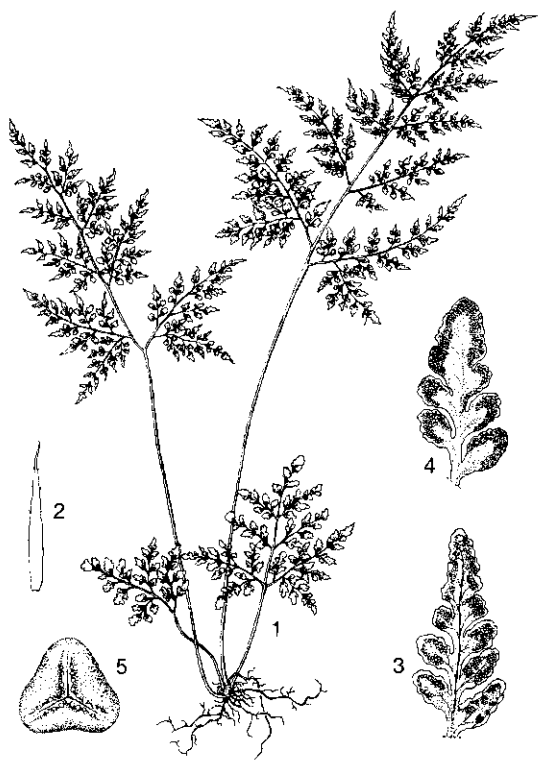
Uses In Peninsular Malaysia, a decoction of *C. tenuifolia* is traditionally used as a hair tonic (to thicken hair), and the ashes of its burnt leaves mixed with those of other plants (e.g. *Biophytum* sp., *Hedyotis* sp. and a wild pepper) are powdered over newborn infants. In Indonesia (Ambon), people also traditionally use a decoction of the plant as a hair tonic, as a substitute for maidenhair fern (*Adiantum* spp.). *C. tenuifolia* is also valuable as an ornamental.

Production and international trade No international trade of *C. tenuifolia* exists and it is not cultivated commercially. The plants are collected from the wild whenever needed.

Properties Reports of toxicity of *C. tenuifolia*

are based on Australian literature and probably refer to *C. sieberi* Kunze.

Description A small, terrestrial fern, up to 70 cm tall, with triangular, long-stalked leaves and marginal sori. Rhizome ascending, much branched, wiry, about 7 cm × 3 mm, clothed with subulate, entire scales, 2–4 mm × 1 mm, light to dark brown. Leaves many, densely tufted, dimorphous, the sterile ones usually much smaller than the fertile ones; petiole slender, up to 45 cm long on fertile leaves, usually about 1.5 times the length of the lamina, much shorter (4–6 cm) on sterile leaves, lustrous dark brown, bearing scattered short brown hairs, sometimes glabrescent when old, slightly swollen and densely scaly at base, sparsely and minutely scaly near apex, sulcate above; sterile laminas ovate to broadly deltoid, about 10 cm × 8 cm, quadripinnate below, grading through tripinnate to pinnate at the apex, chartaceous, all parts setose; pinnae subopposite, approximate to imbricate; rachis coloured as petiole, distally green, glabrous, ribs sparsely hairy or glabrescent; pinnae deltoid to ovate, inequilateral, more developed towards the base, up to about 6 cm long, the lower ones stalked; pinnules ovate to oblong, 2–5 mm × 2–3 mm, sessile, lobed or entire, the first one on the basal pinnae 1.5–2 times as long as the next one; ultimate divisions elliptical, the largest about 3 mm long, entire or slightly lobed; veins dark, simply or double forked in the larger leaflets, invisible above, distinct below; fertile laminas similar but larger, up to 30–70 cm × 7–22 cm, the pinnae more distant. Sori rounded, marginal, confined to the end of veins on the lower pinnule surfaces but appearing continuous at margin of lobes, when young protected by inrolled margins of lobes, edges uneven, pellucid, black; sporangia almost globular, 0.1 mm in diameter, short-stalked, 10–20 per sorus, with a vertical annulus of 16–19 cells. Spores trilete, tetrahedral, 40–60 μm × 41–46 μm, with reticulate-echinate ornamentation, brown or nearly black, 32 per sporangium.



Cheilanthes tenuifolia (Burm.f.) Swartz – 1, habit; 2, scale; 3, lower surface of a portion of a fertile blade with sori and reflexed margins; 4, lower surface of a portion of a fertile blade with sori and unreflexed margins; 5, spore.

Growth and development A spore of *C. tenuifolia* germinates readily in culture; rhizoids emerge within 2 weeks after sowing. The prothallus reaches maturity about 6 months after germination of the spore and the gametophyte is cordate, about 1 cm long, glabrous, with a prominent midrib bearing rhizoids and sex organs. The midrib is 6–8 cells thick and the wing cells are uniformly thin-walled. Antheridia mostly globose, appearing superficially on the underside, occasionally on the margins, when the prothallus is about 2 mm wide (after about 40 days) and still one cell thick. The archegonial neck is composed of 6 tiers of cells and curved. Fertilization and formation of sporophytes occurs profusely in culture and generally only a single sporophyte develops per prothallus. The first juvenile leaf is entire, broadly cuneate to spatulate, with a single median vein dichotomizing equally once or twice, hairy especially on the margin. *C. tenuifolia* grows actively during the rainy season and becomes dormant in the dry season.

Other botanical information In the literature, *Cheilanthes* Swartz can also be found classified in other families such as *Adiantaceae, Parkeriaceae, Polypodiaceae, Sinopteridaceae* or in the so-called *Adiantum* group. Within the *Pteridaceae*, *Cheilanthes* is classified in the subfamily *Cheilanthoideae*, including genera such as *Llavea* Lagasca and *Pellaea* Link. *C. tenuifolia* is a variable species. In Queensland (Australia) two subspecies are distinguished, subsp. *tenuifolia* (syn-

onyms: *C. sciadiodes* Domin, *Notholaena sciadiodes* Domin) and subsp. *shirleyana* Domin (synonym: *C. shirleyana* (Domin) Quirck & T. Chambers) which differ in lamina characteristics. In subsp. *tenuifolia* the lamina is ovate to broadly triangular in outline, usually at least twice as long as wide, the basal branches of the basal pinnae on the lower side not markedly enlarged, ultimate segments of fertile leaves with margins bearing small, obtuse lobes which may or may not be reflexed, partly covering the sori. In subsp. *shirleyana* the lamina is broadly pentagonal, about as long as wide, basal branches of the basal pinnae markedly enlarged; ultimate segments of fertile leaves irregularly crenate, the margins reflexed almost continuously along each side of a segment, covering or partly covering the sori.

The combination *Cheilanthes tenuifolia* has also been applied to 2 other species: *C. insignis* Ching (1974) (homonym: *C. tenuifolia* C. Chr., 1924), and *C. chusana* Hook. (1858) (homonym: *C. tenuifolia* Hook., 1862).

In Burma (Myanmar) leaves of *C. farinosa* (Forssk.) Kaulf., a pantropically distributed species with characteristic white-powdery leaf undersides, form part of religious temple offerings. Bouquets of the leaves which grow abundantly nearby, are left amongst offerings at the temple on Mt Popa, an extinct volcano.

Ecology *C. tenuifolia* occurs often on unfertile, dry or humid, rocky ground in open forest areas, on old stone or earthen walls, sometimes amidst alang-alang (*Imperata cylindrica* (L.) Raeuschel) or as a weed on ridges in plantations, sometimes gregariously, from sea-level up to 1500 m altitude. It is drought-resistant but also grows well in areas with abundant rainfall. In regions with a pronounced dry season the aboveground parts wither and the plant resumes growth after the first rains. It is often able to regenerate when the grassy vegetation in which it grows is mowed not too close to the ground.

Propagation and planting Natural propagation of *C. tenuifolia* is by spores, and it is said to have an apogamous character. It is easier to grow than other species of *Cheilanthes* and does best under semi-protected conditions.

Harvesting Leaves of *C. tenuifolia* are collected from the wild and used fresh, as decoction or stored dry.

Genetic resources and breeding *C. tenuifolia* seems not to be in danger of genetic erosion as it is distributed widely and is rarely collected on a large scale. However, the spore number in each sporangium and the type of spore germination indicate that the species reproduces apogamously. If sexual reproduction is absent *C. tenuifolia* will genetically remain less variable and evolutionary perhaps be in danger. Germplasm collections or breeding programmes are not known to exist.

Prospects Since *C. tenuifolia* is used in South-East Asia as a medicine and because it has potential as an ornamental, research on the possibilities for its domestication is worth considering.

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Dedy Darnaedi & Titien Ngatinem Praptosuwiryo

Cibotium barometz (L.) J. Smith

London Journ. Bot. 1: 437 (1842).

DICKSONIACEAE

$2n = 136$

Synonyms *Polypodium barometz* L. (1753), *Aspidium barometz* Willd. (1810), *Dicksonia baranetz* Link (1841).

Vernacular names Scythian lamb, Tartarian lamb, golden lamb (En). Indonesia: penawar jambi, paku simpai, bulu jambe. Malaysia: penawar jambi, bulu pusi, bulu empusi. Philippines: borabor (Ilokano), salagisog (Bikol), tinampa (Igorot). Thailand: kut phipa (northern), wan kai noi (central), ninla phosi (peninsular). Vietnam: c[aar]u

t[is]ch, l[oo]ng cu li, r[as]ng c[as]t tu, c[aa]y l[oo]ng kh[ir].

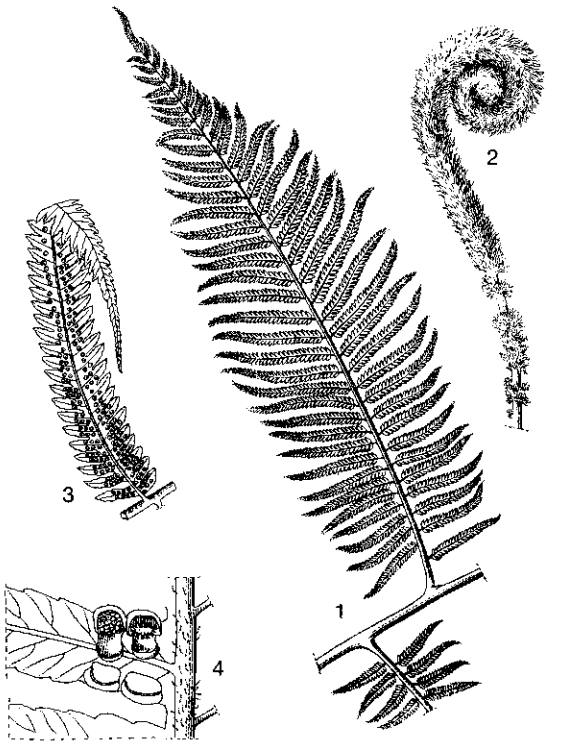
Origin and geographic distribution *C. barometz* occurs from north-eastern India to southern China and Taiwan, throughout continental South-East Asia and to Sumatra, Java, the Philippines and north to the Ryukyu Islands.

Uses The golden-coloured hairs on the rhizome and young parts of *C. barometz* and other *Cibotium* species have long been used in China, South-East Asia and elsewhere as a styptic to stop bleeding. In China and Japan an extract of the rhizome ('gouji') is used as an antirheumatic, to stimulate the liver and kidneys, to strengthen the spine, to expel wind and dampness, and as a prostatic remedy. On indication of deficiency of the liver and kidneys, manifested as pain in the lower back and knees, gouji is used with the bark of the hardy rubber tree (*Eucommia ulmoides* Oliv.), teasel root (*Dipsacus* sp.) and cyathula root (*Achyranthes bidentata* Blume). When accompanied by invasion of wind and dampness, manifested as soreness and pain in the lower back and knees and motoric impairment, gouji is used with cinnamon twigs, bigleaf gentian root (*Gentiana macrophylla* Pall.) and futokadsura stem (*Kadsura japonica* Dunal). In the Philippines, the stem is used to treat topical wounds and ulcers. In Malaysia an infusion of the leaves is said to cure fainting. The hairs have also been used to stuff pillows and cushions; such pillows are very cool during warm nights and are well suited to use in the tropics, but the hairs easily break when they become dry and they can irritate the skin and lungs when they pass through the pillow case. In general, all *Cibotium* species have also ornamental value and, e.g. crowns with croziers are cut for table decoration. In China a diluted solution of plant parts is used to control aphids and spider mites. The hairy rhizome of *C. barometz* is supposed to have given rise to the fable of the Scythian lamb (Tartarian lamb, vegetable lamb) which was said to grow on a stalk like a plant and to devour plants (or just air) around it. The suggestion is that a piece of the rhizome of *C. barometz*, with 4 stipes attached, inverted, may have had a lamb-like appearance. Such pieces of rhizome were sold from a very early date for their hairs which will staunch a bleeding wound. They were also used as charms hung in houses to ward off evil. Such pieces are still sold as charms in the Philippines, Malaysia and Taiwan. When forests were cleared in Peninsular Malaysia in the 1970s, many such tree ferns became accessible to collectors who cut off their apices and sold them in pots as Golden Chicken plants, to be used as table ornaments and charms. The vendors claimed that these plants would keep the house cool, ward off evil and cure certain illnesses.

Production and international trade In the past the golden yellow hairs (variously called 'pili cibotii', 'agneau de Scythie' or 'golden moss') of *C. barometz* were a much-traded medicinal commodity, for which around 1900 a new, strong, worldwide demand arose because its styptic qualities were far better than those of chemical products. Its common trade name was 'penawar jambi'. Interest declined, however, in South-East Asia as supply was unable to meet demand at the time. No further information exists on its current use, but there is still international trade in the hairs, e.g. a single French company is known to process 100 kg of 'pili cibotii' per year. Dried rhizome parts ('rhizoma cibotii') are offered for sale by companies selling herbals. In its trade as an ornamental there is some confusion with *Macrothelypteris torresiana* Gaud. In the medicine trade it is also known by the Chinese name 'gou ji' as well as 'chain fern', which is normally associated with *Woodwardia* sp.

Properties A chemical analysis of *C. barometz* in Japan revealed that 100 g of the aboveground parts contained 11 mg pterosin R, 24 mg onitin, 75 mg onitin-2'-O-β-D-glucoside, and 13 mg onitin-2'-O-β-D-alloside. The rhizome also contains up to 8% (but usually much less) of an oil, of which palmitic acid and linoleic acid were the major constituents. In the rhizomes of several *Cibotium* species starch is present in extractable amounts. In Hawaii it is extracted from *C. chamissoi* Kaulf., but in general it is only extracted in case of serious food shortage.

Description A large tree fern with stem usually creeping and, like the petiole bases, covered with stiff, golden hairs. Caudex (trunk) massive, prostrate to erect, up to 2–3 m long, the young parts at the top very densely covered with shiny golden-brown hairs up to more than 4 cm long, young plants softly hairy throughout. Leaves in a tuft at the apex of the trunk; petiole stout, sometimes attaining 2 cm in diameter, more than 1.5 m long in larger ones, brownish, bases hairy like the caudex, the rest tomentose when young, glabrescent when old; lamina bipinnately compound, ovate to elliptical in outline, up to 2 m × 1 m, under side glaucous, upper side darker green, at underside the veins with pale, entangled, flaccid, appressed hairs (young plants hairy throughout);



Cibotium barometz (L.) J. Smith – 1, pinna-rachis with pinnules; 2, crozier; 3, pinnule (lower surface) with sori; 4, part of pinnule showing sori, inner and outer indusia.

rachis brown, densely covered with pale to ferrugineous hairs; pinnae many, alternating, pinnate-pinnatifid, in outline oblong to lanceolate, the largest ones up to 80 cm × 25 cm, stalk 0.5–1 cm long, apex acuminate; pinnules numerous, often with a few pairs of tertiary leaflets at the base, deeply pinnatifid throughout, very shortly stalked or subsessile at distal parts of pinnae, linear-lanceolate, 10–15 cm × 1.5–2.5 cm, broadly cuneate to subtruncate at base, gradually narrowing towards acuminate apex; ultimate divisions oblong, oblique to subfalcate, 0.8–1.4 cm × about 3 mm, acute at apex, shallowly but distinctly dentate at margin; veins distinct, oblique, once (or twice in larger lobes) forked, sparsely hairy below. Sori protected by two indusia which are alike in texture and different from the green lamina; outer indusium deflexed so that the sorus appears to be on the underside of the lobe, permanently round; inner indusium at maturity bending back towards the costule and elongating, becoming oblong; the two indusia joined together for a short distance at their bases, thus forming a small cup, terminal on usually unbranched lower veins, 2–4 or more pairs on a lobe on the largest leaves, parallel to edge of lobes; paraphyses long and numerous; sporangia gradate, annulus oblique and opening laterally. Spores with equatorial ridge, annulate or annulotrilete; exine with proximal face bearing 3 rows of short laesural ridges, distal face with a distal ridge.

Growth and development When a spore of *C. barometz* germinates it first develops the gametophyte which has no remarkable features except for its primitive antheridia. Although *C. barometz* usually develops as a prostrate creeper, sometimes the stem apex is ascending.

Other botanical information *Cibotium* Kaulfuss comprises 11 species, 3 in Asia, 2 in Central America and 6 in Hawaii, and has also been classified in *Culcitaceae, Cyatheaceae, Cystodiaceae* and *Thyrsopteridaceae*, indicating its somewhat isolated position because it is old and primitive and phylogenetic relations are not clear as a result of extinction. The name 'barometz' derives from the Russian 'baran', a lamb, 'baranets', a diminutive form; some authors prefer the more correct spelling 'baronetz' for the name of this species, but Linnaeus used 'barometz'.

In Indonesia, hairs of the related tree fern *Dicksonia blumei* (Kunze) Moore have been used as a substitute for those of *C. barometz* as a styptic for bleeding wounds. *D. blumei* is only found at altitudes of 1500–2500 m in Indonesia (Sumatra, Java and Sulawesi) in mountain forest. It has a trunk up to 6 m in length with leaves up to 3 m long; the substitute hairs are pale (some are reddish), slender, rigid and spreading and can be found as an undercoat of the petiole base, on the lower surface of pinna-rachis and costae; the petiole base is clothed with much longer spreading red-brown shining hairs 3–5 cm long. It is likely that hairs of other *Dicksonia* species (there are 7 in South-East Asia, particularly in New Guinea) have being used similarly.

Ecology *C. barometz* grows on open hill slopes and stream banks in tropical evergreen forest at 500–800 m altitude, and in lower mountain forest at 1000–1600 m altitude, preferably on non-calcareous soils. It becomes prolific in areas where the forest is disturbed. The thick, prostrate caudex is not killed by light burning.

Propagation and planting *C. barometz* grows from spores and in the wild it possibly chiefly spreads by the establishment of new plants on landslides. In the Botanic Garden of Singapore it

grows well amongst old coral rocks in moderate shade.

Husbandry *C. barometz* is not cultivated commercially. The plant is hardy and easily grown. It will grow in sun or shade, needs good drainage and responds to mulch and extra water during dry periods.

Harvesting The hairs of *C. barometz* are harvested whenever needed. For medicinal use, the rhizomes are dug in autumn.

Handling after harvest The harvested rhizome of *C. barometz* is cleaned of soil and the fibrous roots are removed, then soaked in wine for one day, steamed, cut into slices, dried in the sun and used or stored.

Genetic resources and breeding In most countries where it occurs naturally, *C. barometz* is becoming rare due to the uncontrolled collection of the rhizome parts for medicinal purposes. *C. barometz* has been included in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) which means that no export is allowed (except for spores and seedling or tissue cultures obtained in vitro) without a prior permit issued by the CITES committee. *C. barometz* needs protection and germplasm collection. Breeding programmes do not exist but cultivation for medicinal and ornamental purposes is recommended.

Prospects In the past *C. barometz* was an important source of medicine in China, Europe, Indonesia, the Philippines and Thailand, and it is still being used in South-East Asia in traditional medicine. Research on the possibilities for its domestication also outside its natural habitat may be considered to meet the increasing demand for its hairs and as an ornamental.

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Titien Ngatinem Praptosuwiryo

Cyathea J.E. Smith

Mém. Acad. Turin 5: 416 (1793).

CYATHEACEAE

$x = 69$; all species: $2n = 138$

Major species and synonyms

- *Cyathea amboinensis* (Alderw.) Merr., Interpr. Rumph. Herb. Amboin.: 63 (1917), synonyms: *Alsophila latebrosa* Wall. ex Hook. var. *batjanensis* Christ (1900), *A. amboinensis* Alderw. (1916).
- *Cyathea contaminans* (Wall. ex Hook.) Copel., Philip. Journ. Sci., Bot. 4: 60 (1909), synonyms: *Chnoophora glauca* Blume (1828) [not *Cyathea glauca* Bory (1804)], *Alsophila glauca* (Blume) J.E. Smith (1841), *A. contaminans* Wall. ex Hook. (1844).
- *Cyathea junghuhniana* (Kunze) Copel., Philip. Journ. Sci., Bot. 4: 58 (1909), synonyms: *Alsophila junghuhniana* Kunze (1848), *Hemitelia javanica* Presl (1851), *H. junghuhniana* (Kunze) Mett. (1859).
- *Cyathea lurida* (Blume) Copel., Philip. Journ. Sci., Bot. 4: 45 (1909), synonyms: *Chnoophora lurida* Blume (1828), *Alsophila kingii* Clarke (1883), *Cyathea kingii* (Clarke) Copel. (1909).
- *Cyathea moluccana* R. Br. in Desv., Mem. Soc. Linn. Paris 6: 322 (1827), synonyms: *Schizocaena brunonis* J.E. Smith ex Hook. (1838), *Cyathea brunonis* (J.E. Smith ex Hook.) Wall. ex Hook. (1844), *C. pinnata* Roxb. (1844).

Vernacular names General: tree ferns (En). Indonesia: paku tiang, paku pohon. Malaysia: paku gajah (Malay), paku papan (Orang Asli). Vietnam: r[as]ng ti[ee]n t[oj]a.

- *C. amboinensis*: Indonesia: paku itam (Malay, Ambon), hahuru meten (Ambonese), lemputu (Balinese).
- *C. contaminans*: Blue tree fern (En). Indonesia: paku pohon (general), pakis arjuno (Javanese), paku tihang bodas (Sundanese). Malaysia: paku gajah gunung (Malay), suo luo (Chinese). Philippines: pakong buaya, anonotong, gantaw. Thailand: hua ai pet (central). Vietnam: r[as]ng ti[ee]n t[oj]a b[aaf]n, r[aw]ng d[ee] th[aa]n g[oox].
- *C. junghuhniana*: Indonesia: paku lutung, paku reong (Sundanese).
- *C. lurida*: Indonesia: paku tihang beureum (Sundanese).
- *C. moluccana*: Indonesia: paku itam paya (general). Malaysia: paku gajah paya, paku hitam paya, paku pahat (Malay).

Origin and geographic distribution *Cyathea* comprises 600–650 species and is distributed in the warmer parts of the world, including the tropics and subtropics, but not in the north-temperate zone or in dry areas. The greatest variety is found on tropical mountains. In South-East Asia about 200 *Cyathea* species are known. *C. amboinensis* is a native of Indonesia (Sulawesi, Moluccas). *C. contaminans* occurs naturally from northern India throughout South-East Asia. *C. junghuhniana* is confined to Indonesia (Sumatra, Java). *C. lurida* occurs in Indonesia (Sumatra, Java), Peninsular Malaysia and the Philippines. *C. moluccana* occurs naturally in Malaysia (Peninsular Malaysia, Sarawak, Sabah), Brunei and Indonesia (Sumatra, Kalimantan, Sulawesi, Moluccas). Numerous species are also cultivated as ornamentals.

Uses Young leaves of most tree ferns are edible. After peeling or scratching off the outer layer, the young curled-up leaves are cut into small pieces and steamed, boiled or scalded and eaten as a vegetable and also used as an ingredient in more complicated dishes containing coconut milk, spices and relishes. Young leaf rachises of *C. contaminans* are peeled to remove the spines, then cut into pieces and steamed or cooked and eaten with 'sambal'. Older leaves are sometimes used as forage. The starchy pith of the stem is used as food in some countries. When trees are cut for this purpose the top of the stem is cut off to lengths of about 0.3 m, the pith being cut further into smaller pieces and steamed with rice. The mixture of cooked rice and fern pith is said to have a fresh and rather pleasant taste, but in general it is considered as subsistence food at present, as the starch content is not very high and the resulting meal not particularly palatable.

Tree ferns are grown in gardens as ornamentals and *C. contaminans* is the largest and most handsome one but many other species are also attractive. The fibrous root-encrusted trunks of tree ferns are a source of fern-fibre. The trunks with larger amounts of fibre are cut down, planted upside down in decorative gardens (mostly in the urban areas) or used as a substrate for certain types of epiphytic ferns and orchids. Often the fibre is cut off in slabs and used for a similar purpose. Crushed fibre is also used as a growing medium, pure or in mixtures with other material. The mass of adventitious roots at the base of the trunk of several species has a pot-like shape and is often used for potting orchids. In some countries a regular industry has been established around the supply of tree fern fibre to horticulturists.

In New Zealand a small, cottage-scale industry has developed around the production of lamp stands and bases turned from the trunks of *Cyathea* on a wood lathe; the turning reveals the intricate interwoven design of the dark structural material of the trunk and leaf gaps. This is an industry that would lend itself to village communities in Papuasia, but has not yet been introduced. The stems are also cut and carved as ornamental vases and other objects such as pencil and umbrella holders. Any part is used for inlaying and to make small fancy boxes and frames. 'Bull roarers' are made from the woody parts of the trunks of *C. contaminans* and used on ceremonial occasions (a bull roarer is a flat piece of wood attached to a 1 m long string, making a roaring sound when it spins in the air while the string is swung around). In New Britain the wood is used for crafting fishing spears.

Old tree fern trunks are strong and remarkably durable and can be used for building and hedging. In the highlands of New Guinea the common grassland tree ferns at middle altitudes (*C. angiensis* (Gepp) Domin, *C. contaminans*, *C. magna* Copel.) are used as picket fences for gardens and as posts on which huts are built. These tree ferns are very common in the grasslands and in disturbed areas such as abandoned garden sites. After the fern has died, the pulpy pith collapses but the strongly developed sclerotic strands remain. The trunk commonly attains heights of over 5 m, and its lower half is covered with a dense fibrous sheath of tightly interlocking sclerotic roots which provide substantial support. The structural elements of the tree fern trunks are very durable, even in permanent contact with the ground, being immune to attack from nearby decay-causing or-

ganisms. For fences the trunks are planted upside down, next to each other in a row, and lashed together to form a palissade to keep out pigs. For house posts the trunks are also planted upside down and then a deep notch is cut in the wider fibrous end to receive the floor joints. The fibrous bases of the trunks are sometimes incorporated in the house ridge poles or centre poles so that they extend out from the roof; they are then decorated with various species of ferns or orchids. Less commonly they are carved with designs or faces. They are also hollowed out and used as beehives by the Dusun community of Sabah (Malaysia). In Java the hollowed tree trunks have been filled with carbide to make canons for celebrations.

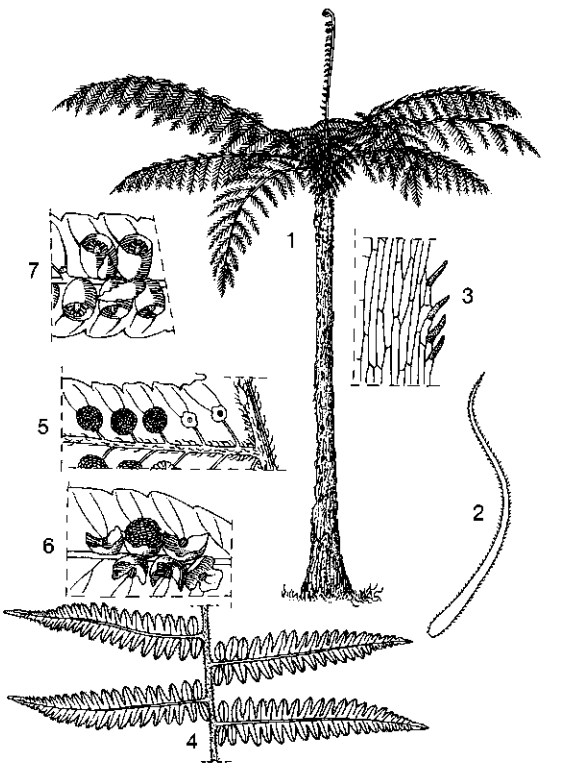
In Papua New Guinea several species are used to produce salt. Their use in farm management plans to soak up excess nutrients and as weed eradicators is questionable.

In Peninsular Malaysia poultices of the leaves are used to treat sores on the legs (e.g. of *C. moluccana*) while infusions of leaves are applied against worms. The hairs on young parts of several species have styptic properties and are used to stop bleeding. Leaves of the African species *C. manniana* Hook. have been used to expel parasitic worms.

Production and international trade *Cyathea* was included in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) in 1975, which means that no export is allowed (except for spores and seedling or tissue cultures obtained in vitro) without prior permit issued by the CITES committee. In the past several South-East Asian countries (Indonesia, Papua New Guinea, the Philippines, Singapore) exported fern stems (e.g. to Japan) in quite large amounts. At present the trade is better controlled because a special CITES export permit is needed. For example, Indonesia has obtained a CITES-export quotum of 45 000 'stalks' for *C. contaminans*. All *Cyathea* species are collected from the wild for domestic use and there is no commercial cultivation of edible young leaves. Mature plants are dug from the wild to be grown as ornamentals but the practice is not widespread. Vases and other articles made from the stems are sold on local markets and roadsides mainly to tourists. In Australia there is a very small amount of trade in cool temperate species between specialist wholesalers of ornamentals. The Netherlands conducts some international trade in artificially propagated tree ferns.

Properties The sclerenchyma of most *Cyathea* trunks is exceedingly hard and durable and provides nearly all the mechanical strength when the trunks are used as posts. It also provides an interesting pattern when cut in different ways and this effect is used in the construction of ornamental objects.

Description Large to very large tree ferns with small to tall, slender to robust caudex; caudex usually erect, seldom climbing or prostrate, from less than 5 cm up to 15(–20) m tall, 2–24 cm in diameter, the apex covered with scales, the surface often bearing a cover of densely matted adventitious roots and prominent leaf scars. Leaves forming a rosette at the top of the stem, essentially monomorphous, pinnately compound; petiole stout, imperfectly deciduous, short to long, bearing scales often inserted on wart to spine-like epidermal outgrowths, sometimes also hairy; pneu-



Cyathea contaminans (Wall. ex Hook.) Copel. – 1, habit. C. moluccana R. Br. – 2, petiole scale; 3, detail of edge of petiole scale. C. lurida (Blume) Copel. – 4, part of sterile pinna. Indusium types in Cyathea spp. – 5, small indusium, completely covered by sorus; 6, indusium attached on costular side and covering part of the base of the sorus; 7, a deep cup indusium.

mathodes present in a discontinuous line or 2–3 lines close together along each side of stipe and rachis; lamina more or less elliptical, lower pinnae always smaller than the middle ones or gradually much reduced and then the petiole short, small to 3.5 m × 1 m, pinnate to bipinnate-pinnatifid, hairs of various kinds rarely on the lamina surface; rachis adaxially sulcate, besides a groove in the middle additional flanking grooves may be present, stramineous to tawny, less often dark and polished, like costae with scales on abaxial and lateral surfaces, at least in early stages of growth; hairs always on upper surfaces of all but the smallest axes, antrorse, sometimes branched; pinnae up to 70 cm × 20 cm, normally again pinnatifid, in a few cases simple, in other cases fully bipinnate; pinnules up to 12 cm × 2.5 cm, almost symmetrical at the base, many on each pinna subequal, distal ones more or less abruptly decreasing; veins free, simple or branched, lower ones usually forked, sometimes pinnate where pinnule-segments are deeply lobed. Sori round, usually at the fork of veins, or seated on a simple vein, a branch of the vein always entering the receptacle; indusium present or absent, if present then either attached all around the base of the receptacle and covering the young sorus, opening to form a firm-edged cup or opening by irregular rupture, or attached on costular side of receptacle and of varying size, in some cases quite hidden by mature sorus; receptacle erect, more or less club-shaped to spherical; sporangia many, always short-stalked, annulus almost vertical, completely bypassing the stalk; paraphyses usually present as multicellular hairs, sometimes flat and several cells wide at base. Spores trilete, tetrahedral to globose, thin-walled, smooth or papillose or irregularly ridged, mostly 64, sometimes 16 per sporangium.

- *C. amboinensis*. Caudex 4–5 m tall. Petiole longer than 50 cm, warty near base; lamina segments firm, strongly crenate; pinnae not greatly reduced proximally, up to 50 cm long; largest pinnules up to 85 mm × 16–18 mm, sessile, lobed nearly to costa; veins in 10 pairs, costules 3.5–4 mm apart, all veins and veinlets bearing many pale bullate scales. Sori near costules; indusium a very small, dark scale on costular side of receptacle; paraphyses abundant, longer than the sporangia.
- *C. contaminans*. Caudex 5–15 m tall and 10–15 cm in diameter, upper part densely covered with scales of the remaining petiole-bases (only in old trees do leaf scars become visible), much thickened by adventitious roots at base. Petiole up to 1 m long, stout, usually strongly spiny, glaucous, purplish towards the scaly base; scales up to 4.5 cm × 3 mm, very thin, pale brown, with dark setae at margin; lamina 1–2 m × 1–1.5 m, green above, glaucous-green beneath, 2–3-pinnate; pinnae up to 80 cm × 30 cm, pinnules about 2.5 cm apart, lanceolate, up to 15 cm × 3 cm but usually smaller, deeply lobed almost to costa, segments oblique, falcate, up to 1.5 cm × 4.5 mm, 5–6 mm apart, crenate at margin. Sori globose, near costules in a double row on the underside of pinnules in older leaves, brown, lacking indusia; paraphyses pale, not longer than the sporangia. *C. contaminans* is easily recognized by the glaucous, purplish and thorny stipe bases.
- *C. junghuhniana*. Caudex up to 5 m tall, diameter 5–7 cm, often branched, petiole bases persistent. Petiole 30–50 cm long or longer, at base with spines up to 3 mm long; scales up to 30 mm × 2 mm, dark shiny; pneumathodes 5–14 mm long in a close double or triple row; lamina 1.5–2.5 m × 1 m, 2–3-pinnate, underside grass-green, never glaucous-green; longest pinnae 55–70 cm long; largest pinnules 80–115 mm × 14–21 mm, lobed almost to costa, margin of lobes subentire to crenate; costules 3–4 mm apart, veins in 10–12 pairs. Sori globose, at underside of older leaves, in a double row near costules, brown, with hemitelioid (attached at costular side of receptacle), semicircular, often inconspicuous indusium and short paraphyses.
- *C. lurida*. Caudex short. Petiole long, very dark, rough near base after fall of scales; scales up to 10 mm × 1.5 mm, pneumathodes 6–9 mm long, widely spaced; pinnae 50(–75) cm long; pinnules dimorphous; largest sterile pinnules 7.5–11 cm × 1.5–2.5 cm, lobed almost to costa, ultimate segments strongly crenate; costules 3.5–4.5 mm apart, veins up to 10 pairs; fertile pinnules much smaller, 6–9 cm × 0.6–1.2(–1.7) cm, costules commonly 3 mm apart, on largest leaves occasionally up to 6 mm, segments then separated by wide sinuses. Sori almost completely covering the lower surface of segments, without indusium, paraphyses shorter than sporangia. *C. lurida* is easily recognized by the dimorphous pinnules with sori completely covering the abaxial surface.
- *C. moluccana*. Caudex up to 50 cm tall. Petiole 20–30 cm long, dark, scaly at base, finely warty when scales have fallen; scales 15–30 mm × 0.5–3 mm, edges with dark setae; lamina simply pinnate, 1.5 m long or longer; pinnae oblong, 12–28 cm × 2–4 cm, base asymmetric rounded

acroscopically, cuneate basiscopically, stalked to sessile and articulate to rachis, margin entire except for crenate, acuminate apex; veins in groups of 3 from the costa, further forking to give a group of 3–6 veins at the edge. Sori in 1–3 rows on each side of the midrib, commonly 4–6 on each vein group, when young usually covered by a thin translucent indusium, at maturity releasing copious, creamy-white spores; paraphyses shorter than the sporangia. *C. moluccana* is easily recognized as a simply pinnate-leaved species, forming only a short trunk.

Growth and development *Cyathea* ferns are slow-growing plants and take many years to reach maximum height. Young leaves are produced regularly but overharvesting of young leaves for food will affect growth. Unlike ordinary trees, tree ferns cannot increase the thickness of their trunk as they grow taller and so in time they outgrow their strength. However, the trunk does increase in effective thickness, especially near the base, as a result of the growth of a dense entangled mass of stiff black roots which completely cover the original trunk, sometimes increasing its thickness several times. Tree ferns usually have a solitary growth habit but are commonly found in association with numerous plants within a small area. Sometimes they grow gregariously. For most species, little is known about the age of individual plants and the longevity of leaves. For young plants of *C. contaminans* the following data from West Java are available: average number of leaves on a plant 6–10; average time between the development of successive leaves 25–28 days; life of a single leaf 165–200 days; time taken for a complete renewal of the whole crown of leaves: 182–243 days; an old tree, 10 m tall, bore 12 leaves and the mean time between unfolding new leaves was 21 days.

Other botanical information *Cyathea* is the only genus of the family *Cyatheaceae*. Little is known about its affinity to other fern families; only *Dicksoniaceae* is regarded as closely related. In the literature the *Cyatheaceae* have often been subdivided into several genera (based on presence or absence and structure of the indusium), e.g. best known are *Alsophila* R. Br. (without indusium), *Hemitelia* R. Br. (with a small indusium attached on one side of the base of the sorus), and *Cyathea* (with a cup-shaped indusium). The presence, however, of hybrids between those genera and the constancy of the chromosome numbers favours recognition of one genus only, the oldest genus name being *Cyathea*. *Cyathea* has been variously subdivided, but the 2 subgenera *Cyathea* and *Sphaeropteris* seem to be most accepted, mainly based on characters of the petiolar scales, and each subgenus with 2 sections and a number of subsections. The most useful feature for distinguishing species of *Cyathea* is the character of the scales of the base of the petiole (edge smooth, edge set with regular short oblique bristles or edge thin with irregular teeth) and scales of the leaf (scales strongly convex so as to appear inflated, or nearly flat, with the edges variously bristly or toothed). *C. contaminans* is the most widespread *Cyathea* species in South-East Asia; it has often been subdivided but most variations are based on characteristics that fluctuate with varying environmental factors. Upon wounding, the stem exudes a bright yellow gum which later turns red-brown.

Many authors have tried to distinguish both *C. latebrosa* (Wall.) Copel. and *C. junghuhniana* in West Java (Indonesia), but the former does not occur there. Fern specimens in herbaria or names in books for ferns in West Java, identified as *Hemitelia latebrosa* (Wall.) Mett. or *C. latebrosa* (Wall.) Copel. are wrong identifications for *C. junghuhniana*. *C. moluccana* was described by R. Brown in 1810, but he forgot to add a name to the fern; in 1827 Desvaux copied the description of Brown and provided the name.

The old trunks of *Cyathea* are the only habitats of the rootless primitive fern ally *Tmesipteris* spp.

Ecology *Cyathea* species are concentrated in the tropics where they are most numerous in montane to alpine vegetation, often in the undergrowth of moist forest, often in ravines. Some species prefer more open habitats, even swamps, and some grow preferentially in cleared areas, sometimes gregariously. *C. amboinensis* is found in forests at low elevations, including swamp forest. *C. contaminans* is common in rather open locations at 200–1600 m altitude, often abundant in forest edges along roads; it needs sun on its crown and moisture at its roots. *C. junghuhniana* occurs, sometimes abundantly, in mountain forest at 1000–2000 m altitude. *C. lurida* is common in sheltered locations on high mountain ridges where a peaty layer of forest litter occurs. *C. moluccana* occurs in light shade and often near streams in lowland forest and at moderate altitudes up to 900 m.

Propagation and planting All *Cyathea* species can be grown from spores, but many tree ferns do not grow well at very low altitudes. Vegetative propagation by tissue culture should be utilised to minimise the destruction of wild stocks.

In Java, *C. contaminans* and *C. junghuhniana* often start growing as weeds in tea plantations.

Husbandry To grow *Cyathea*, the soil should be poor and wet and plants prefer initially a high relative humidity and partial shade, although the requirements differ per species. Too much exposure to sunlight will often result in burnt leaves. Waterlogged conditions are detrimental for most species.

Diseases and pests *Cyathea* growing in natural stands is generally free from serious diseases and pests. Caterpillars of various insects may consume the young leaves when grown in gardens. Mealy bugs may cause problems in plants kept indoors as they hide deep in the crown and the unfurling croziers make it difficult to eliminate this pest. They are spread by ants and seem to reappear every year, usually in warmer weather.

Harvesting Young *Cyathea* leaves are harvested from mature ferns. Tree ferns harvested for the trunk are tall trees at least 10 years old.

Genetic resources and breeding Although *Cyathea* ferns are easily found in the wild at higher altitudes, many species are depleted, becoming rare due to overexploitation for food, medicine, ornamental collections and building material. Harvesting of tree trunks and piths is destructive as the plants are solitary and slow growing. Endemism is a common feature in *Cyathea*. Many species are confined to their own mountain tops. All *Cyathea* species are included in Appendix II of CITES, and several figure on the IUCN Red List. Collection and conservation of all *Cyathea* species, in situ and in germplasm collections, is urgent to ensure that no species are lost forever.

Prospects *Cyathea* ferns are attractive for growing in gardens and the stems are used to make decorative and ornamental items. There are good prospects for tree ferns in landscaping. Existing knowledge on propagation of tree ferns from spores and by tissue culture should be promoted to be used by commercial nurseries to alleviate pressure on wild *Cyathea* populations.

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H.C. Ong

Cyclosorus heterocarpus (Blume) Ching

Bull. Fan Mem. Inst. Biol., Bot. 8(4): 180 (1938).
THELYPTERIDACEAE
$2n = 72$

Synonyms *Aspidium heterocarpon* Blume (1828), *Dryopteris heterocarpa* (Blume) O. Kuntze (1891), *Thelypteris heterocarpa* (Blume) Morton (1959), *Sphaerostephanos heterocarpus* (Blume) Holttum (1974).

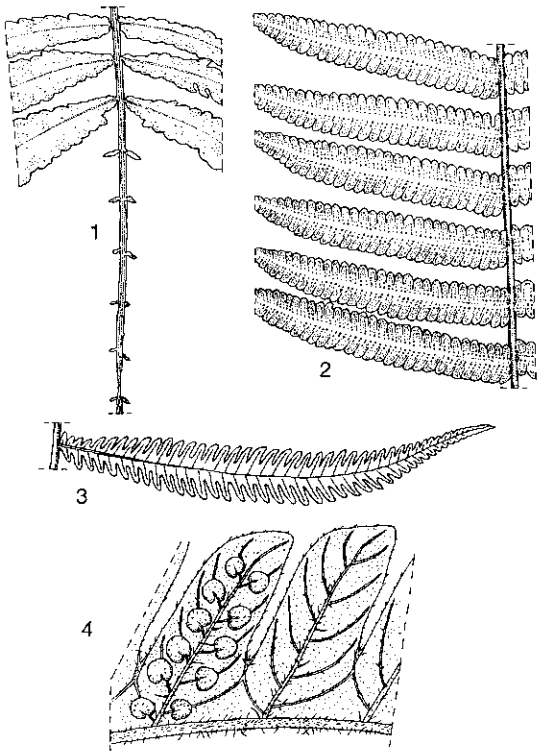
Origin and geographic distribution *C. heterocarpus* is found from southern China throughout South-East Asia to northern Australia and Polynesia.

Uses The leaf of *C. heterocarpus* is rubbed on the skin for treatment of leucoderma in Malaysia. *C. heterocarpus* is also used as an ornamental.

Production and international trade *C. heterocarpus* is collected from the wild or locally grown in gardens. No international trade exists and it is not commercially cultivated.

Properties No information is available about chemical compounds of *C. heterocarpus*. In other thelypterioid ferns (e.g. in some other *Cyclosorus* species) cytotoxic and antibacterial constituents have been demonstrated.

Description A pinnate, hairy, terrestrial fern with the pinnae suddenly reduced on the petiole. Caudex erect, usually branched near the base; scales narrow, up to 8 mm × 1.2 mm, dark brown, hairy. Leaves tufted, pinnate-pinnatifid; petiole 50–80 cm long until the basal real pinnae, bearing auricles (reduced pinnae) down to little more than 5 cm from the base, shortly hirsute, scaly at the base; auricles 6–10 pairs, the distal ones 1–2 cm



Cyclosorus heterocarpus (Blume) Ching – 1, basal part of leaf showing suddenly reduced pinnae; 2, lower surface of fertile middle pinnae; 3, basal pinna; 4, lower surface of central lobes of a middle pinna.

long, with a few lobes and a linear apical part, the lower ones decreasing in size, with short aerophores; lamina oblong-lanceolate, 60–120 cm × 20–40 cm, the basal pinnae suddenly dwarfed to mere auricles, the apex acute, dark green to yellowish-green, thinly papyraceous, pubescent adaxially, the hairs appressed, 0.3–0.4 mm long, sometimes with a few glands, copiously glandular abaxially with yellow glands and a few hairs; rachis, costa and veins hairy throughout, with 1 mm long, antrorse pale hairs abaxially; pinnae linear to linear-lanceolate, ascending, up to 10–20 cm × 1.2–2.5 cm, the fertile ones sometimes narrower, sessile with broadly cuneate to subtruncate base, the apex caudate-acuminate, lobed to over half-way to the costa, the apex-margin entire, basal pinnae narrowed at their bases; ultimate divisions oblong, oblique, subfalcate, up to 4 mm wide, rounded to obtuse; basal veins anastomosing in at least the basal part of the pinna, with excurrent veins to the sinus, the second acroscopic vein sometimes touching the membrane at the sinus. Sori round, medial, 6–9 on a side, dark; indusia firm, persistent, brown at maturity, with a few short hairs and glands; sporangia with glands near the annulus. Spores monolete, spinulous, black.

Other botanical information *C. heterocarpus* has long been known as *Sphaerostephanos heterocarpus*. The *Thelypteridaceae* is a large family with many related species which often are difficult to tell apart, even for specialists. Holttum grouped the Old World species into 25 genera (including *Sphaerostephanos* J. Smith), which however are often difficult to separate without a microscope. Therefore, at present a more conservative classification is maintained, distinguishing 5 genera in which *Sphaerostephanos* is merged as a subgenus (176 species) into the large genus *Cyclosorus* Link (comprising 20 subgenera with in total more than 1000 species). It may be assumed that many uses are not limited to a single species. *C. heterocarpus* is a very variable species in which numerous varieties and forms have been distinguished that are often not sharply distinct.

Ecology *C. heterocarpus* grows in shady locations in the lowlands and up to 1500 m altitude in the mountains, usually near streams or trails and at the fringe of the forest. In the mountains it tends to grow larger.

Propagation and planting *C. heterocarpus* can be propagated by spores. Propagation by separating branched rhizomes seems possible as well but is not really known.

Husbandry If planted, *C. heterocarpus* needs shade, humus and a well-drained soil.

Genetic resources and breeding *C. heterocarpus* is quite common in a large area and it does not seem to be in danger of genetic erosion. No germplasm collections or breeding programmes are known to exist.

Prospects Too little is known of *C. heterocarpus* to predict its future. Since some useful compounds have already been found in various members of the *Thelypteridaceae*, further investigation could be revealing.

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Dedy Darnaedi & W.P. de Winter

Davallia J.E. Smith

Mém. Acad. Sci. Turin 5: 414 (1793).

DAVALLIACEAE

$x = 40$; *D. denticulata, D. solida*: $2n = 80$

Major species and synonyms

- *Davallia denticulata* (Burm.f.) Mett. ex Kuhn, Filic. decken.: 27 (1867), synonyms: *Adiantum denticulatum* Burm.f. (1768), *D. elegans* Swartz (1801), *Trichomanes chaerophylloides* Poir. (1808).
- *Davallia falcinella* C. Presl, Reliq. haenk. 1: 66, t.11, f. 2 (1825), synonyms: *Leocostegia falcinella* (C. Presl) J. Smith (1842), *Humata falcinella* (C. Presl) Copel. (1905), *Trogostolon falcinellus* (C. Presl) Copel. (1927).
- *Davallia parvula* Wall. ex Hook. & Grev., Icon. filic. t. 138 (1829), synonyms: *Humata parvula* (Wall. ex Hook. & Grev.) Mett. (1856), *Leucostegia parvula* (Wall. ex Hook. & Grev.) Bedd. (1883).
- *Davallia solida* (G. Forst.) Swartz, Journ. Bot. (Schrader) 1800: 87 (1801), synonyms: *D. pyxidata* Cav. (1802), *D. fejeensis* Hook. (1845), *D. robinsonii* Copel. (1926).
- *Davallia trichomanoides* Blume, Enum. pl. Javae: 238 (1828), synonyms: *D. bullata* Wall. ex Hook. (1845), *D. lorrainii* Hance (1866), *D. barbata* Alderw. (1911).

Vernacular names General: foot ferns, ball ferns, basket ferns (En).

- *D. denticulata*: Toothed davallia (Am). Indonesia: paku tertutup (Malay), pulak, pullaka (Alor). Malaysia: paku tertutup. Thailand: naakkharaat (central, peninsular). Vietnam: r[aw]ng d[af] hoa c[os] r[aw]ng.
- *D. parvula:* Malaysia: paku lumut batu.
- *D. solida*: Polynesian foot fern, rabbit's foot fern (En). Indonesia: paku kalici. Thailand: phaya nakkharat (northern), wan nakkharat (central), neraphusi (north-eastern).
- *D. trichomanoides*: Japanese ball fern, squirrel's foot fern (En).

Origin and geographic distribution *Davallia* is widely distributed in the Old World tropics, with its greatest diversity in Malesia where 23 species (9 endemics) occur. Only *D. canariensis* (L.) J. Smith is native to South-West Europe. *D. denticulata* is distributed from tropical and southern Africa, Madagascar, Indian Ocean islands (Comores, Seychelles, Christmas Islands), Sri Lanka, India, Thailand, Burma (Myanmar), China (Hainan), Indo-China, throughout Malesia, Australia (Queensland) to the islands in the Pacific. *D. falcinella* occurs in the Philippines and the Marquesas Islands. *D. parvula* occurs in Papua New Guinea, Borneo, East Sumatra and Singapore. *D. solida* is distributed from India, throughout South-East Asia to Australia and the Pacific. *D. trichomanoides* is widely distributed from India, China and Japan throughout South-East Asia.

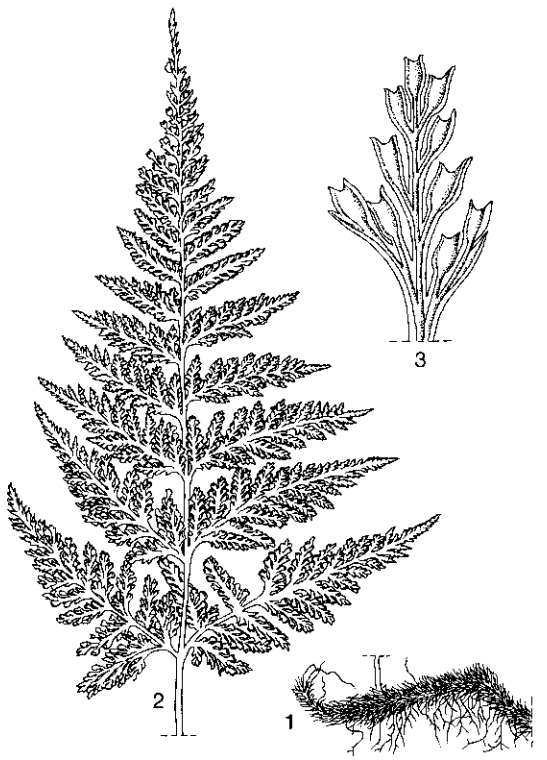
Uses Most *Davallia* species are epiphytes and several are grown for their creeping surface rhizomes, densely covered with red-brown scales and sometimes hairs, overall resembling various animal feet. They are often attractive indoor ornamental plants, grown in pots or in hanging baskets. The leaves are used fresh or dried in floral arrangements. The term ball ferns originates from Japan, where the flexible rhizomes of *D. trichomanoides* are tied into balls and other figures; when these figures are hung and watered, new leaves will subsequently appear on the surfaces, and they become self-contained hanging baskets. The leaf and rhizome of *D. solida* are popular ingredients in mixed medicines of Polynesian local healers.

Production and international trade Several *Davallia* species, particularly those mentioned here, are popular ornamentals worldwide, but no local or international statistics on trade or production are available. Fresh and dried leaves are offered for sale at local florists for use in floral arrangements.

Properties The presence of vicianin, a cyanogenic glycoside, has been found in several *Davallia* species (e.g. *D. denticulata, D. trichomanoides*). Usually, cyanogenesis (production of the dangerous hydrocyanic acid) only occurs after maceration of the plant tissue. In *D. trichomanoides* available cyanogenic disaccharides are de-

graded by the also available β-glycosidase into hydroxynitriles and the corresponding disaccharides. The hydroxynitriles may decompose either spontaneously or enzymically (hydroxynitrile lyase) to produce hydrogen cyanide and an aldehyde or ketone. From the rhizomes of *D. mariesii* T. Moore ex Baker (distributed in Taiwan, Korea, Japan), the following compounds were isolated: davallin (a tetrameric proanthocyanidin), procyanidin B-5, epicatechin-(4 β–8)-epicatechin-(4 β–6)-epicatechin, and epicatechin-(4 β–6)-epicatechin-(4 β–8)-epicatechin-(4 β–6)-epicatechin, which showed an inhibitory effect toward protein kinase C; also a γ-lactone derivative named davallialactone and the 7-O-β-D-glucuronide of (+/–)-eriodictyol along with caffeic acid, 4-β-D-glucopyranosylcaffeic acid and 4-O-β-D-glucopyranosyl-p-coumaric acid.

Description Small to rather large epiphytic or epilithic ferns with creeping rhizomes, roots restricted to the ventral side of lateral buds. Rhizomes fleshy, usually long and somewhat flattened, densely covered with scales; scales peltate or basifixed with cordate base and overlapping lobes, variously shaped. Leaves alternate, arranged in 2 rows; petiole usually well-developed, articulated to the rhizome, sulcate adaxially; lamina triangular-oblong, pentagonal or lanceolate in outline, usually firm in texture, simple, trifoliate or 2–5-pinnately compound with the pinnae further pinnatifid, usually with glandular hairs when young; veins distinct; 'false veins' (bands of regularly arranged short cells without stomata) sometimes present between the veins. Fertile leaves often with leaflets or segments narrower than the sterile ones; sori commonly borne separately on small oblique lobes, terminal on the veins, close to the margin; indusia attached by their base and sides, only the upper edge free, forming a cup-shaped structure. Spores bilateral, monolete, ellipsoid, 25–60 μm long, light brown and translucent, densely subverrucate-areolate.



Davallia trichomanoides Blume – 1, part of rhizome; 2, fertile leaf; 3, fertile segment showing indusia.

– *D. denticulata*. Rhizome without scales 3–15 mm in diameter; scales peltate, 4–8 mm × 0.5–1.5 mm, narrowing evenly towards the apex or narrowing abruptly from a broad base, toothed, red-brown to black. Petiole 4–50 cm long, green or more or less dark brown, with two pale green longitudinal lines near the adaxial surface, glabrous or with few deciduous scales at the base; lamina broadly triangular in outline, (16–)30–60(–90) cm × 13–50 cm, bipinnate to quadripinnate, leathery, shiny; petiolules 4–35 mm long; pinnae broadly deltoid, largest ones 8–45 cm × 5–30 cm, often tapering into a long point; largest pinnules triangular, 0.7–20 cm × 0.4–11 cm; ultimate segments linear or narrowly ovate, 5–27 mm × 2–6 mm, with very oblique, rounded, shallow or deep lobes, the fertile lobes with somewhat narrower segments than those of the sterile ones; veins free, mostly forked, raised on the lower surface, with false veins between the outer branches, reaching almost to the vein junctions. Sori separate, several borne on a segment at the forking point of veins; indusium pouch-shaped, truncate to slightly rounded, 1–1.3 mm × 0.5–1 mm, extending to lamina margin or not; lamina usually extending into a small, incurved tooth at one or both sides of a sorus. Spores shallowly verrucate with a short aperture.

– *D. falcinella*. Rhizome without scales up to 3 mm in diameter; scales peltate, acicular, 6–10 mm × 2 mm, nearly black, at distal part with marginal setae. Petiole 4–9 cm long, dark brown; lamina deltoid, 7–14 cm × 6–14 cm, 3–4-pinnate; petiolules 1–7 mm long, pinnae linear-triangu-

lar, 4–7 cm × 2–7 cm; pinnules linear-oblong, 15–25 mm × 7–12 mm; ultimate segments without a tooth, 1–2 mm long and wide (in sterile leaves up to 4 mm long); veins in sterile ultimate lobes frequently simple, not reaching the margin, false veins absent. Sori separate, often single on a segment, at the forking point of veins; indusium attached at base and only part of the sides, semicircular, about 1 mm in diameter; lamina not extending into teeth beyond a sorus. Spores irregularly verrucate.

- *D. parvula*. Rhizome without scales 0.5–1.2 mm in diameter, white waxy; scales peltate, narrowed evenly towards the apex, 2.5–6 mm × 0.3–0.6 mm, red-brown, in distal part with marginal setae. Petiole (0.1–)1–5 cm long; lamina deltoid, 0.6–4 cm × 0.5–3.5 cm, entirely divided into fine linear segments without obvious rachis; longest petiolules 1–2 mm long; ultimate segments 0.5–4 mm × 0.2–0.4 mm, obtuse or acute without a tooth with simple veins reaching the margin, false veins absent. Sori separate, often single on a segment at the forking point of veins; indusium only attached at the base, semicircular to subtriangular, 0.3–0.8 mm in diameter, upper margin not elongated; lamina usually extending beyond it at either side for 1–1.5 mm into two unequal arms.
- *D. solida*. Rhizome without scales 4–14 mm in diameter; scales peltate, narrowing evenly towards the apex, 5–10 mm × 1–1.2 mm, red-brown to black, when young bearing woolly, multiseptate hairs but when old covered with appressed bases of scales only, the distal parts of scales being deciduous. Leaves dimorphic; petiole 9–35 cm long, distinctly grooved adaxially; lamina broadly deltoid, 15–90 cm × 21–40 cm, 2–3-pinnately compound; petiolules 5–25 mm long; longest pinnae deltoid, 11–28 cm × 6–15 cm; longest pinnules triangular, 4–10 cm × 1.5–8 cm; ultimate segments 10–40 mm × 3–17 mm, usually lobed, with pinnate veins, false veins absent. Sori separate, several borne on a segment at the forking point of veins; indusium also attached along the sides, 1.2–2 mm × 0.5–1 mm, upper margin not elongated; lamina not extending into teeth beyond a sorus. Spores prominently verrucate.
- *D. trichomanoides*. Rhizome without the scales 3–8 mm in diameter; scales peltate, nearly acicular above a broad base, 4–8 mm × 1–1.5 mm, brown to red-brown, toothed or with marginal setae in distal part. Petiole 4–20 cm long; lamina deltoid, 10–35 cm × 9–25 cm; petiolules 1–6 mm long; pinnae 5–19 cm × 3–12 cm, pinnules 2–7 cm × 1–3 cm, ultimate segments 5–27 mm × 2–6 mm; veins in ultimate lobes simple or forked but not reaching the margin; false veins are usually present; indusium also attached along the sides, 1.2–2 mm × 0.5–1 mm, upper margin not elongated; lamina usually extending into a tooth at either side of a sorus, teeth equal in size. Spores verrucate, aperture nearly equal to their length.

Growth and development The leaves of *Davallia* are articulated to the rhizome and are deciduous when old. They do not usually fall off at a definite season, but in *D. denticulata* and *D. solida* all leaves on a plant drop together, and this is followed rapidly by the growth of new leaves. In strongly seasonal climates the leaves fall as soon as the dry season is well established, and the plants rest in a leafless condition until the next rainy season. In non-seasonal climates plants are never bare of leaves for long. The deciduous habit is of great value for adaptation to seasonal climatic conditions. Environmental conditions such as relative humidity, light intensity, soil moisture content, soil nutrients affect the population density of the fern and the size of leaves. In the rainy season the number of leaves increases. Ferns growing under shade produce bigger leaves but fewer in number compared with those exposed to sunlight. Fertile leaves may occur the whole year round.

Other botanical information *Davallia* comprises 35–90 species, depending on the delimitation of the genus and its species. The smaller species with the indusium not attached to the sides, but only to the base, have often been separated into the genus *Humata* Cav.

The false veins in *D. denticulata* indicate that the present leaflets originated during evolution by joining of initially highly dissected segments. The false veins correspond to the lines along which the initial segments were joined. The inner tissue below the false veins has no air-spaces which makes it more translucent. Most other *Davallia* species have lost such characteristics.

Sometimes 2 varieties are distinguished in *D. denticulata*: var. *denticulata* and var. *elata* (G. Forst.) Kuhn. In var. *denticulata*, the indusium is attached at the base but also along the sides and the upper margin not elongated; in var. *elata*, the indusium is attached at the base and only at some parts of the sides, and the upper margin is elongated.

D. parvula is closely related to *D. repens* (L.f.) Kuhn, with which it possibly also hybridises. *D.*

repens is a very variable species, distributed almost as widely as the genus, possibly hybridising with several related species; it occurs in purer form at lower altitudes and in areas where no related species are found. In general the lamina of *D. parvula* is more completely divided and into finer linear segments, without a clear rachis, than the lamina of *D. repens*.

D. solida is a very variable species which in a broad species concept is subdivided into 3 varieties: var. *solida* (distribution similar to the genus in Asia), var. *pyxidata* (Cav.) Noot. (occurring only in Australia: Queensland and New South Wales) and var. *fejeensis* (Hook.) Noot. (occurring in Fiji and the Austral Islands). In a narrow concept the varieties are considered as separate species. The major differences between the varieties are the size and the rate of division of the lamina: the ultimate segments of var. *solida* are 10–40 mm × 3–17 mm, of var. *pyxidata* 5–20 mm × 3–8 mm, of var. *fejeensis* 3–5 mm × 0.2–1 mm. Var. *fejeensis* in particular has many cultivars (e.g. 'Dwarf Ripple', 'False Plumosa', 'Plumosa').

In *D. trichomanoides* plants with nearly black scales on the rhizome and with highly contrasting white setae have been classified as var. *lorrainii* (Hance) Holttum.

Ecology *Davallia* species are perfectly adapted to epiphytic conditions and most of them can stand more exposure than most other epiphytes, which explains the wide distribution of the genus. Several species can withstand short periods of mild frost (e.g. *D. canariensis* (L.) J. Smith, *D. trichomanoides*), but in general optimum temperatures for growth lie between 30–35°C. Although commonly found growing on the ground in Australia, *D. denticulata* is an epiphytic fern found on trunks of many different tree species and often growing together with other ferns such as *Asplenium nidus* L. or *Platycerium bifurcatum* (Cav.) C. Chr. It also can be epilithic on granite, limestone or sandstone, or terrestrial on different soils, in forests and in exposed locations, from sea-level to 2200 m altitude. *D. denticulata* is one of the commonest epiphytic ferns in South-East Asia, particularly on trees near the sea. *D. falcinella* is epiphytic, *D. parvula* epiphytic or epilithic, both species growing from sea-level up to 800 m altitude. *D. solida* is epiphytic or epilithic. It grows on different kinds of rock, or terrestrial on different soils, as well as in exposed locations as in deep shade, from open rocky places and savannas to primary rain forest, up to 1500 m altitude. *D. trichomanoides* occurs epiphytically on mossy branches and tree bases and epilithically on different kinds of rock, mostly in wet locations, but sometimes in dry exposed conditions, at altitudes of 100–3500 m.

Propagation and planting Although spores germinate easily, *Davallia* is usually propagated by rhizome parts. In the wild the rhizomes grow uncovered, so care must be taken when planting not to bury them (especially the growing tips) completely in the planting medium. Uncut sphagnum or a very loose well-drained potting mix is a suitable medium for planting. Propagation by tissue culture using growing points of the rhizomes has also been successful.

Husbandry Most *Davallia* species are easy to cultivate. Since they are epiphytes they require good drainage whereas their roots need adequate moisture. If conditions are too wet rhizomes turn dark and soft. Rhizomes that shrink or shrivel due to lack of water are very slow to recover. Deciduous species should be kept moist during dormancy but not overwatered. Bright indirect light produces finer growth than medium or low indirect light. Regular application of fertiliser during the growing period is beneficial. To keep plants more compact and to encourage lateral branches to sprout, rhizome tips that are over 5 cm long can be cut off.

Genetic resources and breeding Neither germplasm collections nor breeding programmes are known to exist for *Davallia*.

Prospects Since several *Davallia* species are attractive and decorative indoor or outdoor ornamental ferns, further research on domestication and the most suitable cultivation requirements are worth considering.

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Titien Ngatinem Praptosuwiryo & P.C.M. Jansen

Dicranopteris linearis (Burm.f.) Underw.

Bull. Torrey Bot. Club 34: 250 (1907).
GLEICHENIACEAE
$2n = 78$ (diploid), 117 (triploid), 156 (tetraploid)

Synonyms *Dicranopteris dichotoma* (Thunb. ex Murray) Bernh. (1806), *Gleichenia hermannii* R. Br. (1810), *G. linearis* (Burm.f.) Clarke (1880).

Vernacular names Scrambling fern, false staghorn (En). Indonesia: resam (Indonesian), hasam (Lampung), paku andam (Sundanese). Malaysia: resam, bengakawang (Malay), máng ch'í (Chinese). Philippines: kilob, tilub (Tagalog), gapingoi (Bontok). Thailand: kiku kachoei (northern), kut pit (northern), kut taem (peninsular).Vietnam: t[ees], gu[ooj]t, r[as]ng t[aa]y s[ow]n ngay.

Origin and geographic distribution *D. linearis* is an Old World tropical and subtropical species, occurring from Africa to Taiwan and throughout South-East Asia to Australia, New Zealand and Polynesia (as far as Hawaii). In South-East Asia it is one of the most common ferns.

Uses Although *D. linearis* is sometimes considered a weed, its pliant fibrous leaf stems (petiole and leaf axis) are widely used in Asia for various purposes. The lignified peripheral fibres of the stem are used for plaiting. The whalebone-like pith that comes loose from the peripheral fibres is brittle near the base but flexible and resilient at the top and is used for pretty and elegant plaiting. Fishing-stakes, baskets and sometimes ropes have been made from the stems. They are quite resistant to salt water and therefore the fern is widely used in the construction of fish-traps where the stems last for about two years. *D. linearis* is sometimes planted to prevent soil erosion. The stems have also been used to make seats of chairs and stools, mats, pouches, hats, cigar cases, caps and to form woven partition-walls for houses. The caps ('songko'), used in northern Peninsular Malaysia and peninsular Thailand, are durable enough to last several generations. In Malaysia they are sometimes coated with wood-tar to make them more durable. In Papua New Guinea arm bands and belts are made from the stems and the plants are used for casual adornment. The very firm stems can be sharpened to a resistant point. In Malaysia they were shaped into pens ('kalam') used for Arabic calligraphy. The oldest and strongest stems make the best pens and they have also been used to make knives. In Indonesian nursery gardens entire leaves are put upright in the ground to shade young crop plants. By the time the young plants can stand exposure to direct sunlight, the fern leaves have wilted and shed their foliage. *D. linearis* also has several traditional medicinal uses. Crushed leaves are applied as a poultice or drunk as an infusion to combat fever. Apparently, high doses are harmful and decoctions are applied externally as a cooling lotion rather than drunk, unless they are prepared from young leaves or in a low dose in combination with other ingredients. The fern has also been used to cure chest complaints such as asthma and cough, and to cure bruises, burns and sprains. In Indo-China *D. linearis* is considered anthelmintic. In northern Thailand, decoctions are drunk against insomnia and used to bathe children with bad skin rash and people with a broken leg. Together with *Shorea* leaves the leaves are used to treat itching caused by stinging hairs of *Urticaceae*. In Papua New Guinea the leaves are plastered on wounds. In Hawaii the plant is soaked in water and the extract is drunk to cure constipation.

Production and international trade At the beginning of the 20th Century, Peninsular Malaysia exported vigorous stems of *D. linearis* on a small scale to India. Production and trade is mainly local and is dying out as the ready-for-use fibres for matting and weaving are very expensive.

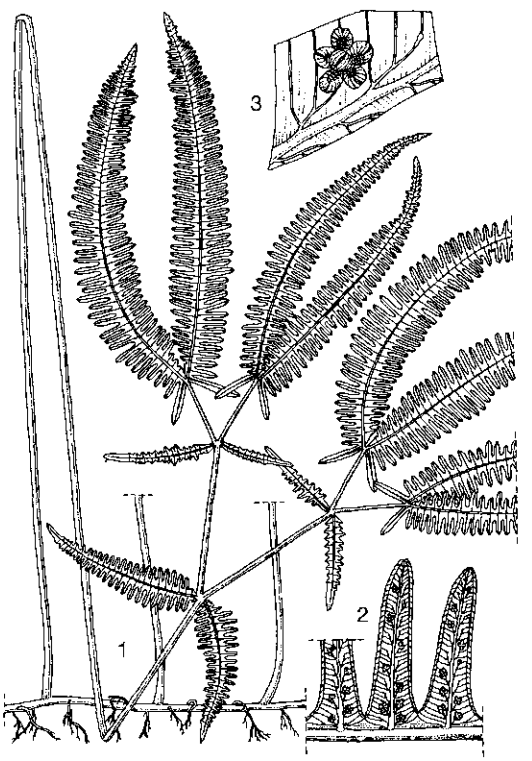
Properties The leaves of *D. linearis* contain tannins (3.8%), essential oils (0.03%) and saponins. They also contain clerodane glycosides. Flavonoids are limited to flavonol 3-O-glycosides,

such as afzelin, quercitrin, isoquercitrin, astragarin, rutin and kaempferol. The 13 varieties of *D. linearis* differ in chemical constituents, each variety containing at least one different flavonol or flavone.

D. linearis plants concentrate relatively high levels of rare earth elements, especially in the roots (Eu, Gd, Ho, Pr, Sm, Y) and the leaves (Ce, Dy, La, Nd, Tb). The lanthanum replaces the magnesium position in chlorophyll and coordinates with the porphyrin ring. The lanthanum has been observed to have a similar coordination structure to a sandwich-type lanthanide complex ('double decker sandwich structured La-substituted chlorophyll a'), with the La surrounded by eight nitrogen atoms from two porphyrin rings with an average La-N bond length of 2.65 Angstrom.

Tests in the Philippines revealed that water extracts of *D. linearis* showed positive antimicrobial activity against *Micrococcus luteus* and *Escherichia coli*.

Description A terrestrial thicket fern, up to 3 m tall, with dichotomously divided leaves. Rhizome several m long, up to 5 mm in diameter, creeping, brown, bearing septate, branched hairs. Leaves 2–3-furcate, with only the ultimate branches bearing pinnae, in addition to a pair of stipule-like pinnae (accessory branches) at the basis of each bifurcation, spaced 6–20 cm apart on rhizome; petiole erect, stout, 10–100 cm or longer, lustrous brownish to purpuraceous, glabrous; lamina of complex three-dimensional shape, 60–200 cm long, bearing hairs, especially near bases of the midribs and minute, oblong-obtuse brown glands along the veins; rachis sometimes very long, at the bifurcations with a dormant bud, with brown, branched hairs, glabrescent; pinnae narrowly lanceolate, deeply pinnatifid, asymmetrical at base, more reduced towards the acute to acuminate apex; ultimate segments linear, 18–40(–70) mm × 3–5 mm, confluent at the broadened base, apex obtuse or emarginate, glabrous. Sori superficial, in a median row on each side of the midrib, subcircular, 1 mm in diameter; sporangia without indusia. Spores trilete, tetrahedral with prolonged angles, somewhat wrinkled.



Dicranopteris linearis (Burm.f.) Underw. – 1, habit; 2, some fertile pinnules; 3, sorus.

Growth and development Spore germination of *D. linearis* is by a thread-like body with transverse divisions. The gametophyte is long-lived, subcordate to ribbon-like, with a thick central strand. The archegonia are long-necked and curve forward, the antheridia many-celled and scattered over the lower surface. Two-celled hairs are frequent. The prothalli grow in enormous numbers in slightly sheltered places on bare earth banks and other exposed positions where other prothalli would not survive. After fertilization the sporophyte starts growing, reaching 2–3 m in height. The leaves of *D. linearis* eventually grow so long that they cannot support themselves in an erect position and so they form a tangled thicket which is extremely difficult to cut through.

Other botanical information *Gleicheniaceae* is an old, rather isolated family, perhaps dating back to the Carboniferous, comprising 5 genera. *Dicranopteris* Bernhardi comprises about 12 species, most strongly represented in South-East Asia with 5 species. *D. linearis* is a very variable species and many varieties have been described. In South-East Asia 13 varieties are distinguished, mainly based on the mode of branching (e.g. equal or unequal branches, angle of branching), the presence or absence of stipule-like pinnae, hairiness and number of veins. Some of them are more distinct than others and should perhaps be considered as species. The existence of a triploid hybrid indicates that it is probably impossible to refer every plant to a clearly defined variety. It is ques-

tioned whether *D. linearis* is conspecific with the neotropical *D. flexuosa* (Schrad.) Underw. *D. curranii* Copel., occurring in Thailand, Malaysia, Indonesia (Sumatra, Kalimantan, Java, Flores, Sulawesi) and the Philippines (ultimate branches are commonly 40 cm × 9–12 cm) is in general somewhat larger than *D. linearis* but is similarly used. It was described formerly as one of the varieties of *D. linearis* and for purposes of matting it is even considered better.

Gleichenia flabellata R. Br. (shiny fan fern, umbrella fern), occurring in New Guinea, Australia, New Caledonia and New Zealand, has a similar positive effect as *Dicranopteris* on soil erosion prevention and is sometimes planted for that purpose.

Ecology *D. linearis* forms dense thickets over large, dry, sunny areas with poor soils, from sea-level up to 2800 m altitude. The indeterminate growth form, the shallow rhizomes, the leaves with low decomposability and its mat-forming capacity enables it to colonize sites and to maintain dominance. After clearing of steep hillsides, it soon covers the open site, preventing landslides during torrential downpours. It is, however, less resistant to cutting and fire than *Pteridium* which penetrates much deeper into the soil. *Dicranopteris* stands offer a suitable microhabitat for the germination of tree seed, but they also outcompete saplings. Its rapid spread makes *D. linearis* a noxious weed in plantations. It can be combatted biologically by some insects, manually by repeatedly removing the rhizomes and chemically by spraying for example paraquat (600 g/ha). Although warm conditions are preferred, it survives in cooler climates but is sensitive to frost. It is highly efficient in extracting P from the soil which enables it to colonize sites poor in P. In Hawaiian sites it contributed up to 74% of the aboveground net primary production where it constituted only 14% of the live biomass. Where it contained only 24% and 30% of plant N and P, it accounted for up to 57% and 47% of total N and P uptake, respectively. Its leaves are short-lived but slow to decompose, even under high temperature and rainfall conditions. More than 50% of the original leaves and more than 77% of the stem mass may still remain after more than two years. The slow decomposition is related to the lamina which remains unabscised on top of the petiole and the high lignin-nitrogen ratio (56-129). As a result it is a major contributor to soil detrital pools; fixed carbon is quickly transferred to the soil where it contributes to the organic matter and makes conditions more oligotrophic.

Propagation and planting *D. linearis* is quite difficult to raise from spores, although this has not been tried frequently. It is difficult to know when sporangia are fully mature and ready for collection. However, propagation by planting rhizome pieces in poor soils exposed to full sun is easy and effective. *D. linearis* is easily killed in fertile soils with excessive mineral supply and for this reason it is seldom found in botanical gardens or otherwise cultivated.

Handling after harvest Harvested stems of *D. linearis* are longitudinally cut into four pieces and soaked in water for 7 days and then rubbed with coconut oil to obtain a black colour. The pith fibres are easily separated by bruising the stem or by cutting them longitudinally. After soaking for two days the fibres turn a light brown colour. The plaiting must be done when the fibres are still wet because when dry they are too brittle. For fish-traps the hardest stems are selected, joined in bundles and carefully dried in the sun for a week until the colour of the stems changes into an even, shining dark brown.

Genetic resources and breeding *D. linearis* is widely distributed and does not seem to be in danger of extinction. No germplasm collections or breeding programmes are known to exist. The genetic variability may be less than suggested by its abundance as many populations consist of few genotypes covering substantial areas. Since the chemical composition is dependent on the variety, loss of variability could pose a risk of losing properties, but none of the Southeast-Asian varieties are confined to a limited area.

Prospects Due to more easily available alternative fibre material, the use of *D. linearis* is declining. Possibly, more attention is now paid to its eradication as a troublesome weed than to its useful properties. Locally it will remain of importance as a fibre source but no new developments are foreseen. The medicinal uses deserve further investigation.

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Titien Ngatinem Praptosuwiryo

Diplazium Swartz

J. Bot. (Schrad.) 1800 (2): 4, 61 (1801).
DRYOPTERIDACEAE
$x = 41$, occasionally 40; polyploidy is frequent

Major species and synonyms

- *Diplazium esculentum* (Retz.) Swartz, J. Bot. (Schrad.) 1801 (2): 312 (1803), synonyms: *Hemionitis esculenta* Retz. (1791), *Asplenium esculentum* (Retz.) C. Presl (1825), *Athyrium esculentum* (Retz.) Copel. (1908).
- *Diplazium polypodioides* Blume, Enum. pl. Javae: 194 (1828), synonyms: *D. asperum* Blume (1828), *Athyrium asperum* (Blume) Milde (1870), *Athyrium blumei* (Bergsma.) Copel. (1908).
- *Diplazium proliferum* (Lamk) Thouars, Fl. Tristan da Cunha: 35 (1804), synonyms: *Callipteris prolifera* (Lamk) Bory (1804), *D. accedens* Blume (1828), *Athyrium accedens* (Blume) Milde (1870).

Vernacular names

- *D. esculentum*. Edible fern (En). Indonesia: paku sayur (Indonesian), paku beunyeur (Sundanese), pakis wilis (Balinese). Malaysia: paku tanjong, paku benar, kuò kuô ch'ai ch'uèh (Chinese). Philippines: pako (general), tagabas (Tagalog). Thailand: phak kuut (general), hasdam (peninsular), kuut khue (northern).
- *D. polypodioides*. Indonesia: paku beunteur (Sundanese). Thailand: kuut yoi (Chiang Mai).
- *D. proliferum*. Indonesia: paku buwah, paku careham (Sundanese), pakis angkrik (Javanese).

Origin and geographic distribution *Diplazium* comprises about 400 species and is distributed all over the tropical and subtropical rain forests of the world. The three major species mentioned here are native throughout South-East Asia. *D. esculentum* also occurs from central China and southern Japan throughout humid tropical Asia and in Polynesia and is widely cultivated in gardens; as a garden escape it may occur outside its natural range (e.g. in Florida, United States). *D. polypodioides* is found from the Himalayas and Sri Lanka to Taiwan, throughout South-East Asia, but not as far as Australia. *D. proliferum* occurs throughout the tropics of the Old World.

Uses The tender uncurling leaves of *Diplazium* are eaten boiled or steamed as a leafy vegetable or raw as a salad with various dressings. It is an appreciated vegetable, being slimy and sweetish after cooking. Occasionally it is used as an ingredient in more complicated dishes. *D. esculentum* is the most palatable and most popular vegetable fern in South-East Asia and the most important fern used as human food in the world. Some restaurants offer it as delicacy when available. A decoction of *D. esculentum* is used by women as a tonic after childbirth and is said to be good to cure expectoration of blood and ordinary coughs. An extract of mature leaves is applied externally against fever and the leaves are rubbed on the body to get rid of the unpleasant smell of sweat. The pulverized rhizome, soaked in water, is taken against diarrhoea and dysentery. The wiry roots (which look like horse hairs) are sold in the Philippines as a growing base for orchids and are worn in the hair by the Sundanese in Indonesia (known as 'kumpai cai') to stimulate hair growth. *D. esculentum* and *D. proliferum* are also attractive ornamentals in gardens and are widely cultivated for this purpose. The bulbils of *D. proliferum*, often present in considerable numbers in the axils of leaflets, are also eaten raw or cooked.

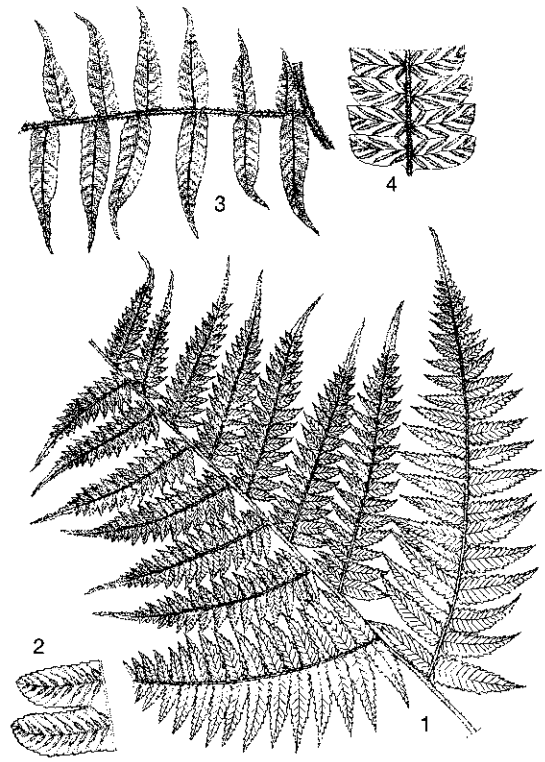
Production and international trade *D. escu-*

lentum is commonly offered for sale on local markets, where demand seems to exceed supply. All *Diplazium* ferns are collected from the wild or grown in gardens for home use. No international trade exists and there is no commercial cultivation.

Properties Per 100 g edible portion, fresh *D. esculentum* contains: water 90 g, protein 3.1 g, fat 0.3 g, carbohydrates 3.9 g, fibre 1.2 g, ash 1.3 g, P 115 mg, Ca 22 mg, Fe 1.2 mg. The data show that it is a reasonable source of Ca, an excellent source of P and a good source of Fe. In Malaysia average ascorbic acid content in fresh young leaves sold as vegetable is 29 mg per 100 g. *D. esculentum* contains the flavonoids procyanidin, quercetin-3-rutinoside, kaempferol-3-rutinoside, quercetin-3-glucoside and eriodictyol 5-O-methyl ether 7-β-D-xylosylgalactoside. It also contains syringic acid (a major component of phenolic acids) and protocathechuic acid. *D. polypodioides* contains kaempferol-3-rutinoside and quercetin-3-glucoside. An ethanol extract of *D. esculentum* showed antimicrobial activity with minimum inhibitory concentration in the range 100–800 µg/ml and minimum lethal concentration values in the range 400–800 µg/ml. Extracts, particularly of the rhizome, also have fungicidal activity e.g. against spore germination of *Alternaria brassicicola* and *Aspergillus niger*.

Description Medium to large, terrestrial or epilithic ferns. Rhizomes creeping to erect, scaly at apex, the scales not clathrate. Leaves not articulate with the rhizome, rachis grooved, U-shaped in transverse section, glabrous; laminas simple to 4-pinnate, linear to deltoid, glabrous or pubescent, the veins free or partly anastomosing. Sori oblong to linear, attached to sides of veins, partly or wholly double, back-to-back; indusia membranous, facing outward, almost always linear.

- *D. esculentum*. A terrestrial, palustrial fern, up to 2.5 m tall. Rhizome erect, up to 100 cm tall above ground level, lower parts often hidden by dark stringy roots, upper part covered with brown scales; scales 10 mm × 1.2 mm, margins denticulate, apex long acuminate, dark brown with black margins. Leaves clustered at apex of the rhizome; petiole 50–70 cm long, black, paler distally, glabrescent but with brown scales at the base; lamina ovate to lanceolate, 0.5–1.5 m × 0.5–1 m, bipinnate with shallowly lobed pinnules, dark green, thin, papyraceous, abaxially glabrous; pinnae ovate, rather suddenly narrowed towards the apex, up to 50 cm × 25 cm, base truncate, apex acute; pinnules linear-lanceolate, the largest ones 10–15 cm × 2–4 cm, the base subsessile, truncate or broadly cuneate, more or less auricled on both sides, margins incised to one fourth length towards the costa, apex gradually narrowed; veins pinnate within each crenation, with 8–10 pairs of lateral veins, the lowest 2–3 of which join with the veins of the next crenation, to form an extra vein running towards the margin, but not originating from the midrib. Sori elongated, occupying almost the whole length of the ultimate veins, with a narrow scarious indusium along one side of each group or running through the middle. Spores monolete, reniform, rugulate.
- *D. polypodioides*. Differing from *D. esculentum* mainly in the following characteristics: leaves up to 3 m tall; petiole and rachis rough or spiny; lamina more finely dissected, with smaller segments, in which the veins of neighbouring groups are not connected.
- *D. proliferum*. Differing from *D. esculentum* mainly in the following characteristics: leaf



Diplazium polypodioides Blume – 1, apical part of the leaf blade; 2, fertile pinnule segments. D. esculentum (Retz.) Swartz – 3, pinna; 4, fertile pinnule segments.

blade only dissected once, segments up to 45 cm × 7.5 cm, often with small bulbils (or young plants) in the axils of the midrib and segments.

Other botanical information *Diplazium* is now placed in the subfamily *Athyrioideae* of the *Dryopteridaceae*. Very often this subfamily is treated as an independent family, the *Woodsiaceae*. With a still narrower family concept, the onocleid genera are excluded and placed into the *Onocleaceae*, and then *Diplazium* forms with the remaining genera the *Athyriaceae*. *Diplazium* (synonyms: *Callipteris* Bory, *Rhachidosorus* Ching, *Triblemma* (J. Smith) Ching) is a difficult and incompletely known genus, which partly accounts for the over 400 described species. The combination *D. asperum* which is given here as synonym to *D. polypodioides* is still often used and might be the correct name. It is not sure whether the specimens found in India and Sri Lanka apply to the same species. In Papua New Guinea *D. cordifolium* Blume (occurring all over South-East Asia) is particularly mentioned as being used as vegetable.

D. subsinuatum (Wall. ex Hook. & Grev.) Tagawa, occurring from India, throughout continental South-East Asia to China, Taiwan, Japan and south to the Philippines and Borneo, is used in Chinese medicine, usually prepared as a tea from dried material, as a diuretic and anti-inflammatory agent. It is said to clear heat, cool the blood, stop bleeding, promote urination and open the urinary pathways, as well as to eliminate or reduce food stagnation and congestion. It is used to treat coughing with phlegm and blood from tuberculosis, red, swollen, or painful eyes, low back pain, diphtheria, vomiting with blood, rheumatoid arthritis in the hands where the muscles have atrophied and the joints have nodular swellings, causing the hands to have a curved, claw-like appearance. All parts of *D. subsinuatum* contain hopane-triterpene gycosides which are named diplaziosides and hopane glycosides with acetylated sugars.

Ecology *Diplazium* ferns grow terrestrially in forests and thickets, occasionally as epilithics, in the warmer parts of the world, only sparingly and locally extending into temperate areas. *D. esculentum* occurs in open, wet, swampy locations, often along watercourses and rivers, usually with some shading, but never in shady forest, in lowland and hill forests up to 1100 m altitude. It forms clonal colonies by vegetative reproduction from root buds. *D. polypodioides* is found in similar environments but also in drier and less shady locations, e.g. as a weed in plantations and along roads. It occurs from sea-level up to 1200 m, but is usually found above 600 m altitude. *D. proliferum* grows in moist forest, along brooks and riversides, up to 1200 m altitude.

Propagation and planting *Diplazium* ferns grow easily from spores. Vegetative propagation is possible by runners and rhizome parts with buds in *D. esculentum* and by bulbils in *D. proliferum*. *D. esculentum* absolutely needs wet conditions and shade in dry periods during planting.

Husbandry If *Diplazium* ferns are grown in gardens, the soil should preferably be poor and wet. Provided wet and shady conditions are maintained, no more care is necessary. In a trial in Sarawak (Malaysia), yield of shaded *D. esculentum* increased linearly with increasing applications of NPK.

Harvesting When grown from spores, 2–3-year-old *Diplazium* plants can be harvested. When grown from runners, harvesting might start after 6 months.

Yield In a trial in Sarawak (Malaysia) in 1995–1996 yield of a NPK fertilized *D. esculentum* vegetable was not profitable at the prevailing market prices.

Handling after harvest In parts of India, where fresh *D. esculentum* leaves ('lungru') are available only for a short period of the year, young leaves are dried and stored. Leaves dried in the shade retain better quality after rehydration for use as a vegetable compared to leaves dried artificially.

Genetic resources and breeding The major *Diplazium* species mentioned are common and seem unthreatened. Germplasm collections and breeding programmes are not known to exist.

Prospects In Malaysia, Indonesia, the Philippines and Papua New Guinea, *Diplazium* ferns are considered the most important ferns for human consumption. They show potential as 'functional food' in view of the significant therapeutic and nutritive benefits. Further research is needed to domesticate these species. A perennial species, a continuous vegetable supply is therefore ensured throughout the year, once the plants are established.

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P.H. Hovenkamp & Y. Umi Kalsom

Dipteris conjugata Reinw.

Syll. pl. 2: 3 (1825–1826).
DIPTERIDACEAE
$2n = 66$

Synonyms *Polypodium horsfieldii* R. Br. (1828), *Phymatodes conjugata* (Reinw.) C. Presl (1836), *Dipteris horsfieldii* (R. Br.) Bedd. (1869).

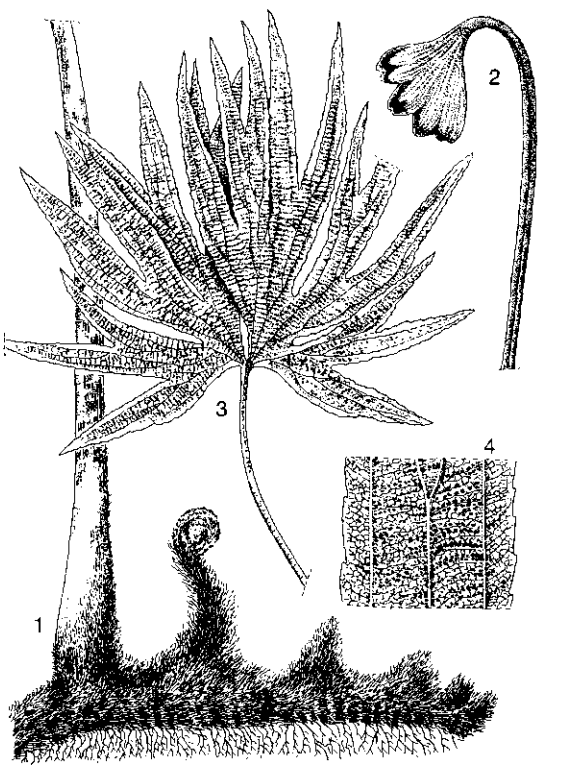
Vernacular names Indonesia: paku payung (Indonesian), pitagar payung (Kedayan Dayak). Malaysia: bua chek (Malay), shûang shàu ch'uèh (Chinese). Philippines: pakong payong. Thailand: bua chaek (peninsular).

Origin and geographic distribution *D. conjugata* is found from Thailand through Indo-China, southern China, Taiwan, Malaysia, Indonesia, the Philippines to New Caledonia and Australia.

Uses In the highlands of Mindanao (the Philippines), the large leaves of *D. conjugata* are used as an umbrella. In southern Thailand, the roots of *D. conjugata* are of medicinal value and often collected.

Production and international trade *D. conjugata* is not traded internationally, nor is it commercially cultivated.

Description A terrestrial, umbrella-shaped fern, 0.5–2 m tall. Rhizome wide- or long-creeping, up to 1.5 cm in diameter, densely setose; setae 0.2 mm × 4–5 mm, lustrous reddish-brown to black, the base sometimes widened. Leaves monomorphous, repeatedly bifid; petiole stout, up to over 2.5 m long, yellow-brown, basally setose; lamina reniform, up to 25–50 cm × 70 cm, divided to the base into two spreading flabellate halves, the base cordate to hastate, apex rounded, coriaceous, glabrous, dark green adaxially, paler or glaucous abaxially, young leaves yellow-green with reddish tinge; segments broadly obovate, up to over 60 cm long, usually twisted through 90 degrees, spreading more or less horizontally, 3 or more times dichotomously divided; ultimate lobes narrowly subtriangular, the margins irregularly and broadly dentate, gradually narrowing into a caudate-acuminate apex; main veins repeatedly dichotomous, intermediate veins forming a dense net-



Dipteris conjugata Reinw. – 1, rhizome and base of petiole; 2, folded two halves of expanding leaf; 3, leaf; 4, part of leaf from below

work with free included veinlets in the areoles. Sori small, numerous, irregular in shape and size, scattered over the undersurface and borne on the minor veins, without indusium, paraphyses capitate. Spores monolete, ellipsoid, 29–38 µm, smooth.

Growth and development The gametophyte of *D. conjugata* is naked, cordate-thalloid with thick midrib, slowly growing, eventually elongating, bearing gametangia on the ventral and often also on the dorsal side. The antheridium is of a primitive, massive type with few sperms. The archegonium is also primitive and has a long, straight neck.

Other botanical information *Dipteris* Reinw. has no close relatives, its family is of considerable antiquity from the Mesozoic Triassic. It had a worldwide distribution formerly but in its present area it is a relict. It is the only genus of the family, comprising about 8 species in the Old World tropics and subtropics. In taxonomic literature it has often been classified in *Polypodiaceae*.

Ecology *D. conjugata* is common in mountain clearings and on steep banks, generally between 300–2900 m altitude. Some of its localities are on coastal cliffs. It is a specialist of extremely poor edaphic substrates, especially the leached gleyed-clay soils of high mountain ridges and saddles. In forests it is found where sufficient light reaches the forest floor, for example on slopes near waterfalls or in disturbed sites. In East Kalimantan (Indonesia) it is found growing along rivers accompanying *Nypa* palm in coastal areas. Under disturbed conditions colonies tend to be relatively short-lived, possibly due to competition.

Propagation and planting *D. conjugata* can be propagated by spores and by rhizome division.

Husbandry If *D. conjugata* is planted, the soil should be acid and well-drained. It likes fairly bright light to light shade and plenty of water. Plants are somewhat difficult to establish, but once growing they are best left undisturbed. Spore germination and vegetative growth are favoured by lower temperatures.

Genetic resources and breeding Though its distribution pattern is of relic nature and its populations may be or become isolated, *D. conjugata* is fairly common over a large area and therefore it does not seem to be in danger of extinction. In Australia, however, *D. conjugata* is among the pteridophytes of conservation interest. Germplasm collections and breeding programmes are not known to exist.

Prospects The medicinal use of *D. conjugata* should be investigated and its active compounds identified before its prospects can be reviewed. Research on the ornamental possibilities of *D. conjugata* is recommended, including the collection of germplasm.

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Dedy Darnaedi & Titien Ngatinem Praptosuwiryo

Drynaria (Bory) J. Smith

J. Bot. (Hooker) 3: 397 (1841).

POLYPODIACEAE

$x = 36, 37$; *D. quercifolia*, *D. rigidula*, *D. sparsisora*: $2n = 74$

Major species and synonyms

- *Drynaria fortunei* (Kunze ex Mett.) J. Smith, in Seeman, Bot. voy. herald: 425 (1857), synonym: *Polypodium fortunei* Kunze ex Mett.(1857).
- *Drynaria pleuridioides* (Mett.) Diels, Nat. Pflanzenfam. 1(4): 330 (1899), synonym: *Polypodium pleuridioides* Mett. (1866).
- *Drynaria quercifolia* (L.) J. Smith in J. Bot. (Hooker) 3: 398 (1841), synonym: *Polypodium quercifolium* L. (1753).
- *Drynaria rigidula* (Swartz) Bedd., Ferns Brit. Ind.: t. 314 (1869), synonyms: *Polypodium rigidulum* Swartz (1801), *D. diversifolia* (R. Br.) J. Smith (1841).
- *Drynaria sparsisora* (Desv.) T. Moore, Index fil.:

348 (1862), synonyms: *Polypodium sparsisorum* Desv. (1811), *D. linnei* (Bory) Bedd.(1869).

Vernacular names

- *D. fortunei*. Northern Indo-China: hou sen chan (monkey's gingler).
- *D. pleuridioides*. Indonesia: tameti (Alor).
- *D. quercifolia*. Oak-leaf fern (En). Indonesia: daun kepala tupai. Malaysia: daun kepala tupai, sakat laipang. Philippines: pakpak-lauin (Tagalog), paipai-amo, kabkab (Bisaya). Burma (Myanmar): thil-ka-sen (Wakema), kyaukpyu (Ramree Island). Thailand: kratae tai mai (central), kra prok waao (Prachuap Khiri Khan, Prachin Buri), kuut khae hok (Karen, Mae Hong Son).
- *D. rigidula*. Basket fern (En). Indonesia: paku kayakas (Sundanese), simbar layangan (Javanese), pasilan kelapa (Java, meaning medicinal rhizome on stem of coconut tree). New Guinea: poto (Southern Highlands), tjekee (Irian Jaya). Philippines: pinog yupar (Luzon). Thailand: kra prok lek (Chanthaburi), kuut tang, kuut mai (northern).
- *D. sparsisora*: Indonesia: paku langlayangan (Sundanese), barang-barang (Makassar), lilianga (Ternate). Malaysia: kakayan (Sarawak). New Guinea: talwala (Sepik), kangkoms (Irian Jaya). Philippines: kabkab (Palawan), apatpat di batu (Luzon), glemu (Mindanao). Thailand: kuut hok (northern), phang-ngaa (peninsular), wean ngun kwak (peninsular).

Origin and geographic distribution *Drynaria* is an Old World fern genus and is found from Africa, throughout Asia to north-eastern Australia and comprises about 15 species (about 10 in South-East Asia). The greatest diversity is found in continental Asia, especially in China. *D. fortunei* occurs in Thailand, Indo-China, southern China and Taiwan. *D. pleuridioides* is only known from Indonesia (Sumatra, Java, Lesser Sunda Islands, Sulawesi and the Moluccas). *D. quercifolia* is distributed from India and southern China (Hainan), throughout South-East Asia to tropical Australia and Polynesia. In South-East Asia it is one of the most common epiphytic ferns, found in the crowns of forest trees but often also on roadside and village trees. *D. rigidula* occurs in Burma (Myanmar), Thailand, Indo-China, China (Hainan), Malaysia, Indonesia, the Philippines, New Guinea, Australia and Polynesia. *D. sparsisora* is found from Sri Lanka, throughout South-East Asia to southern China, tropical Australia and Polynesia.

Uses Most species of *Drynaria* are quite often grown as ornamentals and certainly all have ornamental value. Some are also used medicinally or as a stimulant and as a vegetable. *D. fortunei* is used in Chinese medicine to tonify deficient kidneys manifested as lower back pain and with weakness of the legs, to invigorate blood, to stop bleeding and to heal wounds. In Alor (Indonesia) roots of *D. pleuridioides* are used as a substitute for *Areca* nut (betel) and it is believed that its leaves, placed on a bamboo pole near *Areca* trees, curse thieves with insanity. In Peninsular Malaysia, the leaves of *D. quercifolia* are pounded and applied as a poultice to swellings; the diluted juice is sprinkled over the head of a patient to treat fever. In the Philippines, aside from being an ornamental, it is a medicine for stomach ache, fever, coughs and a dilute decoction of the rhizomes is astringent, helpful for haemoptysis and if made more concentrated, it can be used as an anthelmintic. In Sumba (Indonesia), inner tissues from the rhizome are mixed with gum (from the tree *Lannea coromandelica* (Houtt.) Merr., 'kaju santen') to make a poultice that is applied to the head against headache. In India, this plant is used for strong fever, cough, and phthisis. To comfort an aching stomach, the stem is cut into fine pieces, soaked in water and the extract is drunk. In Sulawesi (Indonesia), leaves of *D. rigidula* are eaten as a vegetable. In Java (Indonesia) the juicy rhizomes are collected by medicine men, but only when they are growing on the coconut tree. As in the Philippines, a decoction of the rhizome is used to cure gonorrhoea and dysentery. Inhabitants of the Treasury Islands used it as a remedy for seasickness and they believed that chewing certain parts of the plant made warriors agile and light-footed. In Indonesia, roots of *D. sparsisora* (like those of *D. pleuridioides*) may be used as a substitute for *Areca* nut. Sap of the rhizome mixed with other plant parts has been considered beneficial for persistent diarrhoea. The bruised rhizome is used externally to reduce swollen limbs and to mature boils. A decoction of the rhizome mixed with *Inocarpus fagiferus* (Parkinson) Fosberg is applied to treat virulent gonorrhoea. The leaves mixed with honey and *Alpinia galanga* (L.) Willd. may be administered into the nose as a treatment against vomiting. It is also used as a medicine for the eyes and in the Philippines the roots are applied against snake bites. In Indonesia, children use the base leaves as kites and in Makassar young foliage leaves are eaten as a vegetable. In India the rhizome paste of *Drynaria* is applied to induce labour and easy childbirth; in diluted form it is used to treat ear infections.

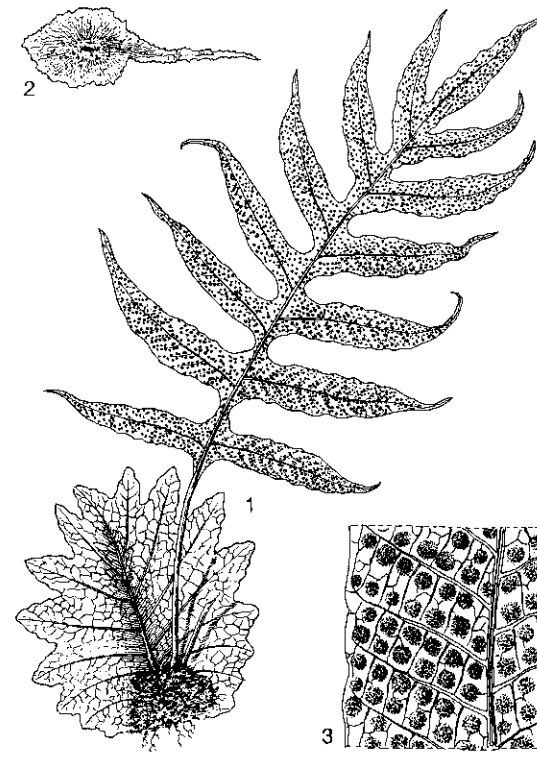
In China, *D. sinica* Diels (syn. *D. baronii* (H. Christ) Diels) ('gusuibu') rhizome is used with *Psoralea* fruit ('buguzhi'), *Cyathula* root ('niuxi') and walnut seed ('hutaoren') for lower back pain and weakness of the legs. It can also be used with prepared *Rehmannia* root ('shudihuang') and dogwood fruit ('shanzhuyu') for tinnitus, deafness and toothache. *Drynaria* is used with magic ingredients and myrrh ('moyao') for swellings and pain due to external trauma or injury. As one of the constituents of 'kwat sui po' it is applied as an antibiotic and tonic against pain in the kidney and broken limbs.

Production and international trade There is hardly any information on production and international trade available for *Drynaria* although most species are also cultivated as ornamentals. In early 2001, the price of a 10% extract (probably of *D. fortunei*) on the wholesale market amounted to US$ 38 per kg and US$ 10 per 100 g for the rhizome extract, and US$ 7 per pound of the powder 'gusuibu'.

Properties Allegedly, *Drynaria* enhances the calcium absorption of bone, increases blood calcium and inorganic phosphorus levels; it lowers blood lipid levels and has an antibiotic activity due to streptomycin. Administration of 100–150 g of the fresh plant per day can result in, e.g. acute toxic reaction with dry mouth, polyogia, palpitation, chest distress, vagueness and platycoria. Through tissue culture and isotope tracing, it has been found that injection of gusuibu (*D. sinica*) significantly promoted calcification of the cultivated chicken embryo bone primordium, increased ALP activity in the cultivated tissue, and accelerated synthesis of proteoglycan. Proteoglycan synthesis was an important factor in the promotion of calcification. The rhizomes of *D. sinica* contain propinqualin ((-)-epiafzelechin-3-O-β-D-allopyranoside), 4-O-β-D-glucopyranosyl caffeic acid, and β-sitosterol-3-O-β-D-glucopyranoside.

In the Philippines *D. quercifolia* contained alkaloids (rhizome, leaf), tannin (leaf), saponin (leaf), oxalic and formic acids (leaf), *D. rigidula* arbutin (rhizome), amygdalin (rhizome), and in all parts formic, oxalic and tartaric acids ranging from detectable to large amounts. A crude extract from the rhizome of *D. quercifolia* has antibacterial properties. In culture, it is effective in inhibiting the growth of the bacteria *Klebsiella pneumoniae* which is assocated with pneumonia in humans.

Description Epiphytic, epilithic or rarely terrestrial ferns with the rhizome concealed by non-green, pinnatifid base leaves (so-called nest leaves) behind which green foliage leaves rise up. Rhizome creeping, branched, densely scaly; scales peltately attached or basifixed, the margins toothed or shortly hairy, apex with a distinct glandular top-cell, spreading or appressed; phyllopodia absent, rhachises often persisting. Leaves dimorphic with shallowly lobed base leaves (nest leaves) and large, deeply lobed foliage leaves; base leaves sessile, lamina rounded to ovate or elliptical, entire to lobate-pinnatifid, initially green but becoming brown and papery, with trichomes, glands and scattered scales, persisting for a long time, acting as humus collectors; foliage leaves green, sessile or with an often winged petiole, lamina pinnatifid, sometimes pinnate, with trichomes, glands and scattered scales, especially around the rachis and costae; pinnae equally wide throughout or with a basal constriction, base adnate, margins serrate, apex acute, apical pinna often aborted; venation reticulate, with very few free included veinlets; nectaries present on the foliage leaves but only active in very young ones, in species with pinnatifid leaves appearing as large translucent spots near the junction of the primary



Drynaria sparsisora (Desv.) T. Moore – 1, habit; 2, rhizome scale; 3, part of leaf with sori.

veins and the midrib, in species with pinnate leaves occurring on the stalks of the pinnae. Sori round, borne at the angles of the small areoles of the foliage-leaves, exindusiate. Spores monolete, ellipsoid to reniform, 37–77 μm in diameter, pale or pigmented, surface echinate or tuberculate.

- *D. fortunei*. Epiphytic or epilithic fern, rhizome 1–2 cm in diameter, densely rufous scaly. Base leaves rounded, up to 9 cm × 7 cm, lobed, lobes oblong-subdeltoid, up to 1.5 cm wide, brown; foliage leaves with up to 10 cm long, winged petiole, lamina ellipsoid to ovate, up to 45 cm × 20 cm, deeply pinnatifid, lobes narrowly oblong, up to 11 cm × 2.5 cm, margin entire but irregularly waved, midrib and main veins minutely pubescent. Sori dispersed from the upper central portion downwards, 2 rows of round sori or a single row of crescent sori between adjacent main veins. Spores with globular excrescences.
- *D. pleuridioides*. Epiphytic fern, up to 1.25 m tall, rhizome 1–2 cm in diameter, internodes up to 10 cm long, scales peltate, spreading, 4–8 mm × 1 mm, dentate or curly ciliate. Base leaves overlapping, lobed, 10–30 cm × 7–22 cm, margin irregularly denticulate; foliage leaves with up to 25 cm long, winged petiole; lamina pinnatifid, 40–100 cm × 20–40 cm, pinnae 12–25 cm × 1–3.5 cm, gradually smaller towards apex, margin entire. Sori round, 2–3 mm in diameter, in one row between midrib and margin, distinctly sunken into the leaf surface, sporangia glabrous. Spores verrucate, without spines or globules.
- *D. quercifolia*. Epiphytic, epilithic or occasionally terrestrial fern, rhizome about 2–3 cm in diameter, woolly because of persistent soft scales; scales gradually narrowing from the peltately attached base to the acute apex, up to 2.5 cm × 1 mm, soft, light brown to black-brown with paler, dentate margin. Base leaves more or less ovate, 10–50 cm × 10–40 cm, shallowly to rather deeply lobed with rounded lobes; petiole of foliage leaves unconspicuously winged, up to 35 cm long, lamina pinnatifid, 40–100(–150) cm × 15–50 cm, upper part often drooping, lobes oblique, 1–25(–30) cm × 2–5 cm, shortly acuminate, separated by narrow sinuses, thin but stiffly leathery with reticulate venation. Sori round, 1–2 mm in diameter, in two almost regular rows between adjacent main lateral veins of the foliage leaves, not or only slightly impressed into the laminal surface, sporangia glabrous. Spores with spines.
- *D. rigidula*. Epiphytic or terrestrial fern, 0.5–2 m tall, rhizome 1–2 cm in diameter, fleshy, densely scaly; scales narrowed gradually from the peltately attached base to an acute or acuminate apex, 5–13 mm × 0.5–1.5 mm, brown to red-brown, margins pale and ciliate. Base leaves overlapping, ovate, 10–30 cm × 5–15 cm, margin shallowly to deeply lobed, the lobes rounded and finely denticulate; young foliage leaves covered with white, very small scales or stellate hairs; petiole up to 40 cm long, not winged but in upper part bearing small appendages spaced like the pinnae; lamina pinnate, in outline 25–100(–200) cm × 12–50 cm, the pinnae jointed to the rachis, papery to somewhat leathery, with short, winged stalks, each bearing a small gland; pinna strap-shaped, 8–25(–30) cm × 0.5–3 cm, base cuneate, margin crenate to serrate, apex obtuse to acuminate, venation reticulate. Sori round, 1–2 mm in diameter, in a single row on each side of the midrib, one sorus between each pair of the main lateral veins, closer to the midrib than to the margin, sunken into the laminal surface, sporangia glabrous. Spores with spines.
- *D. sparsisora*. Epiphytic, epilithic or terrestrial fern, rhizome 1–3 cm in diameter, fleshy, densely scaly, smooth and snake-like when old, covered with dark scale bases, the narrow apical portions having broken off; scales peltate, appressed, overlapping, narrowed abruptly above the rounded base, tapering to a narrow, acute, rather spreading apex, 1–11 mm × 1–3 mm, stiff, brown to very dark brown, margins paler and bearing very fine hair-like teeth. Base leaves imbricate, ovate, 10–35 cm × 10–25 cm, margin shallowly or deeply lobed, the lobes rounded; foliage leaves stiffly erect; petiole 5–18 cm long, winged; lamina leathery, deeply pinnatifid, in outline 30–80 cm × 15–30 cm, the lobes strap-like, narrowed slightly towards the base, tapering to a mostly acute apex, 10–30 cm × 1.5–4.5 cm; veins reticulate between prominent main lateral veins. Sori round, 1–2 mm in diameter, in more than two irregular rows between adjacent main lateral veins of the foliage leaves, not or only slightly sunken into the laminal surface; sporangia glabrous. Spores with spines.

Growth and development When a rhizome of *Drynaria* is exposed to light it develops base leaves (nest-leaves). When the rhizome is subsequently shaded by the closely appressed base leaves, the dark condition signals the development of the foliage leaves. The base leaves collect litter, which contributes to the nutrition of the plant, and also retain water. When the base leaves disintegrate, some *Drynaria* species retain the naked rachises for a long time, sometimes

with an empty mesh of finer veins. Epiphytic *D. rigidula* often encircles the trunk of a tree many times (forming a cylinder around the trunk) and may form large nests in the crown. Juvenile leaves of *D. rigidula* may be variously intermediate between base and foliage leaves; base leaves may be absent in older plants.

Other botanical information *Drynaria* is characterized by its peculiar leaf dimorphism with often sessile, smaller, always sterile base leaves and stalked, sterile or fertile foliage leaves with a characteristically aborted apex with a peculiar lopsided look because a lateral pinna has taken its place, the leathery texture of the leaves and the presence of nectaries between the bases of the pinnae. *D. quercifolia* resembles *D. sparsisora* but can be distinguished by its woolly rhizome, its usually larger, drooping leaves and its very regular rows of sori. In *D. rigidula*, 'Vidgenii' is a cultivar with long, hanging, dark green leaves with narrowly lobed segments; 'Whitei' has leaves with very broad, deeply-lobed segments to impart a ruffled appearance and the crowded segments overlap each other. Characteristic features of *D. sparsisora* are its snake-like old rhizomes, its erect foliage leaves and its irregularly arranged sori. Without rhizomes, it is almost impossible to distinguish between *D. sparsisora* and *D. quercifolia*. A closely related genus of *Drynaria* is *Aglaomorpha* Schott with about 30 species in tropical Asia, of which 14 in Malesia. It can be distinguished from *Drynaria* by the absence of base leaves and its normally developed apical pinnae. In general they are large to very large epiphytic ferns with thick rhizomes and pinnatifid to pinnate leaves. They are beautiful ornamentals, e.g. *Aglaomorpha heraclea* (Kunze) Copel. (synonyms: *D. heraclea* T. Moore, *Drynariopsis heraclea* Ching) with sessile pinnatifid leaves up to 3.5 m long and *Aglaomorpha coronans* (Mett.) Copel. (synonyms: *D. coronans* T. Moore, *D. conjugata* Baker ex Bedd.) with leaves up to about 2 m long.

Ecology *D. fortunei* grows, often in the shade, on trunks of trees in several types of forest, on rocks and occasionally on brick walls. Its altitudinal range is 0–1300 m. *D. pleuridioides* grows on trunks of trees, encircling the trunk many times or spirally climbing. It occurs in primary and secondary forest, occasionally in plantations, usually at 500–1500 m altitude. *D. quercifolia* grows terrestrially among rocks, or as an epiphyte on tree trunks, in open forest, rain forest margins and in dry rain forest, from sea level up to 1200(–1900) m altitude. In South-East Asia *D. quercifolia* is one of the most common epiphytic ferns, found in the crowns of forest trees but often also on roadside and village trees. In rubber and coconut plantations they sometimes become a troublesome weed. *D. rigidula* is often found on or among rocks, terrestrially forming a crust, or it grows as an epiphyte on old trees in open forest, on wayside trees and trees in plantations. It grows from sea level up to 2400 m altitude but prefers a cooler climate and is more often found in mountain forest. *D. sparsisora* normally grows spirally on tree trunks in primary or secondary, open or dry forest, from sea level up to 1700 m altitude. It is found occasionally in sandy soils or on rocks; it tolerates more exposure than *D. quercifolia*. As litter collector, *Drynaria* is less efficient than bird's nest ferns (*Asplenium nidus* L.) and staghorn ferns (*Platycerium* species). The nectaries secrete some fluid and are only active in young leaves. Normally, nectaries attract insects like ants, but their function in ferns is unknown. *D. rigidula* however, frequently harbours ants.

Husbandry All species of *Drynaria* grow from spores, but propagation is easier by rhizome divisions. Most *Drynaria* species can be grown readily on rocks or trees in tropical gardens or in a large pot or basket with a coarse soil mixture. Once established, plants are very tolerant to drought.

Genetic resources and breeding The *Drynaria* species here described are quite common and not threatened by extinction. There are no known germplasm collections or breeding programmes for *Drynaria*.

Prospects *Drynaria* species are very beautiful and prized ornamentals. Further research is needed to facilitate domestication and commercial cultivation and its trade as an ornamental. The medicinal value of several species deserves further investigation.

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Titien Ngatinem Praptosuwiryo

Equisetum ramosissimum Desf.

Fl. atlant. 2: 398 (1799).
EQUISETACEAE
$2n = 216$

Synonyms *Equisetum ramosum* DC. (1806), *E. elongatum* Willd. (1810), *Hippochaete ramosissima* (Desf.) Börner (1912).

Vernacular names Branched horsetail (En). Indonesia: bibitungan (Sundanese), rumput betung (Sumatra), tropongan (Javanese). Papua New Guinea: niglgakagl. Philippines: putod, sumbok (Bukidnon), putuptud (Bontoc, Igorot). Thailand: ya nguak, ya thot bong, ya hu nuak (northern). Vietnam: c[or] d[oos]t.

Origin and geographic distribution *E. ramosissimum* is widespread, from southern and eastern Africa, southern and central Europe throughout Asia to Central and South America. In South-East Asia only subsp. *debile* (Roxb. ex Vauch.) Hauke is found.

Uses The stems of *Equisetum* L. accumulate crystals of silica and the fine abrasive action of these crystals make it a useful cleaning agent. Throughout New Guinea *E. ramosissimum* is used to clean cooking and eating utensils. The sandpaper-like qualities lead to its use in shaping and smoothing tools, ornaments and weapons. In Indonesia and Malaysia, *E. ramosissimum* stems are powdered and made into an ointment which is used externally to treat bruises, fractures and arthritis. A decoction is drunk as a diuretic and astringent to treat dysentery and haemorrhoids. In India it is used as diuretic and given against gonorrhoea. In Nepal juice of the roots (about 4 teaspoons 4 times a day for a week), is given to relieve fever. In South Africa, juice from the plant is used to relieve toothache and applied to the wounds after tooth extraction. In Papua New Guinea, horsetail is crushed together with leaves of *Ficus* sp., *Impatiens* sp. and *Stellaria* sp. and the sap is drunk to soothe a bad cough. In European traditional and modern alternative medicine several horsetail species were commonly used as diuretic and in baths to treat dropsy, urinary complaints and kidney affections. *E. arvense* L., *E. palustre* L. and *E. variegatum* Schleich. were prescribed as 'Herba Equiseti maioris' to cure gonorrhoea and diarrhoea. About 4 g of the dried herb, powdered and taken 3–4 times a day, was used as a remedy for spitting blood, remineralizing organisms with retarded growth, especially in cases of tuberculosis, where the pulmonary tissues were affected by lesions. It was also applied as a haemostatic, diuretic, digestive agent and purifier. The ashes of *Equisetum* are administered in doses of 0.2–0.6 g and considered valuable in treating an acid stomach, dyspepsia, tuberculosis, pain in the bones, gastric and intestinal ulcers, bleeding, blood in the urine and difficulty in urinating. The juice of the fresh plant is used as well, in doses of 20–50 g/l per day. A strong decoction acts as an emmenagogue; it is also cooling and astringent and used for haemorrhage, cystic ulceration and ulcers in the urinary passages. Applied externally the decoction stops bleeding, heals wounds and reduces swelling of the eyelids. In Chinese medicine various *Equisetum* species have been applied. *E. hyemale* L., *E. arvense* L. and *E. ramosissimum* are the sources of the drugs 'mùzéi' and 'wènjing' which serve as an astringent, haemostatic and diuretic. Wènjing is also used as a diaphoretic and to cure eye-diseases, catarrh, urinary calculus and hyperpepsia. There is confusion, however, as to the common names and identity of the drug plants. Moreover, both drugs share a synonym name ('jiéjiécão'). *E. ramosissimum* has been identified in samples of mùzéi, but it is possible that all these species do not vary much in their properties and that the species most

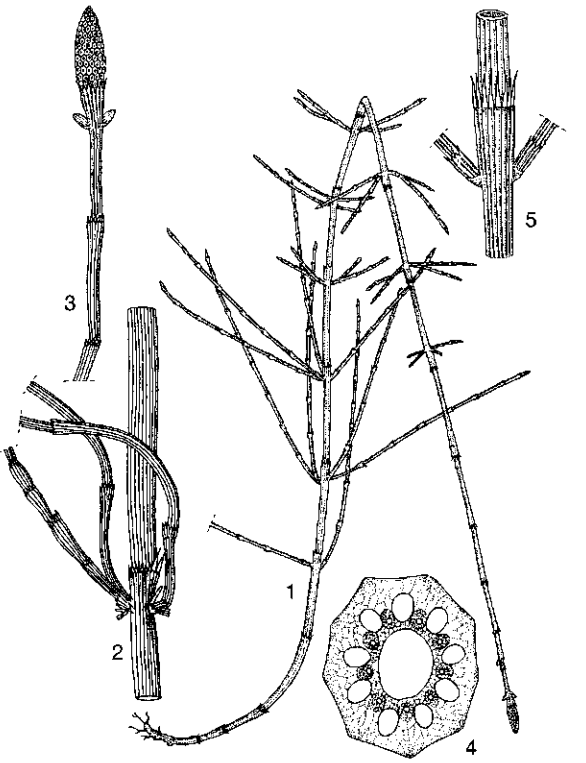
easily obtainable is used. It is striking that *Equisetum* species were applied in similar ways independently in Asia and Europe, as well as in South America by the Indians of Peru.

E. ramosissimum is often cultivated as a pot plant. The stems are sometimes made into handicraft objects, e.g. picture frames.

Production and international trade *Equisetum* species are of diminishing economic importance but are still locally traded as crude drugs. The stems of *E. ramosissimum* are traded in Indonesian traditional medicine as 'greges otot' or 'greges tulang'.

Properties *Equisetum* contains high levels of silica and potassium but the chemical contents are not yet fully known. *Equisetum* species accumulate minerals in their tissue up to 125 ppm. In gold-rich areas as much as 610 g of gold per t *Equisetum* has been recorded. Some contain alkaloids (palustrine, palustridine, nicotine, equisetine), thiaminase, glycosides (dimethylsulphon), aconitinic acids, saponins (equisetonoside), 3-methoxypyridine, β-sitosterol, equisetolic acid and equisetonine. The rhizomes contain a considerable quantity of starch cells. Some species are poisonous to livestock whereas others are used as fodder. *Equisetum* species also contain a thiaminase and the effects of poisoning in animals from ingestion of the plants are similar to those of vitamin B_1 deficiency. *E. ramosissimum* is almost certainly toxic and it irritates the skin. In analysis, β-sitosterol and stigmasterol were found as well as unidentified C_{28} to C_{32} carbohydrates. *E. ramosissimum* plants show considerable thiaminase activity combined with a relatively low thiamine content. In the Philippines, horses are most susceptible to the stem of horsetail, and cattle and sheep also suffer ill effects due to poisonous principles it contains. High rates of nitrogen fixation by acetylene reduction are realized by *Enterobacteriaceae* associated with the roots of *E. ramosissimum*. In in-vivo and in-vitro tests *E. ramosissimum* subsp. *debile* proved effective in inhibiting many phyllosphere fungi.

Description A very characteristic plant with jointed, hollow stems, branches in whorls around the stem, apparently without leaves and spores produced in a terminal, cone-like strobilus. Rhizome rather deep underground, erect or ascending, with many ascending, dark brown to black branches, somewhat rough, 6–8-sectored. Roots numerous, wiry along the length of the rhizomes. Stem irregularly branched or simple, erect or ascending, cylindrical, 15–300(–900) cm × 2–3(–15) mm, articulate with hollow internodes, smooth, evergreen (green to greyish-green); ridges 10–32, convex, usually with small cross-bands of silica, grooves with flat-topped rosettes; stomata arranged in one line on each side of the groove, 71–102 μm × 56–78 μm. Branches solitary or in groups of 2–3(–5), erect, straight or sinuous, simple or occasionally branched, up to 60 cm long, with 6–10 ridges. Leaves small, scale-like, in whorls that fuse into a sheath at the stem nodes; sheath cylindrical to slightly funnel-shaped, 4.5–13 mm × 2–12 mm, its segments smooth, the midrib prominent basally, becoming flattened apically, with 2 distinct lateral ridges, ribs flattened, angular at the sides, green, teeth thin, with a brown central band and white or colourless margins, drying or deciduous, leaving a truncated margin on the sheath; sheath of the branches like the ones of the stem or retaining the teeth, the first internode much shorter than the correspond-



Equisetum ramosissimum Desf. subsp. debile (Roxb. ex Vauch) Hauke – 1, habit; 2, part of the stem with sheath and branches (teeth partly deciduous); 3, stem apex with strobilus; 4, transverse section through internode; 5, sheath with persisting teeth.

ing stem sheath. Strobilus cone-like, ellipsoid, up to 17 mm × 7 mm, apex subobtuse to apiculate with 1 mm apiculum, yellow to black; sporangiophore consists of a short stalk at right angle to the axis of the strobilus, peltately attached to a plate-like, flat, hexagonal structure bearing 5–10 sporangia on its underside. Spores globose, each one bearing 4 filiform, long, apically clavate, hygroscopic appendages (elaters), surface granulate with scattered spherical deposits, bright green.

Growth and development The hygroscopic elaters of the spores of *E. ramosissimum*, which stand out in dry air but quickly contract in moister circumstances, combine several functions that make the spores more susceptible to dispersal by wind in areas unfavourable for germination. The spores contain chlorophyll and remain viable for only a few days after they are released. The absence of a transpiration-resistant spore wall makes them vulnerable to desiccation. Under favourable conditions the spores germinate within a day. Within a few weeks the prothallus develops as an elongated, fleshy structure with upright, photosynthetically active appendages. The larger prothalli may live for months, in culture even up to two years. The prothalli are either male or bisexual. A prothallus may have as many as 200 archegonia many of which are fertilized, although the vast majority do not develop into mature sporophytes. It is not unusual for 8–10(–15) sporophytes to develop from a single gametophyte. The rhizomes of the sporophytes produce aerial stems at close intervals, together often forming dense colonies. Mature plants fruit all year round and show no seasonality.

Other botanical information *Equisetum* L. is the only genus in the family *Equisetaceae* and comprises 15 species. It is a relict group with a long fossil history and is cosmopolitan except in Australia, New Zealand and Antarctica. The many unique features of its anatomy and morphology justify its being segregated as a distinct class, subdivision or even, by some authors, a division of the plant kingdom. *Equisetum* has been subdivided into 2 subgenera, subg. *Equisetum* (stomata superficial, strobili blunt, stem smooth or a little rough) with 8 species and subg. *Hippochaete* (stomata sunken, strobili apiculate, stem rough from silica deposits) with 7 species, including *E. ramosissimum* Desf.

E. ramosissimum is variable and has been subdivided into 2 subspecies:

- subsp. *ramosissimum*: stem with double common endodermis (an inner endodermis surrounding all bundles); stomata in one to several lines; sheath-teeth persistent; from southern and eastern Africa, southern and central Europe to most of Asia except Malesia.
- subsp. *debile* (Roxb. ex Vauch.) Hauke (synonyms: *E. debile* Roxb. ex Vauch., *E. laxum* Blume, *E. timorianum* Vauch.): stem with individual endodermis (an endodermis surrounding each vascular bundle); stomata in one to several lines; sheath-teeth regularly breaking off; India, southern China, throughout Malesia (except Peninsular Malaysia) to New Caledonia.

In the area of geographical overlap, however, there is an extensive intergradation between the two subspecies. Fertile, intermediate hybrids of the two subspecies have been recorded in India, southern China and the Ryukyu Islands.

Ecology *E. ramosissimum* is found in marshes and abandoned rice fields, in meadows along streams or trails, or attached to rocks in streams, from humid lowlands up to severe alpine conditions at 3600 m altitude. The stem may remain tufted and small when growing in sandy soils along river banks, but attains a height of several m when growing in shady and swampy soils of forests. It may profit from soil disturbance, for example by logging or the establishment of plantations. It has become a weed that thrives gregariously on the rice terraces of the Philippines and in the tea plantations of Sumatra.

Propagation and planting *E. ramosissimum* can be propagated by spores but much more easily by rhizome cuttings.

Diseases and pests *Rhizoctonia solani* may cause root rot and stem rot in *E. ramosissimum*, whereas *Gloeosporium* may damage the leaves.

Harvesting The barren stems of *E. ramosissimum* are cut off just above the root.

Handling after harvest *E. ramosissimum* is used either fresh or dried, but allegedly it is more effective when fresh. A fluid extract is prepared from it and the ashes are also employed.

Genetic resources and breeding The variability of *E. ramosissimum* subsp. *debile* is small. Neither substantial germplasm collections nor breeding programmes are known to exist.

Prospects *E. ramosissimum* is common in South-East Asia and its medicinal properties in particular need better investigation. Its use in traditional medicine all over the world makes it an interesting and promising plant resource.

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Dedy Darnaedi, N. Wulijarni-Soetjipto & W.P. de Winter

Helminthostachys zeylanica (L.) Hook.

Gen. fil.: t. 47 (1840).

OPHIOGLOSSACEAE

$2n = 188$ (tetraploid)

Synonyms *Osmunda zeylanica* L. (1753), *Helminthostachys dulcis* Kaulfuss (1824).

Vernacular names Indonesia: rawu bekubang (Malay, western Sumatra), jajalakan (Sundanese), pakis kaler (Javanese). Malaysia: tunjok langit, akar paku, jelai. Philippines: tungkud-langit (Tagalog). Thailand: kut chong (northern), tin nok yung (south-eastern, peninsular), phak nok yung (eastern). Vietnam: s[aa]m d[aas]t, r[as]ng re[uf]ng gi[es], s[aa]m b[of]ng bong.

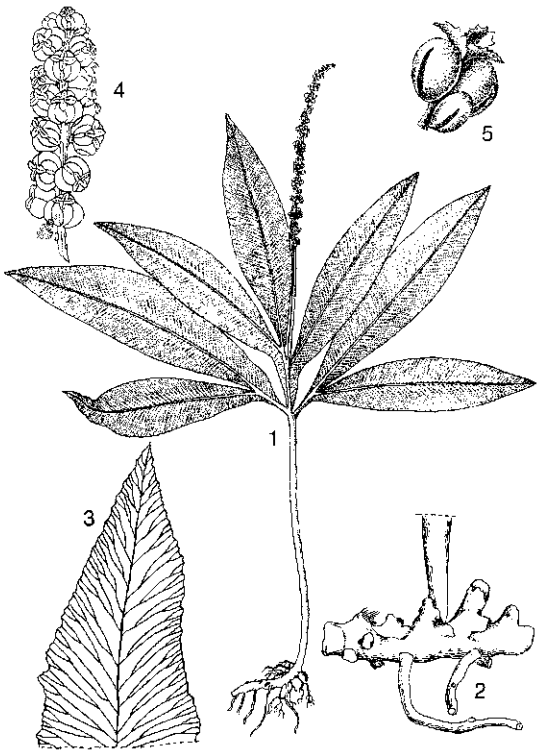
Origin and geographic distribution The exact origin of *H. zeylanica* is unknown but it is widespread at low altitudes from India, Sri Lanka, southern China and Taiwan, throughout South-East Asia to tropical Australia and the western Pacific.

Uses *H. zeylanica* is used as food, medicine and as a source of fibre. In many countries, young leaves are eaten cooked as a vegetable or raw as a salad. Young petioles can be cooked, dressed and eaten as a substitute for asparagus. In Java, the rhizome is used against dysentery (fresh or powdered, said to be very effective), catarrh (some juice is sufficient) and early stages of pulmonary tuberculosis (besides eating a porridge made from the rhizome, spreading the porridge over the chest is also said to be beneficial). In the Moluccas, the rhizome is used as a mild laxative and is eaten with betel for whooping cough (it can be preserved by being candied). In Malaysia, it is regarded as a tonic and the Sakai use it to treat syphilis. In the Philippines it is used against malaria and in India for treatment of sciatica. In Java and the Philippines petioles of old leaves are used in wickerwork and handicraft. *H. zeylanica* can be grown as an ornamental. In Peninsular Malaysia, for some traditional medicinal applications, *Syngramma alismifolia* (Presl) J. Smith (*Pteridaceae*, found in western Malesia, vernacular names: paku tombak, paku tunjok langit) is sometimes used as a substitute for *H. zeylanica*.

Production and international trade *H. zeylanica* is traded only at local markets and no statistics on production or trade exist. Formerly Malaysia exported some rhizomes to China. In the Philippines it used to be sold in considerable quantities on provincial markets but plants are becoming rarer because of habitat destruction.

Properties *H. zeylanica* is a good source of phosphorus, calcium and iron; per 100 g edible portion, young leaves contain approximately 1.5 g ash, of which P 350 mg, Ca 30 mg and Fe 15 mg.

Description Terrestrial fern with short creeping rhizome up to 7 mm in diameter, unbranched, bearing fleshy roots laterally and ventrally; erect stem part absent. Leaves in two rows, one or



Helminthostachys zeylanica (L.) Hook. – 1, habit; 2, apex of rhizome; 3, apex of a lateral leaf lobe showing venation; 4, apex of the spike; 5, sporangiophore with a cluster of sporangia.

rarely two per growing season; petiole 10–60 cm long, fleshy, green or purplish-brown; lamina pinnate to subpalmate, 5–25 cm × 10–50 mm, tripartite, herbaceous; pinnae rhomboid to obdeltoid, up to 25 cm long, short stalked or subsessile, with a terminal lobe and one or two pairs of sessile lateral lobes; lobes lanceolate, 5–25 cm × 2–5 cm, base cuneate, decurrent, margin entire or finely and irregularly dentate, apex acuminate; veinlets all free, once or twice forked. Spike cylindrical, (3–)7–13(–21) cm × 6–7 mm, with a stalk of (3–)7–20(–30) cm, arising from the junction of the petiole and the blade, usually protruding beyond the blade, bearing numerous short branches each with a group of round sessile sporangia that open with a longitudinal slit and with small sterile lobes at the apex. Spores globose, trilete, 20–40 µm in diameter, granular with coarse, more or less fused, cylindrical projections.

Growth and development The tuberous prothallus of *H. zeylanica* grows subterraneously as a saprophyte, dependent on a fungus. Anatomically it has a central strand of elongated, partially lignified cells, sometimes even a strand of true xylem. Initially the rhizome is vertical, but in older plants it changes to horizontal growth. Dormant axillary buds may be stimulated by damaging the apex of the rhizome. The adult plant usually has only 1 leaf, but sometimes up to 5; it grows with the onset of the rains and dies back to a dormant rhizome and root system over the dry season.

Other botanical information The *Ophioglossaceae* is the most isolated family of the ferns and some authors consider it more closely related to a lineage of progymnosperms or cycadophytes than to typical modern ferns. Evidence from fossils to back up speculations, however, is lacking. Cladistic studies based on both morphological characters and DNA sequences suggest a position between the seed plants and the true ferns, with the whisk ferns (*Psilophyta*) as closest relatives. The morphological nature of the spike is a matter of some controversy, but now generally thought to originate from two fused fertile pinnae. *Helminthostachys* Kaulfuss, characterized by the radially branched spike, is represented by one species only.

Ecology *H. zeylanica* grows terrestrially on moist ground, along the bank of streams or on humus-rich slopes in light shade from sea-level up to 400 m altitude. In the wild it is rather difficult to find and is nowhere very common. Locally it may grow gregariously.

Propagation and planting Propagation of *H. zeylanica* is by spores or by rhizome cuttings. It is not cultivated commercially.

Husbandry *H. zeylanica* can be grown in pots with a humus-rich soil mixture. It must be kept wet while in active growth but much drier while dormant. The leaves can suffer from a leaf blight disease.

Genetic resources and breeding Since *H. zeylanica* is very widespread it is not in danger of extinction although habitat destruction makes it rarer in a rapidly growing number of areas. Germplasm collection and breeding programmes are not known to exist.

Prospects *H. zeylanica* is used on a local scale as food, medicine, and as a source of fibre in many countries in South-East Asia and elsewhere. Its many uses deserve further research on nutritional and medicinal values and on requirements for domestication.

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Titien Ngatinem Praptosuwiryo

Hemionitis arifolia (Burm.f.) T. Moore

Index fil.: 114 (1859).

PTERIDACEAE

$2n = 120$ (tetraploid)

Synonyms *Asplenium arifolium* Burm.f. (1768), *Hemionitis cordifolia* Roxb. (1828), *H. cordata* Hook. & Grev. (1828).

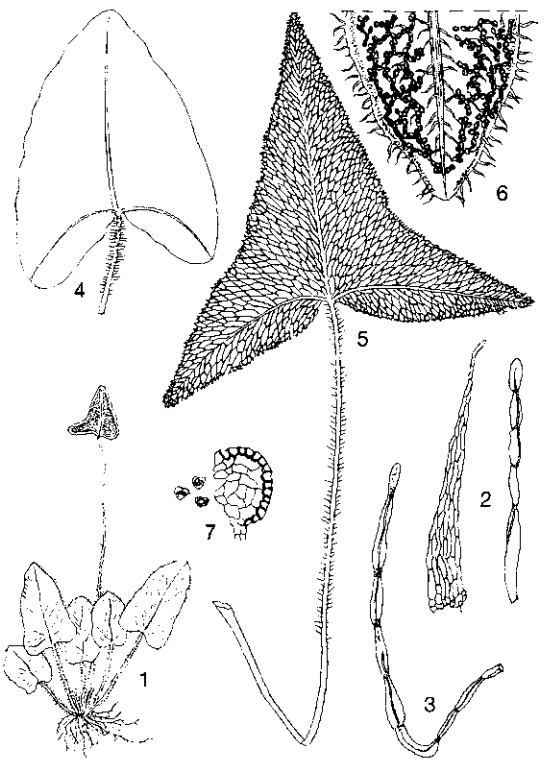
Origin and geographic distribution *H. arifolia* is native from India and Sri Lanka throughout continental South-East Asia to southern China, Taiwan and the Philippines.

Uses In the Philippines, juice of the leaves of *H. arifolia*, sometimes mixed with that of other species, is sprinkled on burns. In Thailand, it is grown as an ornamental in terrariums. In India people have believed since ancient times that *H. arifolia* possesses magical power.

Production and international trade No international trade in *H. arifolia* exists, nor is it commercially cultivated. It is only locally used.

Properties Five flavonol-3-O-glycosides have been identified from *H. arifolia*: quercetin-3-O-glycoside, quercetin-3-O-glucoside, kaempterol-3-O-glucoside, quercetin-3-O-rutinoside and kaempterol-3-O-rutinoside. Furthermore the flavone-C-glycoside apigenin-6,8-C-diglycoside has been found along with 5 other unidentified flavonoids.

Description A small fern, up to about 35 cm tall, with heart-shaped, firm leaves. Rhizome short, suberect, covered with scales and brownish hairs; scales narrowly triangular, 2–3 mm long, entire, brown at both sides. Leaves simple, sterile ones forming a rosette, fertile ones erect; petiole 4–9 cm long in sterile leaves, 15–30 cm in fertile ones, grooved, dark brown to black, hairy (narrowly scaly) throughout, hairs up to 1.5 mm long, lax,



Hemionitis arifolia (Burm.f.) T. Moore – 1, habit; 2, rhizome scale and hair; 3, narrow petiole scale; 4, underside sterile leaf; 5, underside fertile leaf; 6, sori continuous on veins; 7, sporangium releasing spores.

spreading, multicellular, coarse; sterile leaf blade narrowly ovate to oblong, up to 9 cm × 4.5 cm, deeply cordate at base, margins entire, apex rounded, rather thickly papyraceous to chartaceous, under surface with scales and hairs and prominent midrib, the veins reticulate, obscure, without free veinlets; fertile leaf blade oblong-subdeltoid to sagittate, up to 5 cm × 3 cm, at base cordate or biauriculate to hastate, margins entire, apex moderately acute, texture thinner than the sterile leaf blade; at the base of the upper surface of adult sterile and fertile leaf blades 1–3 small bulbils are present which are important for the vegetative reproduction of the fern. Sporangia continuous along the veins, forming a network all over the undersurface, sometimes completely covering it, without indusia but mixed with long narrow scales and hairs. Spores tetrahedral-globose, trilete, 25–30 µm in diameter, with prominent ridges.

Growth and development *H. arifolia* is an apogamic tetraploid. The bulbils at the base of the leaf blades are of epidermal origin and their vascularization joins that of the lamina. The development of the stele of these epiphyllous bulbils is identical to that of the young sporophyte, but the bulbils acquire certain morphological and anatomical characters earlier than the sporeling. The first bulbils appear on the 4–6th leaf. The bulbils usually come into contact with the growing substrate when the leaf decomposes, but they rarely detach from the lamina.

Other botanical information *Hemionitis* L. is here classified in the subfamily *Cheilanthoideae*, family *Pteridaceae*, together with other genera such as *Cheilanthes* Swartz, *Doryopteris* J. Smith and *Paraceterach* (F.v.Mueller) Copel.; it is also classified in *Adiantaceae*, *Parkeriaceae* or *Sinopteridaceae*. *Hemionitis* comprises 8 species, 7 distributed in tropical America, 1 (*H. arifolia*) in the Old World tropics. Although *H. arifolia* is classified in *Hemionitis* now, it is in fact a species not readily included in any recognized genus. In some technical details it is similar to *Paraceterach* but differs in its dimorphic leaves and simple, cordate to hastate leaf blades with sparse indumentum. In Peninsular Malaysia *H. arifolia* is much less common than the related *Doryopteris ludens* (Wall.) J. Smith (creeping rhizome, petiole not grooved, much less scaly) which grows in similar localities.

Ecology *H. arifolia* is found on muddy rocks, especially limestone, or along paths in dense forest at low to medium altitudes up to 900 m.

Propagation and planting *H. arifolia* can be propagated by spores and by the bulbils at the base of the leaf blades. If planted it is best maintained in small pots as long as possible. The plants prefer a moist, humus-rich, neutral to alkaline soil mix, and warm conditions in medium light. *H. arifolia* is not cultivated commercially and cultivation requirements are not well known.

Genetic resources and breeding Germplasm collections and breeding programmes of *H. arifolia* do not exist as far as is known. It is very often stated that *H. arifolia* is not a common plant despite its wide distribution.

Prospects Further research is required regarding the botany and the medicinal value of *H. arifolia*. Its possibilities as an ornamental seem promising but need closer investigation. Because it is nowhere a common fern, germplasm collection is urgently recommended.

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Dedy Darnaedi & Titien Ngatinem Praptosuwiryo

Huperzia carinata (Desv. ex Poir.) Trevis.

Atti Soc. Ital. Sci. Nat. (Milano) 17: 247 (1874).
LYCOPODIACEAE
$2n$ = unknown

Synonyms *Lycopodium carinatum* Desv. ex Poir (1814), *Urostachys carinatus* (Desv. ex Poir.) Herter ex Nessel (1939), *Phlegmariurus carinatus* (Desv. ex Poir.) Ching (1982).

Vernacular names Keeled tassel fern (En). Indonesia: kumpai lubang (Sundanese). Thailand: hang nu, hang pia check, soi nari (south-eastern).

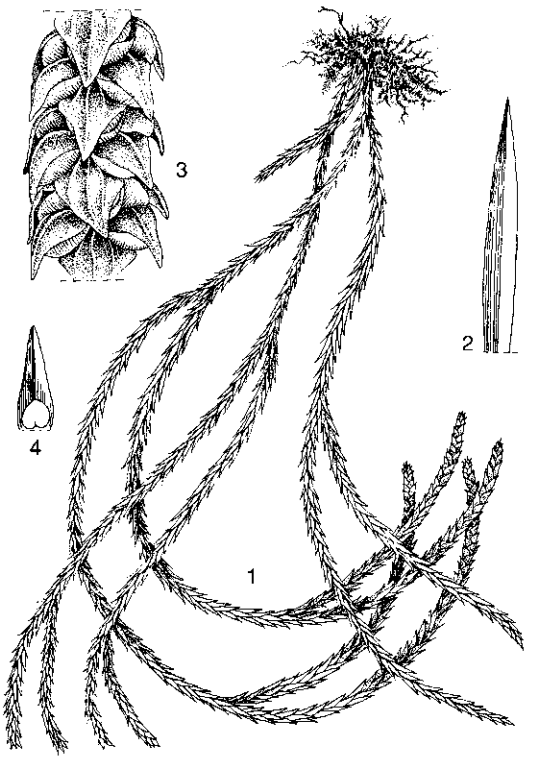
Origin and geographic distribution *H. carinata* grows naturally in tropical Asia (including South-East Asia), the Ryukyu Islands, Taiwan, Polynesia and Australia. In Thailand *H. carinata* is rather rare.

Uses *H. carinata* is mainly used as an ornamental. A pendulous fern ally with slender branches and very small, densely crowded leaves , it is suitable for hanging baskets. In South-East Asia washing the hair with an extract of the whole plant has been used to improve hair growth.

Production and international trade In Thailand and the Philippines *H. carinata* is collected from the forest and sold on local markets, but statistics are not available.

Properties In China, the chemical compounds huperzine A, lycodoline, lucidioline and lycopodine were found from *H. carinata*. From *H. serrata* (Thunb.) Trevis., also occurring in the same distribution area, the alkaloids huperzine A and huperzine B are known. These have demonstrated anticholinesterase activity and have also been effective in behaviour tests for appraising animal learning and improving memory function in humans. Huperzine A improved memory for 1–4 hours after injection and the effect was sustained for approximately 8 hours. It has been approved by the Chinese Committee on New Drug Evaluation for the treatment of senile dementia and aged memory impairment. *H. serrata* has been used in China for centuries to treat fever and inflammation. The use in South-East Asia of an extract of *H. carinata* to stimulate hair growth is based on signature only.

Description A variable, epiphytic herb, with long, lax, pendent branches, the narrower forms slender and snake-like; roots usually forming one basal tuft. Stem at first erect, becoming pendulous, (10–)35–50(–100) cm × 7–15 mm (including the leaf cover), 1–4 times dichotomously branched, pale green. Leaves subapproximate, spirally whorled in 6–8 rows, ascending to appressed, sessile; lamina lanceolate-subulate, 7–13 mm × 1–1.3 mm, base decurrent, margins entire, apex acute, grey-green to yellowish-green, subcoriaceous, midrib distinct, keeled. Strobili terminal, cylindrical, 4–8 cm × 2.5–4 mm, more or less distinctly demarcated from vegetative parts of the stem, not branched; sporophylls in four rows, ovate to oblong-subdeltoid, 4–5 mm long, as broad as the sterile leaves or broader, sharply keeled, acuminate, rather appressed; sporangium borne at the base of the sporophyll, sessile, reniform, smooth, yellow. Spores triangular, trilete, 40 µm in diameter, granulated.



Huperzia carinata (Desv. ex Poir.) Trevis – 1, habit; 2, sterile leaf; 3, part of fertile spike; 4, fertile leaf with sporangium.

Growth and development Gametophytes of *H. carinata* have rarely been observed. The spore walls of *Huperzia* Bernhardi are highly resistant and the spore may germinate only after a long time, developing into a slowly maturing, mycotrophic, subterranean (or in the substrate when epiphytic) gametophyte. After developing antheridia and archegonia, fertilization takes place and sporophyte development can begin.

Other botanical information The *Lycopodiaceae* do not have close affinities to other groups. In older views there was only one genus, *Lycopodium* L. At present, although there is no general agreement, 3 genera have been separated from *Lycopodium*, bringing the total to 4 (sometimes, however, splitting goes as far as 12 genera). *Huperzia* is now the largest genus and comprises about (200–)300(–400) species which are, however, difficult to distinguish due to the wide plasticity of the characteristics. Its diversity is highest in tropical evergreen montane forest. In older literature *Lycopodium laxum* C. Presl (synonyms: *H. cancellata* (Spring) Trevis., *H. laxa* (C. Presl) T. Sen & U. Sen, *Phlegmariurus cancellatus* (Spring) Ching) is mentioned as a synonym of *Lycopodium carinatum* but is now sometimes considered a different species. It is possible that specimens of Thailand might belong to that species.

Ecology *H. carinata* is an epiphyte on tree branches, occurring from sea-level up to 1000 m altitude.

Propagation and planting *H. carinata* is uncommonly found in cultivation, but is easy to grow. It can be propagated by stem cuttings. It cannot be grown in soil; suitable growing media are, for example, sphagnum peat, pine bark and charcoal. The potting mix should be well drained, providing plenty of aeration around the roots.

Husbandry Hanging containers are particularly suitable for *H. carinata*. Wet and shady conditions are necessary. Application of liquid fertilizer such as fish emulsion, seaweed extract or soluble fertilizer stimulates growth.

Diseases and pests Although no serious diseases and pests are known, occasional use of a systemic fungicide and insecticide are recommended to keep the plants healthy. Sometimes, fern scale can cause damage and slugs and snails eat the tips of young shoots.

Genetic resources and breeding No germplasm collections or breeding programmes of *H. carinata* are known to exist. In Australia it has the status of endangered species.

Prospects Lycopodioids are much sought after for subtropical gardens and as indoor plants. Any species, including *H. carinata*, that is easy to grow has potential as an ornamental, and germplasm collection is urgently recommended. It is worthwhile searching for possibly interesting alkaloids in the plant tissue and if found, cultivation of *H. carinata* on a larger scale will need further research.

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T. Boonkerd

Huperzia phlegmaria (L) Rothm.

Feddes Repert. Spec. Nov. Regni Veg. 54: 62 (1944).

LYCOPODIACEAE

$2n = 272$

Synonyms *Lycopodium phlegmaria* L. (1753), *Urostachys phlegmaria* (L.) Herter ex Nessel (1939), *Phlegmariurus phlegmaria* (L.) Holub (1964).

Vernacular names Common tassel fern, coarse tassel fern, Queensland tassel fern (En, Aus). Indonesia: kumpai rantai (general), kumpai rante, kumpai pure (Sundanese). Philippines: tagigongai (Negros), tagolailai (Tagalog), talironghai (Bisaya). Cambodia: kompoi kmeng. Thailand: chong nang khli (south-western), klet nakkharat (north-eastern), yom doi (central). Vietnam: r[ee]u c[aa]y.

Origin and geographic distribution *H. phlegmaria* is distributed in the Old World tropics, from Africa, Madagascar, India and Sri Lanka

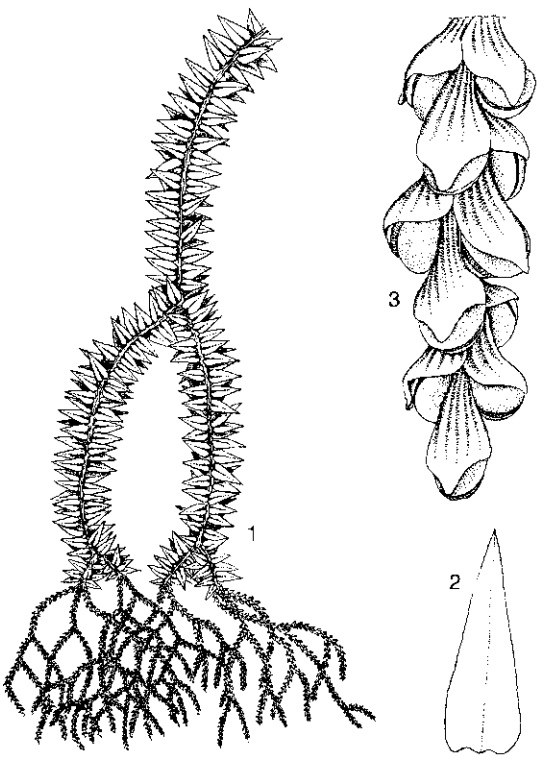
throughout South-East Asia to Taiwan, Japan, Ryukyu Islands and Australia. In and outside its distribution area it is also cultivated as an ornamental, e.g. in Indonesia and the Philippines.

Uses *H. phlegmaria* is used as an ornamental, commonly grown as a hanging plant. It is used to wash hair in the belief that it stimulates hair growth.

Production and international trade *H. phlegmaria* is mainly collected from the wild and sold on local markets, but statistics are not available.

Properties In China, the following chemical compounds were found in *H. phlegmaria*: the alkaloids lycodoline, lucidioline and lycopodine and the flavonoid apigenin. The use in South-East Asia of *H. phlegmaria* to stimulate hair growth is based on signature only.

Description An epiphytic, repeatedly forked, pendulous herb, up to about 2 m long. Stem pendulous, (15–)40–80(–190) cm × 1–2.5(–5) mm, 1–4 times branching into two equal branches at irregular intervals, brown, dark and lustrous in the oldest parts, paler near the growing point, coarse. Leaves subdistant, slightly twisted, spirally whorled in 4–8 rows, spreading, subpetiolate; lamina triangular to ovate-lanceolate, 4–15(–30) mm × 2.5–7 mm, base rounded-truncate or cordate, margins entire, yellowish-green, coriaceous, midrib prominent. Strobili terminal, cylindrical, (1.5–)4–15 cm × 1–2 mm, distinctly demarcated from vegetative parts of the stem, repeatedly dichotomously branched; sporophylls in four rows, crowded to subdistant, appressed, ovate-subdeltoid, about 1.2 mm × 1.5 mm, entire, green, turning yellowish at maturity, only partly covering the sporangium; sporangium borne at the base of the sporophyll, reniform, deeply grooved, sessile. Spores triangular, trilete, 35 µm in diameter, bright yellow, granulated.



Huperzia phlegmaria (L) Rothm. – 1, apical part of a branch with stroboli; 2, sterile leaf; 3, detail of strobilus with fertile leaves and sporangia.

Growth and development Little is known about the development of *H. phlegmaria* from spore to sporophyte. Spores remain dormant for a long time. When germinating, they develop in the substrate a cylindrical, abundantly branched gametophyte, on which the antheridia and archegonia develop. After fertilization, the sporophyte can start growing.

Other botanical information The *Lycopodiaceae* do not have close affinities to other groups. In older views there was only one genus, *Lycopodium* L. At present, although there is no general agreement, 3 genera have been separated from *Lycopodium*, bringing the total to 4 (sometimes, however, splitting goes as far as 12 genera). *Huperzia* Bernhardi is now the largest genus and comprises about (200–)300(–400) species which are, however, difficult to distinguish due to the wide plasticity of the characteristics. Its diversity is highest in tropical evergreen montane forest. Members of the genus *Huperzia* where the fertile leaves are markedly different from the vegetative leaves have sometimes been classified in *Phlegmariurus* Holub. *H. phlegmaria* is very variable and further taxonomic research might reveal that it is possibly a species complex.

Ecology *H. phlegmaria* occurs in relatively cool, partially shaded locations on mossy tree trunks or on rocks, preferring abundant moisture but tolerating dryness, in forests usually at 800–2300 m altitude.

Propagation and planting The spores of *H. phlegmaria* have highly resistant walls and may germinate only after a long time. Vegetative propagation is easier and possible by division.

Husbandry If *H. phlegmaria* is planted in pots, coconut husk or broken adventitious roots of tree

ferns may be used as a medium where wet and cool conditions are maintained. In the tropics daily watering is necessary.

Genetic resources and breeding *H. phlegmaria* is a rare plant in the wild. For ornamental use plants are cultivated so collection from the wild does not seem to pose a real threat of extinction. It is, however, a species growing in a vulnerable environment where habitat destruction may have a severe impact. Therefore, germplasm collection is strongly recommended. Breeding programmes do not exist, but the development of ornamental cultivars seems worthwhile.

Prospects If a reliable propagation method could be developed, a small but high-value market could be developed selling *H. phlegmaria* as an ornamental. It seems logical to search further for alkaloids as several other *Huperzia* species have shown medicinally promising ones.

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V.B. Amoroso

Huperzia serrata (Thunb. ex Murray) Trevis.

Atti Soc. Ital. Sci. Nat. Mus. Civ. St. Nat. (Milano) 17: 248 (1874).

LYCOPODIACEAE

$2n = 528$ (India)

Synonyms *Lycopodium serratum* Thunb. ex Murray (1784), *L. javanicum* Swartz (1801), *L. sargassifolium* Liebm. (1848).

Vernacular names Philippines: kodlala (Igorot), sinang padayao (Bontoc). Vietnam: nb[os] ri (Moi).

Origin and geographic distribution *H. serrata* is found from India, the eastern Himalayas to Korea, and through Japan, Taiwan and Indo-China to Indonesia, the Philippines, Polynesia, the Sandwich Islands and Haiti. A secondary disjunct population exists in wet mountain forests in Mexico, Cuba and Hispaniola.

Uses For many centuries *H. serrata* has been used in China as a herbal medicine ('qian ceng ta', 'jin bu huang') to treat fever and inflammations and as a diuretic, haemostyptic, antispasmodic and analgesic. Drugs based on huperzine A extracted from *H. serrata* are currently awaiting official approval for human use in western medicine and are being applied in clinical trials for the treatment of Alzheimer's disease and myasthenia gravis (disorder of neuromuscular function). Huperzine A is also used in the United States as a supplementary drug for the correction of memory impairment, under the trade name 'Cerebra'. Nowadays it is marketed as 'smart drug' to boost brain power.

Production and international trade Although *H. serrata* is quite important in traditional Chinese medicine in and outside China and is traded internationally, production and trade statistics are not available. In July 2002 the price per kg extract powder with 1–5% huperzine content was US$ 1098–2440, and per g of purified (99%) huperzine A US$ 400–700.

Properties *H. serrata* contains a wide spectrum of alkaloids, namely the huperzines A, B, G, I, J, K, L, and P, huperzinine, huperserratinine, fawcettimine, lucidioline, phlegmariunine, serratinine, serratezomine A, B, and C, N-methylhuperzine B, and 6-α-hydroxylycopodino. It also contains the triterpenoids 16-oxodiepiserratenediol, 21-episerratenediol, 21-episerratenediol-3-acetate, serratanediol-21-acetate, serratenediol, serratenediol-3-acetate and a phenolic glycoside-arbutin. Huperzine A is identical to selagine and is a slow,

reversible inhibitor of the enzyme acetylcholinesterase which is involved in the breakdown of the neurotransmitter acetylcholine. Huperzine A is a more potent inhibitor than tacrine by several orders of magnitude and has a slower dissociation rate. The natural (–)-huperzine A isomer is up to 50 times more effective than the synthetic (+)-huperzine A. In current pharmacological research huperzine A is the focus of much attention as a possible drug for Alzheimer's disease. One of the pathological marks of this disease is the formation of senile plaques from the deposition of β amyloid causing the death of neuronal cells. Both stereomers protect neuronal cells against β-amyloid toxicity. It activates anti-oxidant enzymes that neutralize the free radicals involved in the neurodegeneration. It has also been shown to alleviate the cognitive dysfunction associated with β amyloid.

Nicotinic compounds can act synergetically with huperzine A and B to protect cells of the central nerve system against cell death by excitory amino acids or β amyloid. The combination is expected to prevent or reverse neuronal dysfunction caused by Alzheimer's disease, Parkinson's disease, amyotrophic lateral sclerosis, stroke and injuries of the spinal chord or peripheral nervous system.

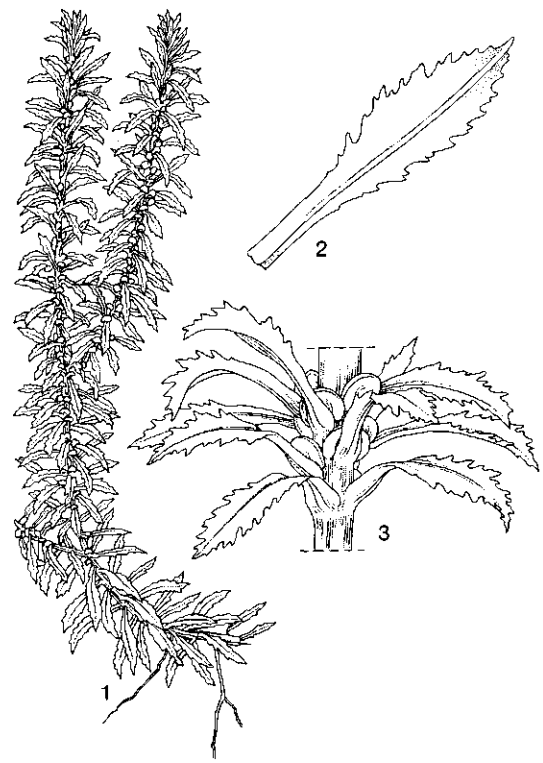
Systemic huperzine A increases norepinephrine and dopamine levels. In aged rats huperzine A lowered the concentrations of malondialdehyde and the activities of Mn-superoxide dismutase. The effects of huperzine A on learning and memory are superior to those of physostigmine. Huperzine capsules are claimed to enhance the memory and learning performance of adolescent students.

Huperzine A has been successfully tested as prophylactic agent in the pretreatment of organophosphate nerve agents, such as the chemical warfare compound soman. These compounds act as irreversible acetylcholinesterase inhibitors. Huperzine A protects the enzyme by binding to it and thus preventing a bond with the organophosphate agent. Unlike the frequently used prophylaxis pyridostigmine bromide, huperzine A passes the blood-brain barrier and can protect the cerebral nerve system. Furthermore, it does not inhibit the plasma butyrylcholinesterase, which is helpful in detoxifying the organophosphate agent.

Huperzine B and huperzine C have similar properties as huperzine A, but have been less investigated. Huperzine B exhibited higher selectivity and efficacy than tacrine in the inhibition of acetylcholinesterase and lower toxicity in mice. Huperzine B, huperzine C and, less pronouncedly, huperzine P show marked inhibitory activity against acetylcholinesterase.

There are very few reports of cases of acute hepatitis and incidentally fibrosis ascribed to the use of the Chinese herb 'jin bu huan'. It has been questioned whether this name applies to *H. serrata*, as allegedly several other herbs are known by the same name. Cases of acute intoxication were recorded in Europe, where *Lycopodium clavatum* L. can be easily confused with *Huperzia selago* (L.) Bernh. Herbal products from *Lycopodium* are generally reputed to be non-toxic and are occasionally used for preparing a health-giving tea, but patients who drank a tea, erroneously prepared from dried herbs of *H. selago*, were hospitalized with symptoms such as sweating, vomiting, diarrhoea, dizziness, cramps and slurred speech, which were attributed to poisoning by huperzine A.

Description A terrestrial, moss-like, repeatedly forked herb with serrate leaves and a ragged appearance. Stem erect, decumbent at the base, 3–15(–21) cm × 1–2 mm (not including the leaves), 1–3 times dichotomously branched, green but the



Huperzia serrata (Thunb. ex Murray) Trevis. – 1, habit; 2, leaf; 3, fertile portion.

older parts yellower. Leaves reflexed near the base, spreading in the younger parts, spirally in many ranks, petiolate; lamina elliptical to lanceolate, 7–17(–30) mm × (1–)2–4(–5) mm, base narrowed, margins deeply irregularly serrate or double serrate, apex abruptly acuminate, deep-green, thin chartaceous, costa distinctly raised above; between the leaves trilobed gemmae may be present. True strobili are absent; sporangia scattered, neither in distinct zones, nor only terminally, on stem parts that are only little different from the vegetative parts of the stem; sporophylls lanceolate, 3–5 mm long; sporangia lunate, wider than the sporophyll bases. Spores trilete, distinctly triangular, concave, truncate.

Growth and development Gametophytes of *H. serrata* have rarely been observed. The spore walls of *Huperzia* Bernh. are strong and the spore may germinate only after a long time, developing into a slowly maturing, mycotrophic, subterranean (or in the substrate when epiphytic) gametophyte. After developing antheridia and archegonia, fertilization takes place and sporophyte development can begin.

Other botanical information The *Lycopodiaceae* do not have close affinities to other groups. In older views there was only one genus, *Lycopodium* L. At present, although there is no general agreement, 3 genera have been separated from *Lycopodium*, bringing the total to 4. *Huperzia* Bernh. is now the largest genus and comprises about (200–)300(–400) species which are, however, difficult to distinguish due to the wide plasticity of the characteristics. Its diversity is highest in tropical evergreen montane forests. The tropical representatives of *H. serrata* have longer leaves than the typical ones from Japan, and have been distinguished as var. *longipetiolatum* Spring. However, the size and shape of the leaves are so variable that this distinction is hardly justified.

Ecology *H. serrata* grows terrestrially in evergreen montane forest above 1000 m altitude. Seasonal growth cycles may leave marked constrictions on the stem with shorter leaves, alternated by zones with much longer leaves, giving the plant a rather ragged appearance.

Propagation and planting Results of trials with spore culture of *H. serrata* are not known. The easiest way to propagate *H. serrata* is by planting the propagules on moist, humus-rich soil in a cool climate.

Genetic resources and breeding No germplasm collections or breeding programmes of *H. serrata* are known to exist. Although rather widely distributed, in tropical Asia at least *H. serrata* is not very common and in its natural habitat it is vulnerable to over-collection.

Prospects At present the alkaloids extracted from *H. serrata* are the focus of much attention and new pharmacological properties are published frequently. Huperzine A has the potential to become a useful agent to reduce neuronal cell damage from strokes, epilepsy and other brain disorders. A successful medicine against Alzheimer's disease would give access to a very large market. Huperzine A is a high-ranking candidate for a prophylactic agent to prevent brain injury from organophosphate nerve gas poisons. The technology for industrial synthesis of its biologically active components is being improved and will alleviate the strain on natural populations of *H. serrata*.

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(25–35)-induced injury in PC12 and NG108-15 cells and cholinesterase inhibition in mice. Neuroscience Letters 317: 143–146.

W.P. de Winter

Hypolepis punctata (Thunb.) Mett. ex Kuhn

Filic. Afr.: 120 (1868).

DENNSTAEDTIACEAE

n = (c. 92), 98, (c. 104); multiple cytotypes may exist

Synonyms *Phegopteris punctata* (Thunb.) Mett. (1864), *Nephrodium punctatum* (Thunb.) Diels (1899), *Dryopteris punctata* (Thunb.) C. Chr. (1905).

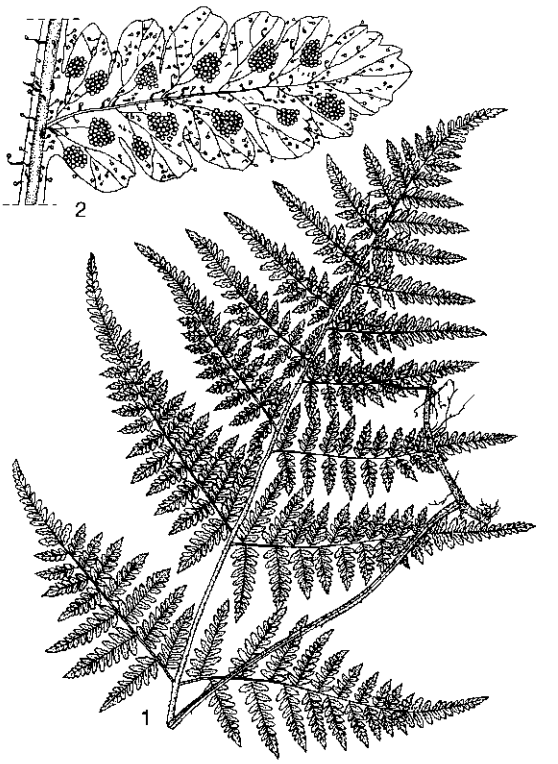
Vernacular names Downy ground fern (En). Malaysia: paku resam paya.

Origin and geographic distribution *H. punctata* is little known and is probably a species complex. In a narrow sense it occurs from north-western India, southern China to Taiwan, Ryukyu Islands and Japan, throughout continental South-East Asia to Peninsular Malaysia, Sumatra and possibly northern Philippines. In a wide sense it extends to New Zealand, Hawaii and other islands of the South Pacific.

Uses In South-East Asia leaves of *H. punctata* are made into a poultice for boils. The plant is also used in Chinese medicine. It can be grown as an ornamental, but due to its very rapid spreading habit it is not really suitable for a garden.

Properties Three sesquiterpene glycosides of the illudane type, analogues of ptaquiloside, were isolated from *H. punctata*. They are named hypolosides (hypolepines) A, B and C, and characterized as compounds related to pterosin Z. From the aerial parts the following substances have been isolated: 3(S)-pteroside D, 3(S)-pterosin D, 3(R)-pterosin D, 2(R), 3(R)-pterosin-L-2'-O-β-D-glycoside and 2(S), 3(R)-pterosin-L-2'-O-β-D-glycoside. Hypacrone, a sesquiterpene containing a reactive cyclopropane ring, has also been isolated; it shows anti-tumour activity and similar reactivity with nucleophiles to ptaquiloside.

Description A terrestrial fern with finely dissected, long-scrambling leaves. Rhizome long-creeping, 1.5–4 mm in diameter, glabrous in the older parts, densely hairy near the apex, hairs up to 2 mm long, pale brown. Leaves 3-pinnate at base, 2-pinnate at apex; petiole 15–75 cm long and 2–4 mm in diameter, adaxially grooved, with hairs up to 2 mm long; lamina broadly ovate in outline,



Hypolepis punctata (Thunb.) Mett. ex Kuhn –1, habit; 2, pinnule from a central pinna.

22–80(–100) cm × 17–70 cm, truncate at base, margin sometimes with very short hairs, apex acute, indeterminate, pale green, papyraceous, with brownish glandular and non-glandular hairs up to 1.5 mm long on the underside, shorter and sparser on upper surface; rachis grooved, with coarse multicellular hairs, their bases remaining as minute prickles; primary pinnae in 15–25 sub-opposite pairs, narrowly triangular to ovate, 9–50 cm × 3.5–20 cm, basal ones longest; secondary pinnae oblong-subtriangular, 2–11 cm × 1–4 cm; tertiary segments oblong, 0.4–1.9 cm × 0.2–0.8 cm, entire in smaller leaves, divided more than halfway in larger leaves; ultimate segments lobed to crenate to dentate, rounded, with pinnate veins. Sori oval or round, originating away from the margin, naked, not covered with a reflexed marginal flap, without hairs. Spores ellipsoid, (32–)34–39(–43) µm long, pale, monolete, echinate.

Growth and development The gametophyte of *H. punctata* consists of three kinds of prothalli: a slow-growing male prothallus loaded with antheridia, and two types of cordate, eventually hermaphrodite prothalli. The cordate propthallus can

be a large-sized, generally fast-maturing prothallus with symmetrical broad wings, initially archegonial but later it may bear antheridia, or a relatively smaller prothallus that usually is initially protrandrous and during subsequent archegonial phase bears only few fresh antheridia. *H. punctata* has an intricate balance between inter- and intragametophytic mating systems. The frequency of intergametophytic mating is relatively higher and correlated with the frequency and duration of the initial archegonial phase on the eventually hermaphrodite prothalli. In *H. punctata* the growth of the leaf apex is controlled by the lateral pinnae. The leaf apex remains suppressed until the lateral pairs of pinnae uncoil and expand. The process is repeated until the expansion of the terminal pinna is completed. The growth and spreading of *H. punctata* tends to be very fast.

Other botanical information The name *H. punctata* has been extensively misapplied and this species has been erroneously published under several other names in a complex nomenclatural history that reflects the variability of the species complex. The review of Brownsey (1987) is a valuable addition to the existing literature but a revision of the genus is badly needed to solve all problems (estimated number of species is 40, distributed pantropically). No certainty can be acquired about the correct identification of the specimens involved in the indicated uses and properties. *H. punctata* Beddome (syn. *H. beddomei* Nair & Ghosh) is not identical with *H. punctata* (Thunb.) Mett. ex Kuhn but refers to *H. pallida* (Blume) Hook., a species from Taiwan, Indo-China, Peninsular Malaysia, Java and perhaps also in Borneo and the Philippines (main difference is that sori of *H. pallida* are protected by a well-developed reflexed membranous flap (indusium), while sori in *H. punctata* are unprotected). However, for both species a similar medicinal use has been recorded.

Ecology *H. punctata* is usually found in open locations and clearings in mountainous forest areas at 750–1500 m altitude. Although the plant can produce huge leaves, it is often much smaller and sometimes quite dwarf, but still fertile. The larger leaves straggle through forest edges. Young leaves are less sticky under less favourable environments.

Propagation and planting The most suitable way to propagate *H. punctata* is by planting rhizome cuttings, but it also easily grows from spores. Under glasshouse conditions dispersal by spores is often spontaneous and can become a nuisance.

Husbandry *H. punctata* can be raised indoors at day temperatures of 21–26°C, at night of 10–15°C, with relative humidity of at least 60%. It requires bright light and moist but well-drained soil.

Genetic resources and breeding *H. punctata* is a common species complex reproducing sexually in its natural area. It is not known at present to what extent the constituting minor taxa and cytotypes may be threatened. Germplasm collections or breeding programmes are not known to exist.

Prospects As long as the identity of taxa within the *H. punctata* complex remains unknown it is impossible to formulate clear prospects. The antitumour activity of the complex may deserve further investigation and might be interesting.

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W.P. de Winter & Bambang Hariyadi

Loxogramme scolopendrina (Bory) C. Presl

Tent. pterid.: 215 (1836).

POLYPODIACEAE

$2n$ = unknown; for *Loxogramme* (Blume) C. Presl: $x = 35, 36$ (ploidy level unknown)

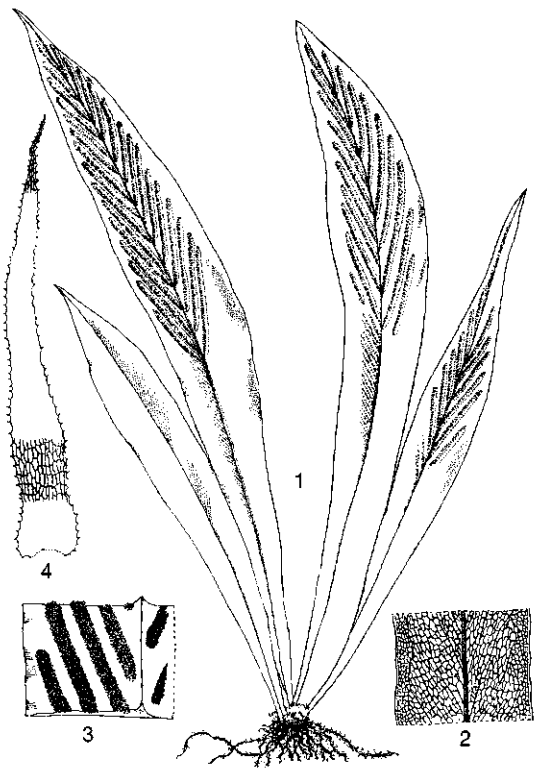
Synonyms *Grammitis scolopendrina* Bory (1829), *Anthrophyum involutum* Blume (1829), *Loxogramme involuta* auct. non (D. Don) C. Presl.

Origin and geographic distribution *L. scolopendrina* is found in South-East Asia from Peninsular Malaysia and Thailand, through Indonesia to New Guinea and the Solomon Islands.

Uses In Indonesia (Sumatra), the leaves of *L. scolopendrina* are used as cigarette paper. The whole plant has ornamental value.

Properties It is not known if the taste of the smoked tobacco is positively or negatively influenced by the use of *L. scolopendrina* as cigarette paper.

Description An epiphytic or epilithic fern, up to about 75 cm tall. Rhizome short, ascending to creeping, 5 mm thick, young parts densely covered with scales; scales lanceolate, 5–10 mm × 1 mm, margin entire, apex filiform, grey-brown, clathrate. Leaves simple, close together, sessile, not distinctly articulate, glabrous; lamina oblanceolate, 15–75 cm × 1.5–10 cm, widest above the middle, base attenuate, margin entire, flat or recurved, apex long acuminate to attenuate, fleshy-coriaceous, glabrous, deep green above, paler below, midrib raised as a prominent ridge below, nearly flat above, venation obscure, anastomosing copiously. Sori linear, up to 6 cm × 2 mm, only in the upper half of the lamina, straight and continuous (running parallel) from close to the midrib to the margin in angles of about 20–35°, a little immersed, without indusium. Spores green, globose.



Loxogramme scolopendrina (Bory) C. Presl – 1, habit; 2, venation; 3, sori; 4, scale.

Growth and development The spores of *L. scolopendrina* contain chlorophyll and do not remain viable for long after their release.

Other botanical information In the past plants in Malesia named as *Loxogramme involuta* (D. Don) C. Presl were in fact often *L. scolopendrina* or *L. avenia* (Blume) Presl. *L. involuta* is a montane, subtropical species from India throughout continental South-East Asia, absent in Malesia; its rhizome scales are much wider (up to 4 mm) and acuminate instead of filiform and the midrib of the leaf is slightly raised above and either flat or raised below. *L. avenia* occurs in continental South-East Asia and western Malesia in the same environments as *L. scolopendrina* and is more common. It can easily be distinguished from *L. scolopendrina* by the midrib: in *L. scolopendrina* the midrib is distinctly raised on the lower surface and nearly flat above, in *L. avenia* the midrib is strongly raised on the upper surface and nearly flat on the lower one. *Loxogramme* (Blume) C. Presl comprises about 40 species, a few in Africa, one in Central America, one in the Pacific, the rest in tropical and warm temperate Asia. The systematic position of this genus remains rather doubtful. Most authors classify the genus in *Polypodiaceae*, but some prefer a separate family, the *Loxogrammaceae*.

Ecology *L. scolopendrina* is a fern of the lowlands, from sea-level up to 300 m altitude, especially in evergreen forest where it grows on mossy branches and sheltered moist rocks. The leaves are persistent; their margins roll inward in dry periods and expand again when the rain comes.

Genetic resources *L. scolopendrina* is neither common nor threatened. Germplasm collections are not known to exist.

Prospects There are no indications that exploitation of *L. scolopendrina* will be developed.

Its potential as an ornamental needs further investigation.

Literature |1| Backer, C.A. & Posthumus, O., 1939. Varenflora voor Java [Fern flora for Java]. 's Lands Plantentuin, Buitenzorg, Dutch East Indies. pp. 226–228. |2| Beddome, R.H., 1969. Handbook to the ferns of British India, Ceylon and the Malay Peninsula. Today & Tomorrow's Printers & Publishers, New Delhi, India. |3| Burkill, I.H., 1935. A dictionary of the economic products of the Malay Peninsula. Vol. 2. Crown Agents for the Colonies, London, United Kingdom. p. 1368. |4| Holttum, R.E., 1966. A revised flora of Malaya. 2nd Edition. Vol. 2. Ferns of Malaya. Government Printing Office, Singapore. pp. 166–170. |5| Tagawa, M. & Iwatsuki, K., 1989. Loxogramme. In: Tagawa, M. & Iwatsuki, K. (Volume editors), 1979–1989. Pteridophytes. In: Smitinand, T., Larsen, K. (Series editors): Flora of Thailand. Vol. 3. Forest Herbarium, Royal Forest Department, Bangkok, Thailand. pp. 576–578. |6| van Alderwerelt van Rosenburgh, C.R.W.K., 1908. Malayan ferns. Handbook to the determination of the ferns of the Malayan Islands. Department of Agriculture, Batavia, Dutch East Indies. pp. 536–539.

T. Boonkerd & W. P. de Winter

Lycopodiella cernua (L.) Pic. Serm.

Webbia 23: 166 (1968).

LYCOPODIACEAE

$2n = 312$ (tetraploid)

Synonyms *Lycopodium cernuum* L. (1753), *Lepidotis cernua* (L.) P. Beauv. (1805), *Palhinhaea cernua* (L.) Vasc. & Franco (1967).

Vernacular names Staghorn clubmoss, monkey's paws (En), nodding clubmoss (Am). Indonesia: paku kawat (Sundanese), pakis kawat (Javanese), singingiri (Siberut). Malaysia: paku serani, rumput serani, rumput kenarus (Peninsular). Philippines: lamong-babae (Tagalog), kolokolud (Igorot), samong-babai (Bikol). Laos: kout ngong (Vientiane), kout khi khép (Samneua). Thailand: kuut khon (northern), rang kai (peninsular), slap (south-eastern).

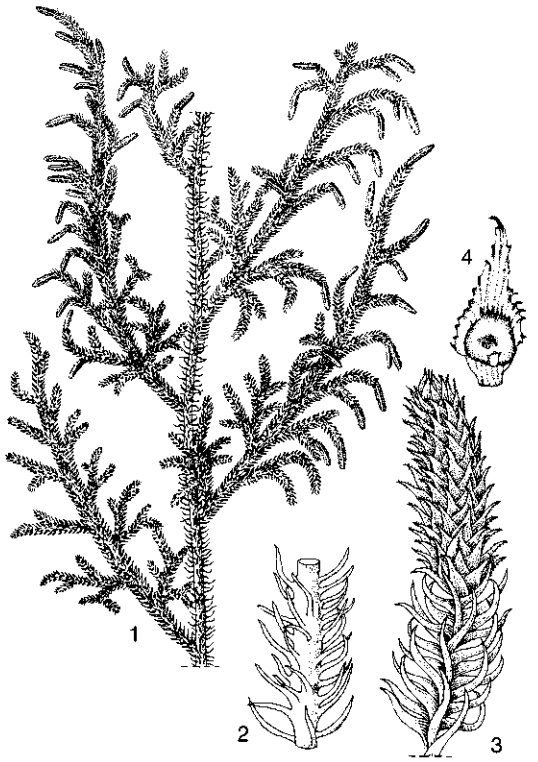
Origin and geographic distribution *L. cernua* is found throughout the tropics and subtropics, extending in Asia to Japan and New Zealand. It occurs throughout South-East Asia (except in the driest regions) where it is the most common club moss.

Uses *L. cernua* is widely used as an ornamental, both indoors and outdoors. In South-East Asia dried or fresh *L. cernua* is also applied in floral decoration, to make wreaths and baskets. It has been tried in Malaysia as a cover crop in rubber plantations, especially on degraded soils. In Indonesia and Colombia it is used to stuff cushions as a kapok substitute. In Micronesia it is applied as a cockroach repellent. In tropical Asia and America it has several applications in traditional medicine. In Indonesia and Malaysia a decoction of *L. cernua* is used externally as a lotion to treat beri-beri, coughs, fever and asthma, and, emulgated in vinegar or lemon juice, in embrocations to treat skin eruptions and abscesses. A traditional Chinese medicine is prepared from *L. cernua* plants by ultrafiltration. It is administered to treat rheumatism, hepatitis and dysentery, and applied externally to bruises, burns and scalds. In tropical America *L. cernua* is also used as a diuretic and applied against gout, arthritic swellings, gonorrhoea, leucorrhoea and dysentery. Hawaiians used to boil *L. cernua* for three hours before bathing rheumatic patients in the decoction. In the Antilles, the abundant spores are applied as dusting-powder for children with irritated skin due to urine contact. In South America the spores are dusted on pills to keep them dry.

Production and international trade *L. cernua* is collected from the wild and traded only at local markets. In the Philippines, dyed plant parts are sold as decoration especially during the Christmas season.

Properties Phytochemical investigations of *L. cernua* plants showed the presence of alkaloids such as annotinine, cernuine, huperzine B, lucidioline, lycodoline, lyconnotine, lycopodine and nicotine, the flavonoid apigenin, apigenin-7-glucoside, the triterpene serratenediol and, as in many other *Lycopodiaceae*, a high concentration of aluminium (up to 12.5% of ash). The ash also contains about 12% SiO_2. Tests with rats showed that injection with the traditional Chinese medicine prepared from *L. cernua* is effective against experimental silicosis, not only as a prophylactic but also when used to treat the disease. Huperzine B has demonstrated anticholinesterase activity and has also been effective in behaviour tests for appraising animal learning and improving memory function in humans.

Description A terrestrial, variable, common herb with creeping main stem of indefinite length, rooting at long intervals; erect shoots distant, somewhat resembling little pine trees, up to 100 cm tall, basal part simple, distal part with numerous subopposite, highly compound, spreading



Lycopodiella cernua (L.) Pic. Serm. – 1, part of a plant with strobili; 2, part of a branch; 3, apical part of a branch with strobilus; 4, fertile leaf with sporangium.

branches, ultimate branches nodding to pendulous, 5–20 cm long. Leaves arranged spirally, linear-subulate, 2–3(–5) mm × 0.1–0.3 mm, base broadly decurrent, margin entire, apex sharply pointed, pale yellowish or brownish, thick but soft, changing gradually from patent-reflexed and rather distant on the shoot axis to falcately ascending and closely approximate on the ultimate branches. Strobili 1–2, terminal on each short branch, sessile, pendent, cylindrical, ovoid to ellipsoid, 3–15(–25) mm ×1.5–3(–5) mm; sporophylls close, appressed and imbricate, arranged in 10 spirals, ovate to triangular, about 2 mm × 1 mm, base attached to the axis by a short stalk arising a little above the base of the leaf and more or less at right angles to it, margins coarsely and irregularly laciniate, apex acuminate and cuspidate, yellowish or greenish; sporangium subglobose, up to half the length of the sporophyll, concealed by the sporophyll base, opening with very unequal valves. Spores globose, trilete, rugulose.

Growth and development Spores of *L. cernua* germinate in a few days and the gametophyte matures quickly, usually in one season and is short-lived. The tuberous gametophyte develops on the surface of the ground, is cylindrical or ovoid with a lobed or branching top, green, very small, 2–3 mm long. The ventral epidermal cells of the gametophyte contain an aseptate fungus. The fungus provides nutrients to a massive absorptive organ, the protocorm, that also derives nutrients partly by photosynthesis. It is a subglobose to cylindrical, parenchymatous body provided with rhizoids and erect, green, leaf-like outgrowths called protophylls. The protocorm becomes separated from the prothallus when the protophylls are formed, thus being an independent intermediate stage between the gametophyte and the sporophyte. It has neither real roots nor vascular tissue. It may persist a long time and develop secondary protocorms. After some time it gives rise to the young sporophyte. *L. cernua* may produce strobili throughout the year, but may also pass the dry season as buried stem tips while the rest of the plant dies.

Other botanical information The *Lycopodiaceae* do not have close affinities to other groups. In older views there was only one genus, *Lycopodium* L. At present, although there is no general agreement, 3 genera have been separated from *Lycopodium*, bringing the total to 4 (sometimes, however, splitting goes as far as 12 genera). The genus *Lycopodiella* Holub comprises about 40 species and occurs in almost all moist temperate and tropical regions of the world. *L. cernua* has been placed in the genus *Palhinhaea* Vasc. & Franco on the basis of phytochemical characteristics. However, it is currently accepted that this genus should be treated as a section of *Lycopodiella*, i.e. sect. *Campylostachys* (K. Müll.) B. Øllg. At least 40 varieties have been described within *L. cernua*, most of which are barely distinguishable.

Ecology *L. cernua* is most common on acid soils in tropical and subtropical lowlands. It occurs along forest fringes, in young secondary forest, often in swamp margins, in grassland (including wet grassland), along roadsides and railways, on moist cliff-faces, hillsides and mountain slopes, from sea-level up to 2800 m altitude. Locally it is often abundant, sometimes as a weed (e.g. in sugar cane in Java). In southern Africa it is fire-resistant and not found in areas with less than 600 mm annual rainfall.

Propagation and planting *L. cernua* can be propagated by spores and by layering of growing tips.

Diseases and pests In Hawaii, the fungus *Stomatogene lycopodii* has caused blotches on the leaves of *L. cernua*.

Harvesting *L. cernua* is harvested from wild populations when needed.

Handling after harvest Fresh stems and branches of *L. cernua* are tied up into bundles and brought to the market for sale.

Genetic resources and breeding *L. cernua* is probably the most common and abundant club moss, therefore it does not seem to be at risk of genetic erosion. No germplasm collections and breeding programmes are known to exist.

Prospects Many aspects of *L. cernua* are still unknown. Since this club moss is in great demand in horticulture, research on its possible cultivation should receive more attention. More research on its pharmacological activity is also desirable considering the applications in traditional medicine and the interesting properties demonstrated by other medicinal *Lycopodiaceae*.

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N. Wulijarni-Soetjipto & W.P. de Winter

Lycopodium clavatum L.

Sp. pl: 1101 (1753).
LYCOPODIACEAE
$2n = 68$

Synonyms *Lycopodium officinale* Neck. (1771), *Lepidotis clavata* P. Beauv. (1805), *Lycopodium trichiatum* Blume (1828).

Vernacular names Staghorn clubmoss (En). Common clubmoss, ground pine, running pine (Am). Lycopode à massue (Fr). Indonesia: pakis simbar, purwalata (Javanese), rane diuk (Sundanese). Laos: kout khi khep khur. Philippines: licopodio (Tagalog). Thailand: kut khon (northern), sam yoi rot (peninsular). Vietnam: th[aj]ch t[uf]ng d[uf]i.

Origin and geographic distribution *L. clavatum* is a widespread species with unknown origin but with an almost global distribution. It is found in all continents except Australia. It is most common in boreal regions, especially Siberia. In South-East Asia and other tropical regions it is confined to mountainous regions.

Uses In many civilizations *L. clavatum* has been appreciated as medicine. In the central highlands of New Guinea and in the Philippines it is chewed to induce vomiting after food poisoning or acute stomach pain. The North-American Indians applied it as a remedy for stiff joints. In traditional European medicine it has been used as a diuretic in dropsy, as a strong medicine to cure diarrhoea, dysentery and suppression of urine, a nervine in spasms and hydrophobia, an aperient in gout and scurvy, a corroborant in rheumatism and as a wound powder. It was also applied against retention of the urine due to grit of a kidney stone, affections of the urinary tract, inflammations of the bladder or kidney and kidney stones.

A late 19th Century herbal mentions the uses of *L. clavatum* against e.g. intractable forms of fever, red urine or urine containing mucus, blood, or red, sandy deposits, dyspepsia, indigestion, palpitation, constipation, borborygmus and water brash. Applications against spasmodic retention of urine in children, cystic catarrh in adults with painful micturition, cough with bloody expectoration, congestive headache, dizziness and tendency to fainting are indicated as well.

The spores have healing properties both in homeopathy and allopathy though they are no longer often used in the latter. They were known under the trade names 'lycopodium seed', 'pulverized lycopodium', 'vegetable sulphur' or 'sporae lycopodii'. For centuries the spores have been used as a

styptic and as a dusting powder in various skin diseases such as eczema and erysipelas and for excoriated surfaces, to prevent chafing in infants, for pills to prevent them sticking together and for metal casting moulds. Because of their inflammability they were used for flashlights in theatres.

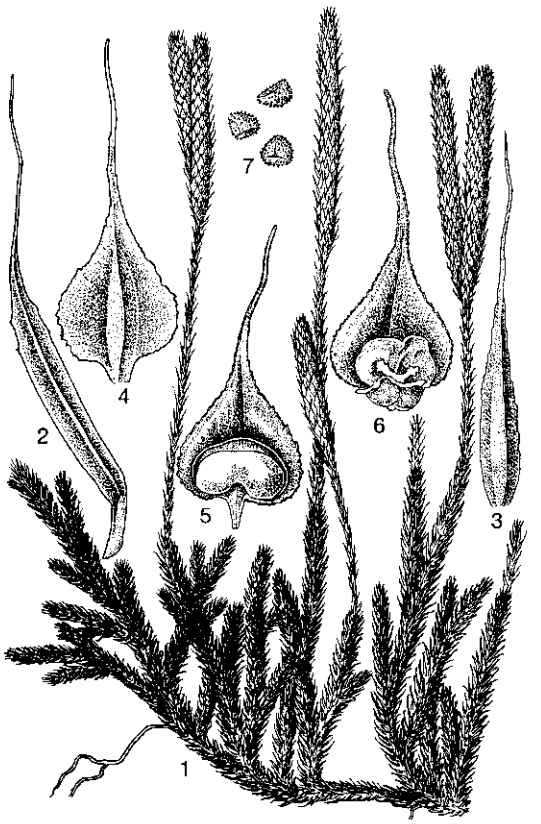
In homeopathic practice *L. clavatum* is still a popular medicine, said to alleviate anxiety, anticipatory fears, apprehension, over-sensitivity and inability to adapt to new surroundings. Moreover, it is also a homeopathic medicine against constipation, bloating and gas, digestive upset, heartburn, migraine, dryness of mucous membranes, dry wrinkled skin, sallow complexion and a whole plethora of other inconveniences.

Modern applications are as an ingredient of a remedy to alleviate jet lag, as a feed additive for cows to improve their constitution and as a medicine against anaemia with jaundice and for dogs suffering from fleas. In laboratories for monitoring pollen in the air to establish hay-fever risks, the spores are applied to establish a particle base number in the pollen traps. Sporopollenin from *L. clavatum* has been found to be capable of acting as a solid support for peptide synthesis. It is stable to chloromethylation and to the standard deblocking procedures and its constant mesh size, ready commercial availability and constant molecular structure give it potential important practical advantages over synthetic resins. *L. clavatum* has been used for sifting milk and other liquids and is used ornamentally e.g. for decorations and garlands.

Production and international trade Trade statistics on *L. clavatum* are not known. China, Nepal, eastern Europe, Russia and the other former Soviet Republics are sources in international trade, but there could be other producing countries as well. In some areas, such as western Europe, natural occurrence has declined too much to allow collecting. In the early 1990s Nepal exported 40 t of the crude herb per year. The wholesale market price per kg spores in early 2001 was US$ 110, and US$ 28 per kg cut and sifted plant material.

Properties Poisonous alkaloids (with 16–18 C and 1–2 N atoms) such as lycopodine, chinoline, clavatine, clavatoxine and annotinine have been found in *L. clavatum*. All these alkaloids increase blood pressure; lycopodine stimulates the peristaltic movements of the intestine; in rats lycopodine contracts the uterus and the LD_{50} is 27.6 ppm. Furthermore derivatives of cinnamonic acid have been detected, especially of phenolic nature, and flavonoids (e.g. apigenine), whereas the ash contained 3.5–12.5% aluminium. A methanol-extract of *L. clavatum* (IC50, 1.3 µg/ml) showed strong prolyl-endopeptidase-inhibiting activity and is expected to have activity against loss of memory. The spores contain approximately 50% oil, 3% sugar, 1–4% ash, and a trace of a volatile alkaloid. The spores are highly inflammable because of the greenish-yellow oil which has an acid reaction and contains 80–86% $C_{60}H_{30}O_2$ (decyl-isopropyl acrylic acid, a peculiar lycopodium oleic acid), 3–5% glycerine and solid fatty acids (mainly myristic acid). Other analyses showed a neutral oil, a constant amount of glycerine (8.2%), 5.3% protein and no alkaloids. In several pharmacopoeias, in both homeopathy and allopathy *L. clavatum* spores are officinal and considered to be a pharmacologically indifferent, fine, pale yellow, very mobile, inodorous and tasteless powder. The officinal powder should be free from pollen, starch, sand and other impurities. When ignited with free access to air, *L. clavatum* spores should not leave more than 5% ash. The spores are strongly water-repellent, e.g. a powdered hand remains dry when submerged in water. *L. clavatum* spores used as dusting powder can cause asthma and other allergy problems (itchy skin, eye and nose problems) when people are in contact with the powder for a long time. The powder is safe for consumers who are exposed to only small amounts. When the spores enter surgical wounds a lesion may develop months or even years later which clinically resembles tuberculosis or neoplasia. Hepatotoxic effects have been observed after administering *L. clavatum* spores as homeopathic drug.

Description A terrestrial herb with creeping shoots, covered with hair-pointed leaves giving the bright green plant a whitish shine. Main stem creeping on the ground, trailing, or hanging over banks, rooting at distant intervals, copiously branched, up to more than 4 m long and 2–4 mm in diameter (excluding the leaves); erect shoots dorsolateral on the main stem, ascending to stiffly erect, 5–25(–50) cm × 0.5–1.1 cm (including leaves), repeatedly branched with a usually distinct main axis, branches terete. Leaves appressed, subdistant to approximate; lamina linear to narrowly lanceolate, (2.5–)4–7(–10) mm × 0.5–1 mm, midrib distinct, margin indistinctly dentate, apex narrowly acute to attenuate, subulate, antrorse; leaves of the branches in spirals or apparently in many rows, lamina similar but with margin entire, apex attenuate subulate, ending in a long, deciduous, 2–4 mm long colourless hair, bright green, ascending to appressed, less often



Lycopodium clavatum L. – 1, habit; 2, leaf at adaxial side; 3, leaf at abaxial side; 4, sporophyll at abaxial side; 5, sporophyll, adaxial side with sporangium; 6, sporophyll, adaxial side with open, empty sporangium; 7, spores.

spreading, loosely imbricate. Strobili terminal on branches near the top of the shoot axis, (1–)2(–5) together on sparsely leaved, (2.5–)5–12(–30) cm long, branched peduncles; strobilus erect, cylindrical, 1.5–6(–8.5) cm × 4–6 mm, base narrowed, apex acute; sporophylls appressed, imbricate, ovate-acuminate, 1.5–3.5(–5) mm × 0.8–1.2 mm, base cuneate to cordate or subpeltate, margins dentate to erose-laciniate, apex elongated, with a 1.5–4 mm long spreading hair-point; sporangium globose-reniform, 1 mm × 1.5 mm, bright ochreous. Spores globose, trilete, reticulate, bright yellow, released in great quantities.

Growth and development The spores of *L. clavatum* remain dormant for 3–8 years. During this period they settle in the soil at a depth of 3–10 cm. Together with a relatively thick spore wall this may retard germination considerably. However, when spores are exposed to sulfuric acid and cultured, spore germination will take only 2 months. The subterranean prothallus develops slowly and reaches sexual maturity after 6–15 years and may live for 20 years. It is top-shaped, differentiated into various tissues and lives in close symbiosis with a fungus, possibly a species of *Pythium*. Without the fungus the development of the gametophyte stops at an early, few-celled stage. Once the sporophyte has established it can spread rapidly by the long creeping stems and the population can survive until years after the canopy has closed. If competition with higher growing plants is not strong, it is long-lived and slowly forms large colonies.

Other botanical information The *Lycopodiaceae* do not have close affinities to other groups. In older views there was only one genus, *Lycopodium* L. At present, although there is no general agreement, 3 genera have been separated from *Lycopodium*, bringing the total to 4 (sometimes, however, splitting goes as far as 12 genera). *Lycopodium* s.s. comprises about 40 species but opinions differ. *L. clavatum* is the type species of section *Lycopodium* of the genus and is widespread and very variable. There is a nearly continuous series of forms from compact plants with parallel branches, sparsely branched peduncles, and firm, imbricate leaves to amply branched plants with diverging branches, branched peduncles and soft, spreading leaves. The former is typical for cold and exposed habitats, the latter for warm and sheltered locations. A large number of synonyms, varieties and forms have been described, only few of which, however, have any systematic or practical value.

Ecology *L. clavatum* is found in cool, wet climates where it prefers open habitats such as mountain sides, moors and heaths, clearings and road cuttings in cloudy forest. In the tropics it grows in mountainous areas above 1300 m altitude. On the bare soil of road embankments it is often found as one of the pioneers, frequently accompanied by ferns of the *Gleicheniaceae*. The same occurs on recently burned patches although neither can stand burning at all.

Propagation and planting *L. clavatum* is usually propagated by division of the rhizome since it is difficult to grow it from stem cuttings although some may produce roots. The long-lived prothalli make propagation by spores virtually impossible. *L. clavatum* is difficult to transplant but once established it may grow vigorously. A well-drained potting mix is recommended.

Diseases and pests The fungus *Leptosphaeria*

crepini has been recorded on *L. clavatum* which blackens the sporophylls with abundant perithecia.

Harvesting The spores of *L. clavatum* are gathered in cool, seasonal climates of the northern hemisphere during the months of July and August. Peasants cut the tops (strobili) from the plants and carry them home, where the spore powder is obtained by shaking the tops and sifting out the extraneous matter. As the plant is not plentiful in all years, the annual yield is rather variable.

Genetic resources and breeding Germplasm collections or breeding programmes do not exist for *L. clavatum*. It is widespread but in some areas it is threatened with extinction. Germplasm collection is recommended.

Prospects At present *L. clavatum* is well utilized for various purposes. Research is being carried out to elucidate the value of the many pharmacological claims. Cultivation would be desirable, both for the quality of the crude herb and spores and its protection. However, due to its peculiar life-history, further research is needed to solve all practical problems.

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W.P. de Winter

Lycopodium complanatum L.

Sp. pl.: 1104 (1753).
LYCOPODIACEAE
$2n = (44–)46(–48)$

Synonyms *Diphasium complanatum* (L.) Rothm. (1944), *Diphasium anceps* (Wallr.) A. Löve & D. Löve (1958, nom. illegit.), *Diphasiastrum complanatum* (L.) Holub (1975).

Vernacular names Flat clubmoss (En). Northern running-pine (Am). Lycopode aplatie (Fr). Indonesia: purwalata (Javanese). Vietnam: th[aj]ch t[uf]ng gi[ej]p, th[aj]ch t[uf]ng d[ej]t, r[ee]u th[eef]m nh[af].

Origin and geographic distribution *L. complanatum* is widely distributed in the temperate regions of the northern hemisphere. In South-East Asia and other tropical and subtropical regions it may occur in high mountainous areas.

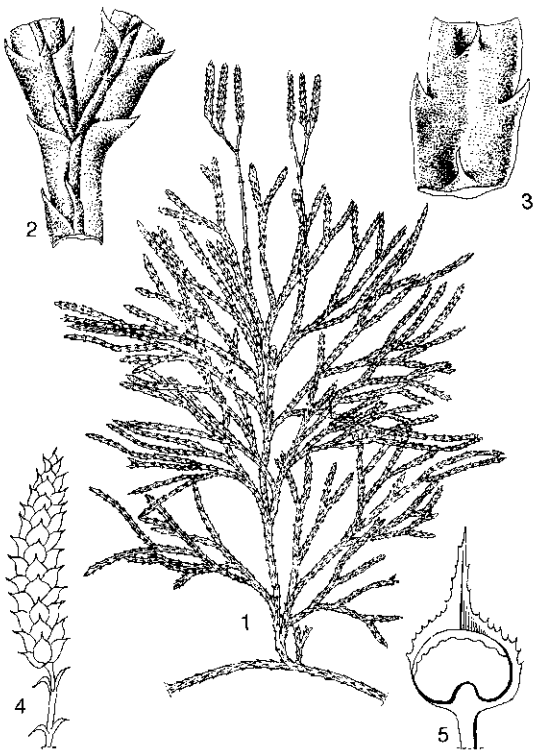
Uses *L. complanatum* is widely collected from the wild for ornamental purposes (e.g. in Christmas decorations). Medicinally, the whole plant of *L. complanatum* is used, usually dried and powdered for infusions. It is said to be a powerful diuretic, promoting urine and removing obstructions of the liver and spleen. It is valued as a remedy in jaundice, rheumatism and most of the chronic diseases. A decoction, combined with dandelion (*Taraxacum officinale* Weber) and agrimony (*Agrimonia eupatoria* L.), is used as a herbal remedy for liver complaints and obstructions. The spores, in large quantities a fine yellowish powder, are used for dusting pills, suppositories and rubber gloves and in powders, soaps and shampoos. The Scandinavian Vikings used it for dying of fabrics, probably as a mordant because of its aluminium content.

Production and international trade *L. complanatum* is not cultivated commercially. Statistics for production or trade are not available.

Properties *L. complanatum* contains about 0.25% alkaloids such as lycopodine and clavatine and the ash contains 16–25 % aluminium and 6–7% SiO_2. Lycopodine is a poison which causes paralysis of the motoric nerves while clavatine is

toxic to many mammals. The spores, however, are not toxic. Spores of *L. complanatum* contain large amounts (up to 30%) of hexadenic acid; the spore powder is inflammable and can cause burns. Because spores are used on surgical gloves, granulomatous reactions in wounds can occur. Spores used in cosmetics can cause dermatitis.

Description A terrestrial, evergreen herb, with creeping main stem bearing upright shoots with markedly flat branches. Main stem creeping on the ground or through the moss or litter layer, rooting at distant intervals, up to more than 1 m long and about 1–3 mm in diameter excluding the leaves; erect shoots distant at about 8 cm, usually 5–15(–40) cm long and 1.5–3.5 mm in diameter (including leaves), repeatedly branched with a usually distinct main axis, forming flabellate branch-systems; branches flat in cross-section, narrowly blade-like, 2.5–10 cm × 1.8–4 mm, green above, pale below. Leaves appressed, distant; lamina linear to narrowly lanceolate, 1.4–4 mm × 0.5–1.2 mm, base decurrent, apex acute to shortly subulate, yellow-green; leaves of the branches trimorphic, scale-like, decussate, adnate to the stem more than half their length, clearly in 4 rows (dorsal, ventral and two lateral); blade of the dorsal leaves appressed, linear-lanceolate, free portion of laminas 0.7–2 mm × 0.5–1.2 mm; blade of the lateral leaves appressed, 2.6–7.3 mm × 0.8–2.1 mm, apex triangular, often curved; blade of ventral leaves weakly developed, appressed, narrowly triangular, 0.7–1.5 mm × 0.4–0.9 mm. Strobili laterally on branches near the top of the shoot axis, 1–3(–4) on 1–2 sparsely leaved, dichotomously branched peduncles, erect, cylindrical, 2.5–50 mm × 2–3 mm, apex obtuse without sterile tip; sporophylls appressed, imbricate, broadly triangular to nearly cordate, 2–3 mm × 2–2.4 mm, margins scarious, often slightly dentate, apex shortly acuminate. Sporangium reniform, 1 mm × 1.5 mm. Spores globose, trilete, 30–38 µm in diameter, reticulate.



Lycopodium complanatum L. – 1, habit; 2, detail of shoot branch, dorsal view; 3, detail of shoot branch, ventral view; 4, strobilus; 5, sporophyll.

Growth and development The subterranean gametophyte of *L. complanatum* lives saprohytic in close symbiosis with a mycorrhizal fungus. It is carrot-shaped, without paraphyses. It may take some years before the sporophyte develops.

Other botanical information The *Lycopodiaceae* do not have close affinities with other groups. In older views there was only one genus, *Lycopodium* L. At present, although there is no general agreement, 3 genera have been separated from *Lycopodium*, bringing the total to 4 (sometimes, however, splitting goes as far as 12 genera). *Lycopodium* s.s. comprises about 40 species but opinions differ. *L. complanatum* is the type species of the section *Complanata* Victorin (synonym: *Diphasiastrum* Holub), which section is also often considered as the separate genus *Diphasiastrum* Holub. In South-East Asia, a few more species of this section are found such as *L. platyrhizoma* J.H. Wilce (Sumatra, Toba) and *L. wightianum* Wallich ex Grev. & Hook. (Java, 2500–3250 m altitude).

Ecology In South-East Asia and other tropical regions, *L. complanatum* occupies exposed or sheltered slopes in upper montane forest or mixed alpine forest, usually at 1000–3200 m altitude; in temperate regions it occurs in the half shade of trees and heather, from sea-level up to 1000 m altitude. It prefers well aerated, humus-rich, acidic soils. In Indonesia on Java it occurs in exposed, dry, stony locations, on mountain (hollow) roadsides and in old volcano craters at 1400–3100 m altitude.

Propagation and planting *L. complanatum* generally produces abundant spores but plants

are difficult to grow from spores. Propagation by layering of growing tips is easier and faster. When grown from spores they are best sown as soon as they are mature on the surface of a humus-rich sterilized soil. To keep the compost moist, a polythene bag can be put over the pot. Small clumps of plantlets can be transplanted into other pots as soon as they are large enough to handle; they should be kept humid until they are well established. The plants can be planted outside when they are at least 2 years old and only in very sheltered locations.

Husbandry *L. complanatum* thrives in a rough spongy peat in the shade and requires a humid atmosphere. The plants are difficult to establish. The roots are delicate and liable to rot, most water being absorbed through the foliage. *L. complanatum* has an aromatic resinous smell which makes it unpalatable and unattractive for deer.

Genetic resources and breeding Germplasm collections and breeding programmes are not known to exist for *L. complanatum*. Worldwide it is not directly threatened with extinction but its population is declining due to overcollecting, air pollution and habitat destruction.

Prospects *L. complanatum* is a cold-temperate species and limited to a few alpine regions in South-East Asia. Cultivation would only be successful in high mountainous areas. The alkaloid constituents may be of pharmacological importance and deserve further research.

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T. Boonkerd

Lygodium Swartz

in Schrader, J. Bot. 1800(2): 106 (1801).
SCHIZAEACEAE

x = 28, 29, 30; *L. auriculatum*: $2n$ = 140; *L. circinnatum*: $2n$ = 58, 116; *L. flexuosum*: $2n$ = 112; *L. japonicum*: $2n$ = 58, 116; *L. microphyllum*: $2n$ = 60, 120

Major species and synonyms

- *Lygodium auriculatum* (Willd.) Alston, Reinwardtia 5: 16 (1959), synonyms: *L. semihastatum* Desv. (1827, nom. illeg.), *L. circinnatum* (Burm.f.) Swartz var. *semihastatum* Fosb. (1941).
- *Lygodium circinnatum* (Burm.f.) Swartz, Syn. fil.: 153 (1806), synonyms: *L. dichotomum* (Cav.) Swartz (1806), *L. pedatum* (Burm.f.) Swartz (1806), *L. basilanicum* Christ. (1907).
- *Lygodium flexuosum* (L.) Swartz, in Schrader, J. Bot. 1800(2): 106 (1801), synonyms: *L. pinnatifidum* Swartz (1801), *L. serrulatum* Blume (1828).
- *Lygodium japonicum* (Thunb.) Swartz, in Schrader, J. Bot. 1800(2): 106 (1801), synonyms: *L. dissectum* Desv. (1811), *L. tenue* Blume (1828), *L. mearnsii* Copel. (1908).
- *Lygodium microphyllum* (Cav.) R. Br., Prodr.: 162 (1810), synonym: *L. scandens* Swartz (1801, excl. syn. L.).

Vernacular names General: climbing fern, snake fern (En). Philippines: nito.

- *L. auriculatum*. Philippines: nito, nitong puti (Tagalog), balanitu (Bontoc).
- *L. circinnatum*. Indonesia: pakis rambat (Javanese), paku hata (Sundanese), kapai gorita (Moluccas). Malaysia: ribu-ribu dudok, ribu-ribu bukit, paku jari merah (Malay). Philippines: nito (Tagalog), agsam (Albay), nitong puti (Tayabas). Thailand: yaan phi phek, li-phao haang kai (peninsular).
- *L. flexuosum*. Indonesia: hata kembang (Sundanese), paku ribu-ribu (Asahan), durhawa (Alor). Malaysia: ribu-ribu gajah, akar sidin (Malay), haî chîn shâ shù (Chinese). Papua New Guinea: tatan (Orokawa Mumuni), zangi (Orokawa Horata). Philippines: nito (Tagalog), nito a

dadakkel (Iloko), kalulung (Ibanag). Thailand: kra chok (Prachin Buri), kuut kong (northern), lee phao (peninsular). Vietnam: thong bong, bong bong, duong vong.

- *L. japonicum*. Japanese climbing fern (En). Indonesia: pakis kembang (Javanese), paku areuy, hata kawat (Sundanese). Malaysia: ribu-ribu, selada, capay alus (Malay). Philippines: nito (Tagalog), nitong puti (Rizal, Cavite, Batangas), kerekai (Ibanag). Thailand: kuut ngo ngae, phak ngo ngae (northern).
- *L. microphyllum*. Small leaved climbing fern, climbing maidenhair (En). Indonesia: paku tali (general), paku kawat (western Sumatra), paku hata leutik (Sundanese). Malaysia: ribu-ribu, selada, kapai alus (Malay). Philippines: nito, nitong puti (Tagalog), nitong parang (Rizal). Thailand: kachot nuu (south-eastern), ree-bun paa dee, liphao yung (peninsular).

Origin and geographic distribution *Lygodium* is a pantropical to southern temperate genus. Most of the about 40 species are found in South-East Asia and Central America (with one species extending into south-eastern United States).

L. auriculatum is distributed in Indo-China, eastern Borneo, the Philippines and Micronesia.

L. circinnatum is found from Sri Lanka and north-eastern India to southern China, throughout South-East Asia to Vanuatu and Solomon Islands. In the Philippines it is the most common species.

L. flexuosum occurs from Sri Lanka and the Himalayas to southern China, Hong Kong, Ryukyu Islands, throughout South-East Asia to northern Queensland (Australia).

L. japonicum is distributed from Sri Lanka and the Himalayas to northern China, Korea, Japan and throughout most of seasonal South-East Asia to New Guinea but absent in areas with a uniformly humid climate as in Peninsular Malaysia, Sumatra and Borneo. It has become naturalized in Florida and Texas (United States) and is also cultivated as an ornamental.

L. microphyllum is distributed in tropical Africa, throughout South-East Asia to Bangladesh and Hong Kong, Australia and Melanesia. It has naturalized in the southern United States where locally it has become a nuisance.

Uses The very young leaves of all *Lygodium* species are eaten as a cooked vegetable, especially in Indonesia when other vegetables are lacking, but also in Malaysia. All over South-East Asia the winding rachises are used for plaiting and weaving, sometimes in combination with rattan and bamboo, to make hats, boxes and baskets. The splints of the rachises are freed and dried in the sun (known as 'nito' in the Philippines). Everywhere the cord-like rachises are used for tying rice sheaves as they are usually ready to hand. In some areas it played a role at initiation ceremonies for new houses, fishing stations and, especially, new rice fields. In the latter case, the attributes used in the ceremony such as the broom (for sprinkling consecrated rice paste) and the baskets might be made of *Lygodium* rachises. In the Philippines bracelets made of *L. auriculatum* are believed to protect against poison. Medicinally, *Lygodium* is used in the treatment of various ailments, especially those related to the skin. In Malaysia *L. circinnatum* was used as a childbirth medicine and in New Guinea as a contraceptive. In Indonesia, the pounded leaves of *L. circinnatum* were applied to wounds. In Indonesia and the Philippines, the roots and rachises were chewed and applied to bites of venomous reptiles and insects to neutralize the poison. Likewise in Bangladesh the juice of the whole plant of a *Lygodium* sp. is applied to insect bites after squeezing out a little blood. *L. flexuosum* was used in Malaysia in external applications for skin complaints, including ringworm, and in an extract prepared with many other ingredients drunk for fever. In Vietnam the plant is boiled and taken as diuretic or crushed to cover wounds. In Nepal, the aerial parts of *L. japonicum* are made into a paste to treat scabies, the juice to treat herpes and wounds. *L. microphyllum* was used for external application in poultices or emollients to bruises, burns and sprains and it is also supposed to reduce bleeding. In Malaysia it was processed into an astringent decoction to treat dysentery and spitting of blood. The decoction may be sweetened or combined with cordyline and some salt and taken before the meals. Pills made of the leaves were variously used: taken internally for skin complaints, applied externally as poultices against skin diseases, measles and swellings and as an ingredient of lotions to cool fever. In Java (Indonesia), *L. microphyllum* was used as a remedy for sprue and in Ivory Coast to cure hiccup. In the eastern highlands of New Guinea, fresh leaves of *L. longifolium* (Willd.) Swartz are chewed with ash salt for stomach-ache and diarrhoea. The Kofanes and other Indian tribes of Colombia added a handful of leaves of *L. venustum* Swartz to the 'ayahuasca', a hallucinogenic drink made of *Banisteriopsis caapi* (Spruce ex Griseb.) Morton.

Production and international trade No in-

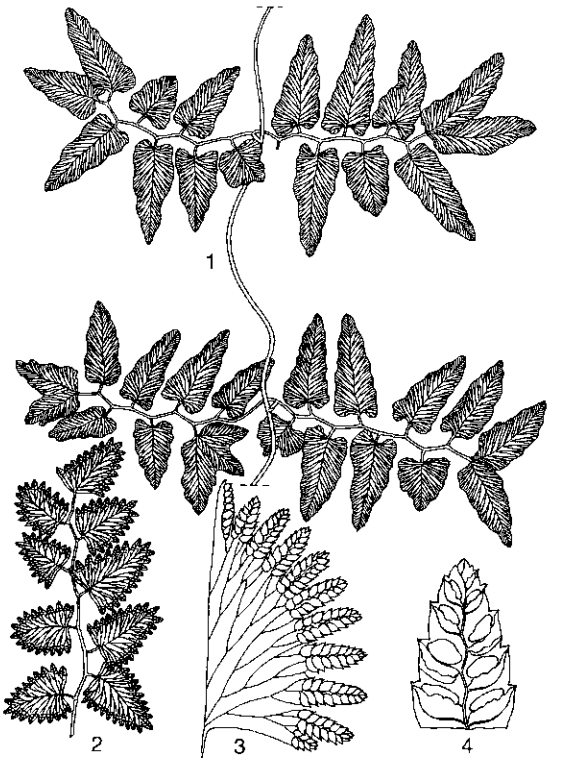
ternational trade in *Lygodium* exists. *Lygodium* is not cultivated commercially except for *L. japonicum* which is widely available as an ornamental. All other species are only collected in the wild and used locally.

Properties *L. flexuosum* has been reported to show antifertility activity. It contains O-p-coumaryl-dryocrassol, dryocrassol, tectoquinone, kaempferol, kaempferol-3-β-D-glucoside, β-sitosterol and stigmasterol. Methanol extracts of *L. japonicum* exhibit antiviral activity against the Sindbis virus and antibiotic activity against *Bacillus subtilis*, *Mycobacterium phlei*, and the dermatophytic mould *Trichophyton mentagrophytes*. Water extracts of *L. japonicum* showed antimicrobial activity against *Bacillus subtilis, Escherichia coli, Micrococcus luteus, Pseudomonas aeruginosa* and *Staphylococcus aureus*. *L. circinnatum* and *L. flexuosum* have also been investigated for their antimicrobial property. Rachises of *L. longifolium* have a higher tensile strength than those of *L. circinnatum*, *L. flexuosum* and *L. microphyllum*.

Description Ferns with extremely long leaves that climb, twining through the vegetation. Rhizome creeping, hairy but without scales. Leaves monostichous, twining, of indefinite growth, usually a few m long; the climbing rachis bears alternate, short primary branches with a hairy, dormant apex, and a pair of apparently opposite secondary branches; secondary branches may bear leaflets or tertiary branches which are pinnately arranged or once or more times dichotomously branched; sterile leaflets entire, toothed or lobed, veins free or less often reticulate; fertile leaflets fringed along their margins with short narrow lobes (sorophores), each lobe bearing 2 rows of sporangia, each sporangium attached to a short vein and covered by a small indusium (each sorus consists of 1 sporangium only). Spores tetrahedral and trilete.

– *L. auriculatum*. Rhizome short-creeping, bearing leaves close together, its apex and bases of petioles densely covered with dark hairs. Juvenile leaves once dichotomous, each branch bearing a palmatisect leaflet, usually 5-lobed, with truncate base, edges closely and irregularly serrate; rachis of climbing leaves hardly 2 mm in diameter, usually glabrous; apex of primary rachis-branches covered with pale brown hairs having a swollen base; secondary rachis-branches rarely bearing a simple leaflet, most commonly once dichotomous, one branch with a simple, one with a forked leaflet, less often each branch with a simple leaflet; sterile leaflets suboblong, 12–20 cm × 1–3 cm, base usually asymmetric and strongly cordate-auriculate on the outer side, margins not thickened and very shallowly serrate, apex subacute; lamina of fertile leaflets 1–2(–3) cm wide. Sorophores 3–9 mm long, constricted at the base, at the apices of short triangular lobes of the lamina; indusia glabrous; spores irregularly warty, very variable.

– *L. circinnatum*. Rhizome short-creeping, bearing leaves very close together, its apex and bases of petioles densely covered with black hairs. Juvenile leaves once dichotomous, each branch bearing a pedato-palmatisect leaflet; lobes 4–5, subequal, up to 25 cm × 3.5 cm, the midrib of an outer lobe arising near base of the next inner lobe, margins entire but often somewhat crisped, pale and much thickened (translucent when living), apex acute to acuminate, surface glabrous but conspicuously warty when dry (not when living), veins uniting with the thickened margin; rachis of climbing leaf up to 10 m long and 2–5 mm in diameter, glabrous; apex of primary rachis-



Lygodium microphyllum (Cav.) R. Br. – 1, habit; 2, leaflets with marginal sorophores; 3, some sorophores enlarged; 4, apex of a sorophore enlarged.

branches with sunken dormant apex covered with pale hairs which are not thickened at the base; secondary rachis-branches unbranched, 2–6 cm long, or once dichotomous with each branch 1–2 cm long beyond the fork; sterile leaflets usually with 2–6 subequal diverging lobes which are separate to within 2 cm from the base, base cuneate or truncate, margin entire, pale and thickened, surfaces nearly always warty when dry; fertile secondary rachis-branches unbranched or 1–3 times dichotomous (rarely sub-pinnate); fertile leaflets usually sessile in pairs at the end of the ultimate branches, or members of a pair partly fused at the base, less often 3–5 lobed (always so if the secondary rachis is unbranched), lamina more or less reduced and commonly 3–6 mm wide. Sorophores 2–5 mm long, sessile; spores finely and evenly verrucose all over the surface.

- *L. flexuosum*. Rhizome short-creeping, densely covered with roots, the petioles very close together, apex covered with brown-black hairs. Juvenile leaves once or twice dichotomous, each branch bearing a single leaflet which is deeply palmately 3–7-lobed; lobes almost equal, base cordate, margins serrate; rachis of scandent leaves narrowly winged, flattened and puberulous on the upper surface between the wings; primary rachis-branches up to 3 mm long, dormant apex covered with pale brown hairs; secondary rachis-branches pinnate; sterile leaflets of lower branches palmately 5-lobed; higher secondary branches bearing 3–5(–7) leaflets on each side and an apical one, the apical and lower leaflets asymmetrical or more or less lobed at the base, the lowest often with 2 or 3 (exceptionally up to 6) separate quaternary leaflets at its base; sterile leaflets 3–10 cm × 8–15 mm, margins serrate, apex subacute, lower leaflets stalked, upper sessile, lamina rather thin, costae usually bearing scattered long hairs, less often densely short-hairy, veins often with scattered short hairs on the lower surface; fertile leaflets smaller than sterile ones. Sorophores 3–5(–10) mm long at the apices of small triangular lobes; indusia subglabrous; spores finely verrucose.
- *L. japonicum*. Rhizome wide-creeping, dichotomously branched, 2–5 mm in diameter, densely clothed with dark brown hairs, leaves usually 5–10 mm apart. Juvenile leaves erect, the first branching an unequal dichotomy, the two main branches of large leaves bipinnate, deltoid in outline, with palmatisect leaflets, their margins doubly serrate. Rachis of climbing leaves hardly 2 mm in diameter, glabrous apart from minute hairs on the flattened adaxial surface between the narrow wings; primary rachis-branches 3–10 mm long; secondary branches of leaves on young or stunted plants pinnate, on well-grown plants leaves 2–3-pinnate, deltoid in outline, commonly 12 cm × 12 cm, rachises densely short hairy on the upper surface and bearing fewer longer hairs elsewhere; sterile tertiary leaflets of lower rachis-branches palmate with 5–7 lobes, the middle lobe much longer than laterals; tertiary leaflets higher up the leaf trilobed with an elongate middle lobe or pinnate with small oblique and often lobed quaternary leaflets and a usually deltoid-pinnatisect terminal leaflet about 3 cm long, margins acutely biserrate, apex obtuse or subacute; stalks of leaflets up to 3 mm long, never articulate or thickened at apex, costae usually bearing long scattered hairs, veins and surfaces usually glabrous; fertile secondary branches tripinnate, the leaflets smaller than sterile ones. Sorophores 2–12 mm long; indusia glabrous or with a few hairs if the lamina is hairy; spores sparsely and finely verrucose.
- *L. microphyllum*. Rhizome wide-creeping, dichotomously branched, 2.5 mm in diameter, densely clothed with short brown-black hairs. Juvenile leaves small, commonly once dichotomous (the stipe distinctly winged below the dichotomy), each branch bearing a 4-lobed leaflet not jointed at the base; lobes 3–5 cm × 5 mm, thin, glabrous, margins crenately toothed; rachis of climbing leaves glabrous, commonly 2–3 m long, hardly 1.5 mm in diameter; primary branches about 4 mm long; secondary rachis-branches pinnate, in all up to about 15 cm long, with 3–6 stalked leaflets on each side (stalks 2–4 mm long) and a similar or geminate leaflet; leaflets quite glabrous, mostly ovate (sterile leaflets often elongate with broader base on young plants), 1–4(–6) cm × 6–18 mm, margins of sterile ones minutely crenate, a joint always present at base of lamina, where the wing, which in other species connects stalk and lamina, is constricted; fertile leaflets usually shorter than sterile ones but lamina hardly narrowed. Sorophores 4–6 mm long; spores faintly granulose with a raised reticulum on the outer surface.

Growth and development The gametophytes of *Lygodium* are more or less cordate, sometimes asymmetrical, and glabrous. The antheridia are larger, and of a more complex, primitive, pluricel-

lular type than in most leptosporangiate ferns. The *Lygodium* leaves are borne on the dorsal surface of a subterranean rhizome and undergo a twining growth to form the aerial part of the shoot. These leaves have continuous apical growth, circumnutation, a delay in leaflet expansion below the leaf apex and budlike resting leaflet apices. The determinate primary leaves and the indeterminate climbing leaves arise from a single cell on the flank of the apical meristem; they are strictly foliar in nature and structurally homologous with each other. The climbing leaves of *L. japonicum* mature in a period of more than 70 days during which about 36 primary rachis-branches are produced alternately on the main rachis. The crozier remains compact throughout the growing period. The lamina segments on secondary rachis-branches expand simultaneously; in basal segments it takes about 23–28 days. In addition to apical growth, the length of the main rachis is increased by elongation of the internodes. The growth of the rachis is maximal when growing upward, but retarded when the vine grows either upside down or horizontally; the number of primary rachis-branches on such leaves is relatively low. Damaged leaves may activate dormant buds.

Other botanical information *Lygodium* stands apart from the rest of the *Schizaeaceae* (which comprises 4 genera) through its asymmetrical sporangia, each covered by a kind of indusium, and also through its twining rachis. Furthermore it is biochemically divergent. It fits very well in the subfamily *Lygodioideae*. Other authors give it a family on its own, the *Lygodiaceae*.

Ecology *Lygodium* plants are twining climbers, mainly in secondary vegetation, producing fertile leaflets on parts exposed to the brightest light. *L. auriculatum* usually grows in light shade in tropical forests. *L. circinnatum* occurs in light shade in tropical evergreen forest, from sea-level up to 1500 m altitude. It grows in wet soils and never in locations where the soil becomes seasonally very dry. *L. flexuosum* climbs on shrubs or on branches of tall trees in open locations and in deciduous or mixed forest, from sea-level up to 1000 m altitude. It is a vigorous fern which may form thickets along forest margins and in swampy areas. *L. japonicum* occurs in regions with a pronounced dry season, on dry open grass fields or mountain slopes in deciduous forest, from sea-level up to 2500 m altitude. *L. microphyllum* grows in edges of secondary forest or is a climber on woody plants, bushes or on branches of tall trees, usually on dry slopes in open areas. It prefers clay soils and frequently forms thickets in open, swampy locations in regions with a dry season, from sea-level up to 1300 m altitude. Its naturalization in south-eastern Florida (United States) was first detected in 1965. Growing in tropical and subtropical wetlands and areas with moist soils, it is well adapted to most parts of Florida where its current rate of spread and environmental impact is serious. It has become an aggressive invader of natural vegetation in many different habitats that are frequently dominated by the species. Currently, increasing densities and continued expansion of its distribution are observed. Moreover, it has become a serious fire hazard.

Propagation and planting All *Lygodium* species grow from spores. Those with long-creeping rhizomes can be propagated by rooted rhizome cuttings.

Husbandry *L. circinnatum* is suitable for planting in a tropical garden, requiring warmth and plenty of moisture. It can also be grown in a pot but the roots are sensitive to drying. *L. flexuosum* can be grown easily. It should be planted in the ground and trained on supports such as trees and trellises because it can be very vigorous. *L. japonicum* can be grown in a pot or basket in a warm garden position and is cultivated commercially as an ornamental. *L. microphyllum* adapts readily to cultivation and will succeed in pots, baskets or in a semi-shady garden position. Because of its rampant climbing habit it needs regular trimming.

Diseases and pests The thrips *Octothrips lygodii* was widely found in South-East Asia causing severe damage to *L. microphyllum*.

Harvesting All used parts of *Lygodium* are harvested whenever needed.

Handling after harvest Particularly the lower parts of rachises of *Lygodium* are used for cording. They are cut into pieces of about 1.5–2 m length and split to take out the green inner part. The bast is then split into pieces of the required length and can be stored for later use. Sometimes the rachis parts are first dried before being split. Entire plant parts, stored dry for 6 years at room temperature, had retained at least part of their antibiotic activity.

Genetic resources All *Lygodium* species are rampant in common, non-vulnerable habitats. There are no known germplasm collections, but none of the species is threatened with genetic erosion or extinction.

Prospects *Lygodium* ferns are used as medici-

nal plants in many countries, in addition to their uses as fibres and vegetables. Their widespread medicinal application on wounds and infections suggests antimicrobial properties, which have been partly confirmed experimentally. Further pharmacological research is needed to explore these possibilities. The use in plaiting will persist in touristic and traditional niche markets.

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Titien Ngatinem Praptosuwiryo

Marsilea crenata C. Presl

Reliq. haenk. 1: 84, t. 12, f. 13 (1825).
MARSILEACEAE
$2n = 40, (60)$

Synonyms *Marsilea quadrifolia* Blume non L. (1828), *M. minuta* Raciborski non L. (1898), *M. elata* A. Braun var. *crenata* (C. Presl) Sadeb. (1900).

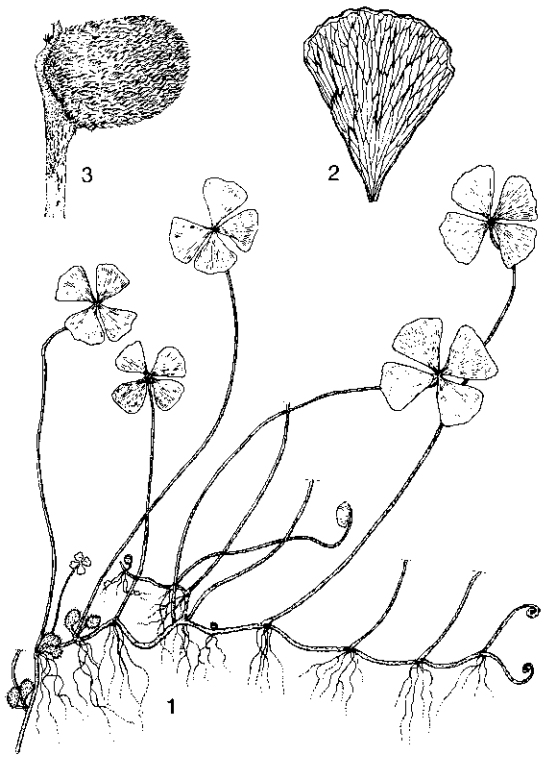
Vernacular names Water-clover fern, pepperwort (En). Indonesia: semanggi (Javanese), jukut calingcingan (Sundanese). Malaysia: tapak itek (Malay), nán kuó t'ién tzù ch'auo (Chinese). Philippines: upat-upat, kaya-kayapuan, banig-usa. Cambodia: chutul phnom. Laos: pak vaen. Thailand: phak waen (northern, central), nuu-toh (northern), phak lin-pee (peninsular). Vietnam: rau b[owj], c[or] ch[uwx] di[eef]n, rau d[eej]u r[aw]ng.

Origin and geographic distribution *M. crenata* is widely distributed throughout South-East Asia from Thailand to Hong Kong and from Taiwan to Australia.

Uses In Indonesia (Java), the Philippines (Bukidnon) and Thailand the young leaves of *M. crenata* are cooked and eaten as a vegetable. They are eaten fresh in Thailand as a side dish with local hot and spicy dishes, and are also grazed by cattle when grass is scarce. In the Philippines *M. crenata* is applied medicinally for neurasthenia and oedema. In India it is used against leprosy, skin diseases, fever and blood poisoning. The large sporocarps of Australian species are ground into flour and eaten. *M. crenata* is also a popular aquarium plant and a potential aquatic garden plant. In many countries it is a noxious weed of irrigated rice.

Production and international trade *M. crenata* is used on a very small scale only and sometimes offered on local markets, but there is no international trade.

Properties *M. crenata* is a source of potassium, calcium, iron, magnesium and crude protein. Nutrient analysis of *M. crenata* in Thailand revealed that per 100 g edible portion it contained: protein 1.0 g, fat 1.2 g, fibre 3.3 g, Ca 48 mg, Fe 25 mg, vitamin A 12166 IU, vitamin C 3 mg. The energy value was about 63 kJ. An analysis in the Philippines revealed that young, unexpanded fronds of *M. crenata* contained on dry-weight basis: crude protein 3.7%, K 0.2% , Ca 0.4%, Fe 1.7% and Mg 7.2%. The sporocarps are rich in thiaminase which breaks down vitamin B1, and a prolonged diet may cause poisoning. When fed to gerbils, the related palaeotropical *M. minuta* L. had a cholesterol and trigliceride lowering effect, prevented the accumulation of cholesterol and triglicerides in the liver and aorta, and was able to dissolve atheromatous plaques of thoracic and abdominal aorta. Faecal excretions of cholesterol and triglycerides were significantly increased. When tested for its nutritious value, the widespread *M. quadrifolia* L. exhibited wide fluctuations between seasons and was not very promising in nutrient composition compared to other commonly used green leafy vegetables.



Marsilea crenata C. Presl – 1, habit; 2, leaflet, showing anastomosing venation; 3, sporocarp.

Description A small, creeping fern with erect leaves much resembling four-leaf clover. Rhizome long-creeping, irregularly branched, rooting at the nodes, of few mm in diameter and indefinite length, with pale brown hairs; the nodes 3–5 cm apart when submerged, much closer when terrestrial. Leaves arising from the nodes of the rhizome, solitary or clustered; petiole 2–4 cm long on terrestrial plants, 6–30 cm long on aquatic plants, pale to green, darker towards the base, glabrous or sparsely scaly; lamina symmetrical quadrifoliate with the four leaflets broadly obovate, flabellate, 3–25 mm × 2–23 mm, base cuneate, distal margin entire, subentire or sinuate, apex rounded, thin, coriaceous, glabrescent or hairy; veins anastomosing with narrow areoles without included veinlets. Sporocarp oblong, 3–4 mm long, stalk 1–5 mm long, attached to the base of the petiole, apex rounded with 2 small teeth, not ribbed, covered with caducous hairs, with the entire base perpendicularly attached to the stalk, solitary or in groups of 2–5; sporangia of 2 different kinds, one kind producing smaller spores (microspores) which give rise to prothalli bearing only male gametes, the other kind producing much larger spores (megaspores) which develop into prothalli producing only female gametes.

Growth and development *M. crenata* has long and slender rhizomes during the growing season when grown in flooded rice fields. The rhizomes are submerged and root in the mud. When the fields dry up, the rhizomes become short-creeping and produce much smaller leaves closer together. The length of the petioles depends on water depth. When water level is low, the leaves protrude above the water surface, when the water is deep the leaflets float. The leaves respond well to light intensity and direction. During the day the leaflets lie in a plane to catch a maximum of radiation, while at night they fold together.
Sporocarps open only in water, splitting along their ventral sides and apices, the edges spreading, exposing many sori. A mucilaginous ring surrounding a sorus expands as water enters. The spores are set free by dissolution of the indusium and sporangial wall and will germinate only under suitable conditions. *M. crenata* needs abundant water to grow vegetatively. It multiplies rapidly under favourable conditions and often becomes noxious.

Other botanical information *M. crenata*, like the entire genus *Marsilea* L. with 60–70 species, has a history of ample synonymy and homonyms due to misidentifications. The genus is 'sorely in need of a revision'. *M. crenata* as treated here is not well defined and might either refer to a species complex or be conspecific with plants presently known by another specific name. The leaves of *M. crenata* at first glance resemble the foliage of *Oxalis corniculata* L. of the family *Oxalidaceae*, but bears 4 leaflets at the end of the slender petiole. Inspection of the creeping rhizome of *Marsilea* easily removes any doubts. *M. crenata* is related to *M. polycarpa* Hook. et Grev. in Peninsular Malaysia which has many sporocarps attached 3–5 cm above the petiole base.

Ecology *M. crenata* grows in muddy soils with stagnant water, in ditches, shallow pools and in rice fields, from lowland up to 900 m altitude. It tolerates polluted fresh water. The sporocarps are very persistent and can keep spores viable for many years, which is an important trait in environments that periodically dry up. The spores can also pass undamaged through the digestive tract of water birds.

Propagation and planting Propagation of *M. crenata* is by spores, rhizome cuttings or plantlets separated from rhizomes. Under natural circum-

stances spores spread and germinate in muddy media. In Thailand, for vegetative propagation, 4–5 rhizome parts about 5 cm long and with 2–3 buds are tied together to a pole and planted 1 m apart in swampy areas.

Husbandry *M. crenata* has been commercially grown locally in Thailand, in ditches with a water level of about 30 cm depth and without shade along roads in the vicinity of urban areas.

Diseases and pests In Thailand, the snail *Pomacea canaliculata* may cause serious damage to *M. crenata*.

Harvesting *M. crenata* is harvested from the wild at the beginning of the rainy season. When cultivated, the first young, full-grown leaves can be harvested 3 months after planting. The leaves are cleaned thoroughly and sold tied in bundles.

Genetic resources and breeding Due to its wide distribution, rapid growth and low exploitation, it seems that *M. crenata* is not in immediate danger of genetic erosion. However, due to changing cultivation practices in rice cropping, it has rapidly declined in many areas during the last decade. Germplasm collections and breeding programmes are not known to exist.

Prospects *M. crenata* grows easily in ditches, shallow ponds and swamps, and even tolerates polluted fresh water. As it has no specific flavour, it has the potential to be widely accepted. Efforts to cultivate *M. crenata* should be encouraged by making use of neglected water areas to produce greens. The medicinal cholesterol-lowering properties of *Marsilea* are promising and should be further explored.

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J.J. Afriastini

Microlepia speluncae (L.) T. Moore

Index fil.: 93 (1857).

DENNSTAEDTIACEAE

$2n = 86, 172, 258$

Synonyms *Microlepia flaccida* (R. Br.) J. Sm. (1842), *Davallia speluncae* (L.) Baker (1867).

Vernacular names Cave fern, limpleaf fern (En). Thailand: kut phi (central), chon (southwestern), neraphusi (peninsular).

Origin and geographic distribution *M. speluncae* is pantropical and occurs in Africa, Australia and tropical America. In the latter area it may have been introduced.

Uses In Sepik River (Papua New Guinea), *M. speluncae* was used as a green vegetable. In the Nicobar Islands the crushed leaves are applied on the skin as febrifuge.

Production and international trade *M. speluncae* is only used and traded locally.

Properties Several 1-indanone-type sesquiterpenes (pterosins and pterosides) have been isolated from the leaves, e.g. 13-hydroxy-3(R)-pterosin D or spelosin, 13-hydroxy-3(R)-pterosin D 3-O-α-L-arabinopyranoside, 3(R)-pterosin D 3-O-α-L-arabinopyranoside and 2(R),3(R)-pterosin L 3-O-α-L-arabinopyranoside and the 2-O-acetyl derivative of 4-O-p-coumaroyl-D-glucose.

Description A finely cut terrestrial fern. Rhizome short-creeping, the young parts covered with short pale hairs. Leaves in two rows, approximate, monomorphic, deeply 3(–5)-pinnatifid to tripinnate; petiole (20–)45–60(–100) cm long, 2–8 mm in diameter, green to purplish, minutely pubescent, glabrous near the base; lamina triangular to ovate-lanceolate, 35–175 cm × 20–120 cm, the basal pinnae usually somewhat reduced, herbaceous to membranaceous, more or less pubescent to setose, or with few to many long, flaccid, glistening, scale-like hairs; rachis indumentum like the leaf surface; pinnae ovate-lanceolate, 16–70 cm × 15–18 cm, petiolate, the basal acroscopic pinnule often the largest; pinnules narrowly deltoid, acuminate, pinnate near the base and lobed almost to the costa, the basal acroscopic segment the largest; ultimate segments 3–4 mm wide, oblique, unequilateral at the base, margins crenate to lobed, apex obtuse; veins conspicuous but hardly raised, concolorous. Sori near the base of the sinuses between the lobes, 2–10 to a segment, varying in size, with a conspicuous hydathode on the opposing surface; indusium half-cup shaped, with few to many hairs, rarely glabrous; sporangia many, often hiding the indusium.

Microlepia speluncae (L.) Moore – 1, part of leaf; 2, pinnules with sori; 3, sorus.

Spores trilete, pale, finely echinate or smooth.

Other botanical information *Microlepia* Presl is predominantly found in tropical to warm temperate Asia where about 45 species occur. It is notorious for its species being hard to discriminate due to morphological variation (hairiness, degree of leaf cutting), age and habitat. Many of these forms have been described as species, varieties and forms, but their status still remains unclear. *M. scaberula* (L.) Mett. ex Kuhn of New Guinea and Polynesia is used in the Rotuma Islands where the immature leaves are applied against pain in the thorax.

Ecology *M. speluncae* occurs in rain forest, forest and thicket margins, where there is shelter for the roots and sufficient bright light reaches the leaves, often on moist banks, river banks or alluvial flats, up to 1200 m altitude. It is also found on the trunks of oil palms where some humus has accumulated.

Propagation and planting *M. speluncae* can be propagated by spores but is most easily propagated by rhizome cuttings.

Genetic resources and breeding *M. speluncae* is widespread and does not seem to be endangered by genetic erosion. No germplasm collections or breeding programmes are known to exist.

Prospects The pharmacological properties of *M. speluncae* and other members of the genus might receive some attention, but on the whole it will probably remain a fern of minor importance.

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Norma O. Aguilar & W.P. de Winter

Microsorum Link

Hort. Berol. 2: 110 (1833) (often misspelled *Microsorium*).

POLYPODIACEAE

$x = 36, 37$; *M. linguiforme, M. membranifolium, M. scolopendria*: $2n = 72$; *M. rubidum*: $2n = 74$; *M. punctatum*: $2n = 72, 144$

Major species and synonyms

- *Microsorum linguiforme* (Mett.) Copel., Univ. Calif. Publ. Bot. 16: 116 (1929), synonyms: *Polypodium linguiforme* Mett. (1866), *Pleopeltis linguiforme* (Mett.) Alderw. (1909), *Dendroconche kingii* Copel. (1931).
- *Microsorum membranifolium* (R. Br.) Ching, Bull. Fan Mem. Inst. Biol. 10: 239 (1941), synonyms: *Polypodium nigrescens* Blume (1828), *Phymatodes nigrescens* (Blume) J. Smith (1866),

Pleopeltis nigrescens (Blume) Bedd. (1883), *Microsorum nigrescens* (Blume) Copel. (1938), *Phymatosorus nigrescens* (Blume) Pichi Serm. (1973).

- *Microsorum pteropus* (Blume) Copel., Univ. Calif. Publ. Bot. 16: 112 (1929), synonyms: *Polypodium pteropus* Blume (1828), *Pleopeltis pteropus* (Blume) T. Moore (1857), *Colysis pteropus* (Blume) Bosman (1991).
- *Microsorum punctatum* (L.) Copel., Univ. Calif. Publ. Bot. 16: 111 (1929), synonyms: *Polypodium punctatum* (L.) Swartz (1801), *Pleopeltis punctata* (L.) Bedd. (1876), *Microsorum musifolium* (Blume) Copel. (1929).
- *Microsorum rubidum* (J.Smith) Copel., Gen. fil.: 197 (1947), synonyms: *Drynaria rubida* J. Smith (1841), *Phymatodes longissima* (Blume) J. Smith (1857), *Pleopeltis longissima* (Blume) Alderw. (1909).
- *Microsorum scolopendria* (Burm.f.) Copel., Univ. Calif. Publ. Bot. 16: 112 (1929), synonyms: *Polypodium scolopendria* Burm.f. (1768), *Polypodium phymatodes* L. (1771), *Phymatodes scolopendria* (Burm.f.) Ching (1933), *Phymatosorus scolopendria* (Burm.f.) Pichi Serm. (1973).

Vernacular names General: microsoroids (En).

- *M. linguiforme*: New Guinea: koiwa (Nauti), gwau-utu (Daga).
- *M. membranifolium*: Indonesia: pakis tanganan (Javanese). Malaysia: paku chai, paku sempak (Malay). Thailand: kalo rawa (Malay, peninsular).
- *M. pteropus*: Winged star fern (En). Thailand: kut hang nok kaling (peninsular).
- *M. punctatum*: Fish-tail fern, crested fern (En), climbing bird's nest fern (Am). Indonesia: teke (Timor), wassanke (Alor), saugtikel (Manggarai, Flores). Malaysia: keluwah. New Guinea: baluk (Kurte Plestok), kopeh-kopek (Matapaili), vata-vata (Kulumo). Philippines: eawawan (Igorot, Luzon). Thailand: krapok sing (south-eastern), prue mai (northern, south-western), haang nok waa (peninsular).
- *M. rubidum*: Indonesia: paku leyat (Sundanese). Thailand: kraprok bai chaek (south-eastern).
- *M. scolopendria*: East Indian polypody (Am). Indonesia: paku ular (Malay, Jakarta), paku cacing (Sundanese). Malaysia: paku wangi, sakat hitam (Malay). Thailand: khuut chakkhep (northern), yai phaek (peninsular).

Origin and geographic distribution *Microsorum* is distributed in the Old World tropics, extending to eastern Australia and New Zealand and to most tropical islands in the Pacific. In South-East Asia, 31 species are currently recognized. *M. linguiforme* is distributed from India (Kerala), through non-continental South-East Asia (Sumatra, Borneo, Sulawesi, Moluccas, New Guinea) to the Solomon and Fiji Islands. *M. membranifolium* occurs from India, Sri Lanka and China throughout South-East Asia to the Pacific (Solomon Islands, Fiji, Society Islands, Marquesas) and Australia (Queensland). *M. pteropus* occurs from the Himalayas, throughout South-East Asia to China, Taiwan and Japan. It is cultivated in tropical aquariums all over the world. *M. punctatum* is widespread all over the tropics and subtropics of the Old World, from west tropical Africa and India, throughout South-East Asia, to southern China, northern Australia and the Pacific. *M. rubidum* is distributed from northern India, southern China, throughout South-East Asia except New Guinea to Taiwan, Japan and the Pacific. *M. scolopendria* is distributed throughout the tropics of the Old World, including tropical Africa, South and South-East Asia, Australia (Northern Territory, Queensland) and most tropical islands in the Pacific.

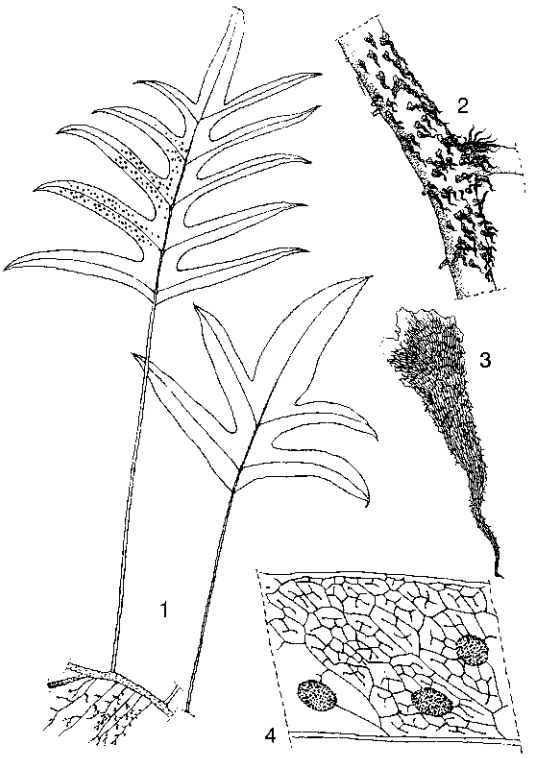
Uses In New Guinea, uncooked salted leaves or young boiled leaves of *M. linguiforme, M. commutatum* Copel. (distributed in non-continental South-East Asia) and *M. punctatum* are locally eaten as a vegetable. In Malaysia and Indonesia, the young leaves of *M. membranifolium* are eaten steamed or cooked. In Indonesia (Java), the croziers and young leaves of *M. rubidum* are eaten raw or cooked as a flavouring, said to taste like bitter almonds or endive. In Malaysia and Hawaii, the fragrant leaves of *M. scolopendria* are used to perfume clothes and to scent coconut oils. In Indonesia, chewed rhizome of the species is applied to lizard bites in Sulawesi and Bali, and in Java a compound paste containing this species is applied to the abdomen to treat difficult labour. In Indo-China it is used as a remedy for chronic diarrhoea, in the Philippines it is said to have laxative properties and to promote perspiration. The juice from the leaves of *M. punctatum* is used as a purgative, diuretic and to heal wounds. The leaves have been used to cure fever, after chewing they were spattered on the head of a patient. It is easily grown as an indoor ornamental and cultivars are sold (e.g. in Australia). *M. pteropus* is one of the most popular aquarium plants all over the world. Several *Microsorum* species are occasionally cultivated as ornamentals (e.g. *M. rubidum* in Singapore, *M. punctatum* (for landscaping and as indoor pot plant cut foliage), *M. thailandicum* T. Boonkerd &

Noot. in Thailand (also exported to United States and Europe for its remarkable blue iridescent leaves) and *M. scolopendria* in the Philippines).

Production and international trade All *Microsorum* species are mainly collected from the wild and locally used, but statistics are not available. The aquarium fern *M. pteropus* is widely cultivated and traded. Since it grows in heated water tanks international trade is probably limited and local production prevails. *M. punctatum* is cultivated on a rather small scale (e.g. in the Philippines and in Australia as an ornamental). It is said that it has a high potential as cut foliage and large-scale cultivation in the Philippines is being promoted. *M. scolopendria* is abundantly cultivated in Hawaii in gardens and around resorts.

Properties Histochemical findings of *M. punctatum* revealed that it contains the following substances and respective level of occurrence: alkaloids in rhizome and pinna detectable to very abundant, saponin in pinna detectable, formic acid in rhizome and pinna detectable to very abundant, oxalic acid in rhizome and pinna abundant to very abundant, and fats in rhizome and pinna detectable to abundant. The tissues of *M. scolopendria* contain glycyrrhizin, saponin and coumarin, the latter giving fragrance to the plant.

Description Ferns with rhizome short or long creeping, flattened or cylindrical, 1–10 mm in diameter, usually with a dense mat of roots; scales usually narrowly ovate, light to dark brown, (pseudo)peltate or (sub)clathrate, margin entire to dentate, sometimes hyaline, apex acuminate, with an apical hair and often marginal short glandular hairs, sometimes with a central tuft of long lax multiseptate hairs. Leaves alternating in two dorsal rows, more or less distinct, contiguous or up to 8 cm apart; petiole articulated to a phyllopodium; lamina usually simple, sterile and fertile similar, obovate, ovate or lanceolate to linear, base usually narrowly angustate, margin entire, sinuate, or undulate, apex usually acute to acuminate, membranaceous to coriaceous, usually herbaceous, with few to many small glandular hairs, occasionally with a few small scales and acicular hairs; venation more or less distinct but usually visible when viewed against the light, at least the larger veins often distinctly raised on upper surface, forming a more or less regular row of up to 10, with about equally sized areoles between each pair of adjacent secondary veins, or forming one row of main areoles parallel to the primary vein and bordered by one or two marginal rows of smaller areoles; secondary veins often slightly zigzag, free included veins 0–2 times forked, ending in hydathodes, usually directed to all sides except for some recurrent and occasionally excurrent veins near the margin. Sori roundish, 3–7 mm long or in diameter, often a few sori slightly confluent, scattered over the lamina or in one to several irregular rows between midrib and margin, usually superficial; paraphyses few to many, in most species uniseriate, occasionally once branched, 1–4(–8)-celled, apex glandular. Spores monolete, bilateral, up to 75(–105) µm, smooth to slightly sculptured.



Microsorum scolopendria (Burm.f.) Copel. – 1, habit; 2, rhizome part with petiole base and scales; 3, rhizome scale; 4, venation and sori.

- *M. linguiforme*. Rhizome flattened, long-creeping, with sclerified circumvascular sheaths; scales peltate, ovate to triangular, 3–10 mm × 1–2.5 mm. Leaves simple; petiole up to 12 cm × 3–5 mm; lamina subcircular to obovate, 3–70 cm × 2–17 cm, veins prominent, connecting veins forming a single row of large areoles along the midrib bordered by several smaller ones. Sori irregularly scattered on the lower surface, generally present in the midrib areoles.
- *M. membranifolium*. Rhizome creeping, terete,

with only scattered sclerenchyma strands, not white waxy; scales pseudopeltate, circular to triangular, 4–8 mm × 2.5–3.5 mm. Leaves pinnatifid; petiole 20–100 cm × 0.3–1 cm; lamina elliptical to ovate in outline, 27–175 cm × 36–90 cm, membranaceous, blue-green with prominent dark veins shorter than those of *M. rubidum*; lobes 2–20 at each side, longest ones at position 2–10 from the base, 15–50 cm × 2–4.5(–7) cm, base decurrent and connected to a long wing about 1.5 cm wide, margin undulate and crisped, apex long-acuminate. Sori more or less in one row between the midrib and the leaf margin but usually closest to the midrib.

- *M. pteropus*. Aquatic fern, rhizome creeping, without sclerified circumvascular sheaths, not white waxy; scales pseudopeltate, ovate to triangular, 1.5–5 mm × 0.4–1 mm. Leaves simple, entire or deeply trilobed, very dark green; petiole 1–28 cm long; lamina (central lobe) narrowly elliptical, up to about 30 cm × 5 cm, lateral lobes smallest, base decurrent to a long wing, margin entire, apex acuminate, main veins prominent and distinct beneath, anastomosing veins forming a row of large areoles on both sides along the midrib irregularly bordered by several smaller ones. Sori irregularly scattered on the whole leaf under surface, generally absent from the marginal and midrib areoles. The apex of the leaves (particularly when submerged) occasionally producing new young plants.
- *M. punctatum*. Rhizome creeping, white waxy, without sclerified circumvascular sheaths; scales pseudopeltate, ovate to triangular, 1.5–8 mm × 0.5–3 mm. Leaves simple, subcoriaceous; petiole 0–12 cm long; lamina ovate to linear-elliptical, 10–175 cm × 1.5–15 cm, base decurrent into a wing along the petiole, margin entire to irregularly lobed, apex rounded to acuminate; connecting veins forming several equally sized areoles between two adjacent veins. Sori scattered on the whole lamina under surface but most frequent in upper half.
- *M. rubidum*. Rhizome long creeping, flattened, not white waxy, with sclerified sheaths but without sclerenchyma strands; scales pseudopeltate, ovate to triangular, 3–6 mm × 1–3 mm. Leaves herbaceous, bright green; petiole 15–120 cm long; lamina pinnatifid, elliptical in outline, 30–120 cm × 8–60 cm, larger than those of *M. scolopendria*, lobes 10–40 at each side of the midrib, longest ones in lower half, oblong, 7–40 cm × 1–3.5 cm, base running into a connecting wing up to 1 cm wide, margin entire, apex rounded to acuminate. Sori more or less in one row between the midrib and the margin, usually close to the midrib.
- *M. scolopendria*. Rhizome terete, white waxy, with sclerified circumvascular sheaths and scattered sclerenchyma strands, scales peltate, ovate to triangular, 2–7 mm × 0.6–1.4 mm. Leaves simple, entire or pinnatifid with 1–9 lobes at each side of the midrib, light green, herbaceous; petiole up to 55 cm long; lamina or lobes narrowly elliptical, up to 45 cm × 8 cm, margin entire, apex acuminate. Sori in 1–3 rows between the midrib and the leaf margin, deeply sunken and visible as protrusions on the upper surface.

Growth and development A germinating spore of *Microsorum* first develops a usually heart-shaped prothallus, the gametophyte. In the sporophyte the *Microsorum* species with lobed leaves are thought to be more advanced than those with unlobed simple leaves. In the Philippines, spores of *M. punctatum* germinated about 6–7 weeks after sowing and sporophyte formation started after an additional 7 weeks.

Other botanical information When *Microsorum* was established in 1833, it included only one species: *M. punctatum*. One century later, almost forgotten by most botanists, it was revived by Copeland (1929) in an influential publication, and included all polypodioid ferns with reticulate venation and round sori. In this broad sense it also comprised the genera *Crypsinus* C. Presl (now in *Selliguea* Bory), *Lepisorus* (J. Smith) Ching and *Leptochilus* Kaulf. and totalled about 200 species. At present *Microsorum* comprises about 60 species but the number varies according to inclusion or exclusion of several groups (genera) and more research is needed before the taxonomy of *Microsorum* can be stabilized. *Microsorum* is closely related to *Leptochilus* Kaulf., the only differences being the arrangement of the sori (sori usually fused to coenosori, forming an elongated line) and peltate paraphyses in the latter, and not fused round or elongated sori and lack of peltate paraphyses in the former). It is also close to *Lepisorus* which differs in its arrangement of sori (one single row between midrib and margin while in *Microsorum* the sori are arranged in several irregular rows or scattered). *M. rampans* (Baker) Paris from New Guinea is closely related or possibly conspecific with *M. linguiforme*. The venation in *M. pteropus* with its rows of areoles is characteristic; populations with only unlobed leaves have been classified as var. *minor* (Bedd.) Ching.

When no rhizomes are available, *M. membranifolium* and *M. rubidum* are often difficult to distinguish. *M. scolopendria* and *M. papuana* (Baker) Parris (distributed in non-continental South-East Asia and Pacific Islands) are closely related and often confused; the former has sori in one to several rows, the latter usually in one row parallel to the midrib. In the Philippines, a popular cut leaf cultivar of *M. punctatum* is 'Grandiceps'.

Ecology *Microsorum* species are of a rather fine texture, found in moist shady locations, often on rocks or trees near streams in the forest. *M. linguiforme* is a low epiphyte, rarely epilithic or terrestrial in primary and secondary forests, in shady, moist locations, from sea-level up to 1650 m altitude. *M. membranifolium* is a fairly common epiphyte in moist, partially shaded sites, especially near streams, in the lowlands but also epilithic or terrestrial on dry rocks (particularly on limestone but also on granite) in mixed forest, from sea-level up to 1700 m altitude. *M. pteropus* grows terrestrially near running water, on the banks or even submerged for part of the year, but it survives and reproduces predominantly vegetatively (sori only incidentally produced) when submerged permanently; it usually occurs at low altitudes but can be found up to 1200 m. *M. punctatum* is usually epiphytic on tree trunks and branches, but can also be epilithic or terrestrial in various types of forest, sometimes in savanna but also in wet locations in streambeds, most common in lowland but occurring up to 2800 m altitude. It is one of the few *Microsorum* species inhabiting fairly open sites and can change to the crassulacean acid metabolism (CAM) pathway to limit water loss during daytime. *M. rubidum* is a terrestrial fern, usually in wet locations, occurring at low altitudes but sometimes up to 1500 m. In South-East Asia *M. scolopendria* is a common epiphyte on old trees in open locations, on the trunks of plantation oil palms, sometimes occurring on rocks and earth banks in full sunlight, from the lowlands up to 2100 m altitude.

Propagation and planting Propagation of *Microsorum* is possible by spores and by rhizome cuttings. In aquariums it is recommended that *M. pteropus* rhizome cuttings be planted on a piece of wood or on stones to which the growing rhizome can attach itself. In the Philippines, *M. punctatum* is planted in a mixture of 2 parts compost and 1 part garden soil. Rhizome cuttings should be buried not deeper than 5 cm. Spores are sown on a sterilized medium and kept in a very high relative humidity. Sporophytes are transplanted in groups when they are about 1 cm tall and again transplanted individually when they are taller than 3 cm.

Husbandry If planted in gardens, *Microsorum* can grow in pots like orchids or on dead or living tree trunks, generally requiring partial shading. In some oil-palm plantations natural stands of *Microsorum* are already common and could be used to start commercial exploitation. The natural stands can be tended and given horticultural care to optimize production. In rubber plantations *Microsorum* can be grown on the ground. In aquariums *M. pteropus* requires a water temperature above 20°C; it can also grow in salty water (3–5 g sea salt per litre). In the Philippines, for cultivation of *M. punctatum*, 75% shade is recommended, varying from 90% for the young sporophytes to about 50% for adult plants. Watering (sprinkler irrigation) is necessary as soon as the soil cover is dry, but waterlogging should be prevented. The optimum average temperature depends on the desired type of plant; at 18–20°C the fern grows slower but becomes sturdier. Monthly NPK application (14-14-14, one tablespoon per 4 litres water) is recommended.

Diseases and pests Natural stands of *Microsorum* do not show signs of any serious diseases or pests. Some damage may be caused by insects and leaf deformations may occur due to fungi and viruses. *M. pteropus* is reported to suffer from a disease that frizzes the leaves. In the Philippines, cultivated *M. punctatum* is susceptible to leaf blight or leaf spot caused by *Sclerotium* sp. Control is difficult and infected plants can best be burned. Major pests are white louse scales (*Unaspis* sp.), midrib borers, snails and slugs.

Harvesting In general, when grown from spores, 2–3-year-old plants of *Microsorum* can be harvested as a vegetable or for other use. When grown from runners, harvesting may start 6 months after planting. In the Philippines, leaves from mature cultivated *M. punctatum* plants are cut when fully expanded, just before the appearance of sori. After harvest they are stored in water in the shade.

Genetic resources and breeding *Microsorum* is widely distributed and common in natural stands but some species are less common. Further research is required to determine its genetic diversity. This may lead to the development of plants producing many young leaves (for vegetable use) or plants with a high coumarin content for use as a perfume. Subsequent selection and

breeding programmes might result in higher-yielding cultivars.

Prospects As *Microsorum* can easily be grown in the shade of plantation trees there is a potential for increasing the production of young leaves for vegetable use and for coumarin production for the perfume industry. Growing *Microsorum* in existing plantations may reduce pressure on land utilization and at the same time increase productivity and diversification of existing plantations and products.

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H.C. Ong, Isa B. Ipor, Norma O. Aguilar & W. Somprasong

Nephrolepis Schott

Gen. fil.: pl. 3 (1834).

NEPHROLEPIDACEAE

$x = 41$; *N. biserrata*, *N. cordifolia*: $2n = 82$

Major species and synonyms

- *Nephrolepis biserrata* (Swartz) Schott, Gen. fil.: pl. 3 (1834), synonyms: *N. acuta* (Schkuhr) C. Presl (1836), *N. ensifolia* (Schkuhr) C. Presl (1836), *N. exaltata* (L.) Schott var. *biserrata* (Swartz) Baker (1870).
- *Nephrolepis cordifolia* (L.) C. Presl, Tent. pterid.: 79 (1836), synonyms: *Polypodium cordifolium* L. (1753), *N. tuberosa* (Bory ex Willd.) C. Presl (1836), *N. exaltata* (L.) Schott var. *tuberosa* (Bory ex Willd.) Kuntze (1891).
- *Nephrolepis hirsutula* (Forst.) C. Presl, Tent. pterid.: 79 (1836), synonyms: *Polypodium hirsutulum* Forst. (1786), *N. exaltata* (L.) Schott var. *hirsutula* (Forst.) Baker (1867).

Vernacular names General: sword ferns, ladder ferns, boston ferns (En).

- *N. biserrata*. Broad sword fern, coarse sword fern (En). Indonesia: paku uban (Lingga), paku harupat (Sundanese), moba (southern Irian Jaya, Papua). Malaysia: paku larat (Malay), ch'âng yèh shèn ch'uèh (Chinese). Philippines: alolokdo. Thailand: foen kaang plaa, foen teen takhaap, foen haang plaa (central). Vietnam: r[as]ng th[aaj]n l[aa]n.
- *N. cordifolia*. Common or erect sword fern, fishbone fern (En). Indonesia: paku acel, paku ubi (Sundanese). Philippines: bayabang (Tagalog), olaluent, bangduan (Igorot). Thailand: kut soi (northern).
- *N. hirsutula*. Rough sword fern (En). Indonesia: pakis kinca (Javanese), paku jeler, paku sepat (Sundanese). Philippines: alolokdo (Bisaya), bayangbang (Tagalog), lagunton (Iloko).

Origin and geographic distribution *Nephrolepis* is distributed throughout the warmer parts of the world, extending into the temperate zones, but with the greatest species concentration in South-East Asia. Many species are also cultivated indoor and outdoor and, due to escapes and subsequent naturalization, natural distribution patterns are not always clear. *N. biserrata* is distributed pantropically and it is one of the commonest ferns in South-East Asia. *N. cordifolia* is distributed pantropically and sometimes also more to the north (Japan) and to the south (New Zealand). Possibly it has been introduced in East Africa and naturalized in New Zealand. *N. cordifolia* is only found terrestrially in open locations in the moun-

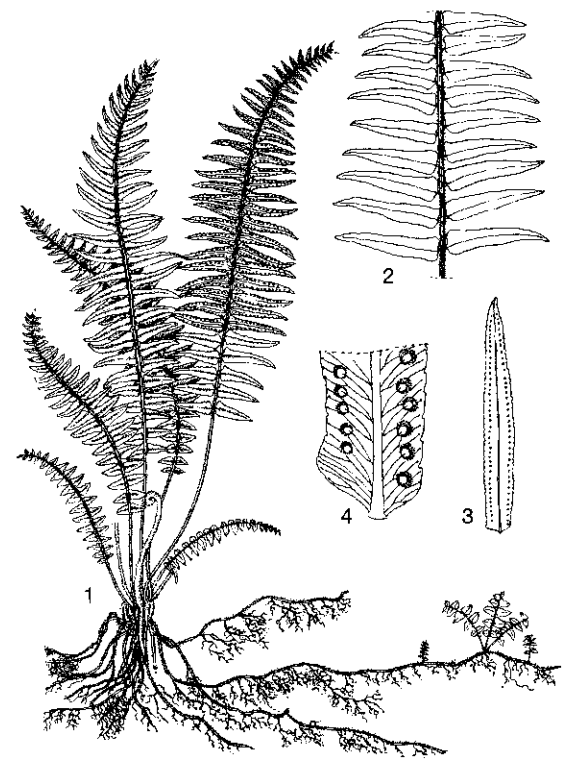
tains of Peninsular Malaysia while in Java (Indonesia) and the Philippines it is commonly found cultivated or naturalized in the lowland. *N. hirsutula* is widely distributed in tropical Asia and far into the Pacific and is common in South-East Asia.

Uses Very young curled-up leaves of *N. biserrata* and *N. hirsutula* are eaten cooked or steamed as a vegetable in Java and New Guinea. In southern Papua (Indonesia), the rhizomes of *N. biserrata* are dried, pounded, prepared and eaten in the same way as sago. In India and tropical America the tubers of *N. cordifolia* are eaten. In Java, *N. biserrata* is used in traditional medicine against cough. In Ivory Coast, it is applied to stop wounds bleeding. In Malaysia it is planted on a large scale as soil cover in rubber plantations because the roots release a considerable amount of nitrogen. In the Philippines a decoction of fresh leaves of *N. cordifolia* is used as a drink for cough, while a decoction from its tubers is applied against goitre. Young leaves of *N. hirsutula* are used as a poultice for swelling wounds and boils. In Papaua New Guinea *Nephrolepis* leaves are placed among bones in death ceremonies. In Indonesia and the Philippines the fibro-vascular bundles of the stems of *N. hirsutula* are extracted and occasionally used in the manufacture of hats, mats, baskets and other wickerwork. In South-East Asia and elsewhere many *Nephrolepis* species are used and commonly cultivated as ornamentals, including for example *N. cordifolia* and *N. hirsutula* which are popular ornamentals in Indonesia, Malaysia, Singapore, Thailand and the Philippines (both as plants and as cut leaves in flower arrangements). When grown in hanging baskets they produce hundreds of gracefully hanging, thin stolons.

Production and international trade The genus *Nephrolepis* comprises some of the most popular ornamental ferns, including the 3 major species mentioned here although they are not the highest ranking. In many countries *Nephrolepis* species and cultivars are cultivated on a large scale and a considerable amount of international trade exists (e.g. for tropical American *N. exaltata* (L.) Schott cultivars). Cultivated and wild *Nephrolepis* species in South-East Asia are offered for sale as ornamentals on local markets only but statistics are not available.

Properties The thin epicuticular wax layer of *N. biserrata* contains three drimane-type sesquiterpenes which all have a hemiacetal esterified with acetic acid. The plant contains about 7% tannin and 0.1 % essential oil and the leaves contain sequoyitol. A small amount of sugar (a hexose) is stored in the stolon buds of *N. hirsutula*. In the Philippines, histochemical tests indicated an abundance of alkaloids in the 3 species treated here.

Description Terrestrial, epilithic or epiphytic ferns with short, erect, peltately-scaly rhizomes each bearing a cluster of leaves and often also forming slender horizontal runner rhizomes or stolons with adventitious buds and sometimes tubers. Leaves pinnate, petiolate; petiole not articulated, often persistently hairy, erect to pendent; lamina long and narrow, simply pinnate with numerous and often close pinnae but the apex only pinnatifid and of indeterminate growth; rachis slightly grooved above; pinnae sessile, articulate at base, inserted on the ridges bordering the rachis groove, base often auriculate, midrib prominent and grooved, margin entire, crenate or lobed, basal pinnae often reduced, veins free, arranged in small groups for each crenation, ending in a hydathode with a white scale, fertile pin-



Nephrolepis biserrata (Swartz) Schott – 1, habit; 2, part of sterile leaf; 3, fertile pinna; 4, part of fertile pinna showing venation and sori.

nae occasionally more incised and narrower. Sori terminal on the veins, one in each vein group, usually close to the margin, usually with circular or kidney-shaped, subpeltate, persistent indusia. Spores monolete, ellipsoid or rarely spheroidal, 25–34 μm in diameter, translucent brown, with irregularly roughened surface.

– *N. biserrata*. A terrestrial or epiphytic fern up to 3 m or taller. Rhizome up to 25 cm long, scales lanceolate, 3–10 mm × 0.6–0.8 mm, base peltate, margins denticulate-ciliate, apex attenuate aristate, very pale green when young, dark brown with pale brown edges when old, lustrous; stolons numerous, rather stout, in a close tuft with the leaves. Leaves tufted; petiole 12–60(–75) cm long, with linear-filiform scales shorter than those of the rhizome; lamina linear-oblong-lanceolate in outline, 1.5–2(–3.25) m × 15–30(–50) cm, pendent, chartaceous, surfaces bearing scattered small scales when young, the scales on the upper surface bearing irregularly curved hairs; rachis with up to 70 pairs of spreading pinnae, the basal ones gradually shorter and more widely spaced, the middle ones 3 cm apart, the upper ones so closely spaced as to touch each other, in large leaves often separated as wide as their width or more; sterile pinnae linear-oblong, 7–25 cm × 12–29 mm, the basal ones sometimes slightly auriculate, margins crenate, midrib hardly falcate, apex shortly acuminate; fertile pinnae 1–1.5 cm wide near the base; veins indistinct in living plants and not raised, usually once or twice forked, ending in inconspicuous hydathodes that often bear white excretions on the upper surface. Sori round, 1.5 mm in diameter, situated nearer to margin than to midrib, indusium reniform, entire, about 0.5 mm long, opening outwardly. Spores ellipsoid, monolete, low tuberculate.

– *N. cordifolia*. Rhizome erect, about 10 cm long, crowded with erect to arching leaves; runners numerous, up to 2 m long, often bearing scaly tubers. Petiole 5–25 cm long, scaly, deeply grooved on the upper surface; lamina in outline linear-elliptical, 30–80 cm × 4–7 cm, pinnae sessile, 40–100 on each side of the rachis, imbricating at their widened bases; sterile pinnae narrowly deltate-oblong, about 2 cm × 5–9 mm with auricled upper base, margin crenate, apex rounded or bluntly pointed, veins simple or once forked, often with lime-dotted hydathodes on upper surface; fertile pinnae at base more abruptly narrowed, in the middle about 3–5 mm wide. Sori about midway between midrib and margin; indusium 1–1.4 mm wide, attached by a broad curved base oblique to the vein, the free edge facing the apex of the pinna. Spores spheroid, tuberculate with partly fused tubercles.

– *N. hirsutula*. Rhizome erect, very short, bearing a tuft of leaves and many long slender runners, bearing appressed, imbricating, hairy scales 3–4 mm long. Petiole 25 cm or longer, scaly; lamina erect or arching, in outline 60–100 cm × 16 cm, pinnae very close and overlapping with their widened bases, covered with small hair-like scales when young, lowest pinnae more widely spaced and 1.5 cm long; sterile pinnae up to about 8 cm × 1.5 cm with a triangular auricle at base, margins irregularly crenate, slightly falcate at apex, veins hardly visible in living plant, ending in small hydathodes near the margin often with white scales; fertile pinnae narrower, up to about 1 cm wide. Sori close to or touching the margin; indusia round-reniform, about 1 mm in diameter.

Growth and development The gametophyte of *Nephrolepis* is cordate, often bearing several-celled hairs and short-stalked antheridia. The stolons of *N. biserrata* can grow fast, under controlled conditions 2–4 mm per day. The apical cells are mitotically more active than the lateral ones in the organization and shaping of the stolon meristem. In tropical gardens it is often considered a weed due to its rapidly spreading runners. When kept too dry in cultivation, some species shed their pinnae quite quickly, leaving only bare dry rachises; however, when conditions improve, a new flush of leaves will develop quickly. The rachis of the leaves shows a kind of perennial growth which accounts for the crozier-like apex of many leaves. These often produce a few new pinnae long after the older pinnae have shed their spores or fallen off.

Other botanical information *Nephrolepis* is often included in the *Oleandraceae*, or, with an increasingly wide family concept, in the *Davalliaceae* and *Dennstaedtiaceae*, respectively. Spore characters however, as well as other uncommon features such as the many stolons, the hydathodes excreting calcareous deposits, and the peltate indusium justify a separate, monotypic family. *Nephrolepis* is closely associated with *Arthropteris* J. Smith (*Oleandraceae*), which may be very similar in appearance but has long, slender, creeping rhizomes with petioles jointed to it some distance above their bases (known from Borneo and Sumatra). *Nephrolepis* comprises about 30 species, all closely related, many of wide distribution, about 8 in Malesia.

N. biserrata has been described under at least 16 different names and many more combinations. As a popular ornamental, *N. biserrata* has several cultivars, many with bizarre, dissected pinnae, of which 'Furcans', with bifurcated pinnae, is best known. In the tropical New World, specimens of *N. multiflora* (Roxb.) Jarrett ex Morton have often been misidentified as *N. biserrata*.

The name *N. cordifolia* is under discussion because of doubts about the identity of the depicted fern of the type material which is a plate of Petiver and Plumier, by some identified as *N. auriculata* (L.) Trimen. *N. cordifolia* has relatively few cultivars. In tropical gardens, cultivar Duffii (particularly popular in the Philippines) is best known and most distinctive, forming characteristic scaly tubers used for food and water storage; its leaves are usually forked at the apices, the pinnae are subcircular and attached in more than one plane; they usually remain sterile; in cultivar Plumosa the pinnae have lobed margins. In older literature the name *N. duffii* Moore is used for cultivar Duffii. Mr Duff (hence the name) first discovered this form on the Duke of York's Island in New Britain, Papua New Guinea. In cooler climates the pinnae are usually longer than in the tropics.

N. hirsutula appears to be very closely related to *N. acuminata* (Willd.) C. Presl, which occurs in similar habitats but is more commonly epiphytic. It differs from *N. biserrata* in the position of the sori on small, rounded marginal lobes. However, some specimens are difficult to place in one group or the other with certainty; hybridity or other species might be involved.

N. hirsutula has been confused with *N. exaltata* (L.) Schott and *N. biserrata*, which is larger, with pinnae less close and hardly auricled at base, sori not close to the margin and usually growing in the lowland; it is not sure whether it occurs in tropical America.

The most commonly grown and horticulturally most remarkable *Nephrolepis* worldwide is *N. exaltata* (L.) Schott var. *bostoniensis* hort. (Boston fern, lace-fern), which has finely dissected leaves that are much shorter than in the South-East Asian species and of which numerous cultivars have been derived, including cultivars with bi-, tri- or quadripinnate leaves. Most cultivars are sterile but can easily be propagated by the stolons or by the proliferous buds on their rachises.

Ecology Most *Nephrolepis* species grow in thickets, on rocks and in similar, somewhat open locations; some are pioneers on lava flows, but others prefer very acid, humus-rich habitats such as peat swamps or leaf bases of palms. Some species can grow terrestrially as well as epiphytically, e.g. *N. biserrata* and *N. hirsutula* are often found on trunks of palms with persistent leaf bases (e.g. oil palm) and are very common everywhere in South-East Asia. *N. biserrata* is a very common lowland fern occurring in wet boggy ground, grassland, thickets, village groves, plantations, secondary forest and other regrowth conditions or on forest-grassland margins, from sea-level up to 1300 m altitude. It grows in the open or in light shade, terrestrially or on tree trunks, sometimes on rocks. It also thrives in moister conditions such as swamps and in swamp or river margins, and mangrove forest. Under favourable conditions it can spread rapidly by its long runners and form dense thickets. Together with *Davallia denticulata* (Burm.f.) Mett. ex Kuhn it is the first fern to invade new oil-palm plantations. In a lowland rain forest in Sabah, the fern dominated the secondary vegetation in burnt plots two years after a forest fire in Borneo. *N. cordifolia* is a hardy fern found in South-East Asia in various situations from shade in the lowland to open locations at higher altitudes up to 3500 m. Some cultivars tolerate temperatures down to 0°C. It can grow terrestrially, epilithically or epiphytically. *N. hirsutula* occurs in South-East Asia in more exposed locations than *N. biserrata*, from sea-level up to 2000 m altitude. In cool temperate climates *N. cordifolia* and *N. hirsutula* can overwinter in a cool greenhouse while *N. biserrata* needs warmer greenhouse conditions.

Propagation and planting *Nephrolepis* can be propagated by spores, clump division, rhizome or stolon runner plantlets, and some species also by proliferous buds and tubers. Tissue culture is used for propagation on a large commercial scale. Runner tips produce green globular bodies when quarter-strength Murashige and Skoog medium is used supplemented with 0.5 mg/l benzyladenine (BA). Green globular bodies easily regenerate plantlets when cultured on BA-free medium, and they multiply rapidly on BA medium. Multiplication rates of over 40 per month can be realized, which means that 160 000 plantlets can be obtained from one runner tip in 6 months. Growing is quite simple because most soils and composts are acceptable as long as drainage is free. *N. cordifolia* can be propagated by tubers which only start sprouting in total darkness.

Husbandry When grown in pots, frequent watering and occasional fertilizing of *Nephrolepis* are necessary. As an ornamental plant, *N. biserrata*

should be planted outdoors or indoors in such a way that it receives the morning sun. When planted in a pot it is best grown in a mixture of soil, sand and humus (1:1:2). To promote vigorous growth N fertilizer should be applied to the leaves by spraying. Watering twice a day is appropriate when the fern is placed in the open. Too much water is as harmful as too little, and plants need bright, airy locations, in greenhouses as much as 95 lux and an optimum temperature of 24°C. Many cultivars react to stress conditions (drought, low or high temperature, poor soil) by reverting to the leaf shapes of their wild form.

Diseases and pests In general, *Nephrolepis* is quite disease and pest resistant. Cultivars are particularly susceptible to botrytis, fern scale, whitefly, slugs and snails. In Bangalore (India), *N. biserrata* is sometimes severely infected by leafspot diseases caused by *Alternaria tenuissima* and *Bipolaris sorokiniana* (synonym: *Cochliobolus sativus*). A smut (*Entyloma nephrolepidis*) has been found in Java, invading the meristematic portions of plants resulting in abnormal, sterile leaves that are wider, thicker and paler. The gall mite *Eriophyes pauropus* infects the leaves of *Nephrolepis* species, inducing the fern to form outgrowths (hollow swellings) and branched hairlets.

Handling after harvest Freshly harvested leaves of *N. cordifolia* (without sporangia) placed in water for 10–20 hours at 2–4°C can be stored in perforated plastic film for 14 days without adverse effects on vase life. Even after 5 weeks' storage a vase life of 7–16 days can be expected. Wrapping the leaves in wet newspaper packed in perforated cardboard box lined with polyethene sheet gives better results than packing in airtight plastic bags.

Genetic resources and breeding Most wild *Nephrolepis* species are common and widely distributed, not being overcollected for vegetable, medicinal or ornamental uses and hence not in danger of genetic erosion. Germplasm collections or breeding programmes are not known to exist.

Prospects Several *Nephrolepis* species are cultivated on a commercial scale. It seems worthwhile investigating the possibilities for large-scale cultivation and export of promising species and cultivars in South-East Asia. There could be a niche market for young *Nephrolepis* leaves as a vegetable delicacy.

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Dedy Darnaedi & Titien Ngatinem Praptosuwiryo

Odontosoria chinensis (L.) J. Smith

In: Seeman, B.C.: Bot. Voy. Herald: 430 (1857).

DENNSTAEDTIACEAE

$2n$ = 188, about 200, 290–294 (tetraploid, hexaploid)

Synonyms *Sphenomeris chinensis* (L.) Maxon (1913), *S. chusana* (L.) Copel. (1929), *Stenoloma chusana* (L.) Ching (1933).

Vernacular names Chinese lace fern (En). Indonesia: paku jamuju, paku camara (Java).

Origin and geographic distribution *O. chinensis* is widespread in the tropical and subtropical parts of the Old World from Madagascar (but not in continental Africa), throughout South-East Asia to Polynesia and Hawaii and northwards to Japan and Korea.

Uses *O. chinensis* is mentioned as a medicinal and an ornamental plant in the Philippines. Fresh or dried plant parts are used against bacillary dysentery, enteritis, food poisoning, as an adjunct to antidote against pesticide poisoning, for poisonous snake bites, bleeding wounds, scald and burns and upper respiratory tract infections. In the mountainous areas of Java (Indonesia) it is sometimes grown as an ornamental. In Hawaii, a brown dye is derived from the leaves, and the fern is said to cure various female maladies, e.g. premenstrual syndrome. The attractive, fine leaves are also used to decorate hula altars and are often used as a kind of garland around the neck or on the head.

Production and international trade Although *O. chinensis* is an attractive fern, it is only rarely grown and statistics on production or trade are not available.

Properties In the Philippines, histochemical tests revealed the presence of alkaloids, amygdalin, saponin, oxalic acid, arbutin, tannin, formic and tartaric acid in the petiole and rachis of *O. chinensis*.

Description Rhizome short-creeping, 2–4 mm in diameter; scales uniseriate except for the base, acicular, up to 4 mm long, dark to reddish-brown. Leaves clustered, olive-green, brown to blackish when dry, herbaceous to chartaceous; petiole 5–60 cm long, 0.6–1 times as long as the lamina (shorter and more slender in juvenile fertile plants), terete, 1.5–3 mm in diameter in the middle, upward gradually sulcate, the groove broad and flat, glabrous and lustrous green to yellow-brown; lamina lanceolate, oblong, elongate-ovate or narrowly triangular, 10–85 cm × 12(–25) cm, rarely smaller in fertile plants; fertile leaves at the base from bipinnate-pinnatifid up to quadripinnate-pinnatifid in large specimens; rachis stramineous, glabrous, subterete, upward gradually flattened; pinnae 6–10 to a side in larger leaves, free, strongly ascending to strongly spreading, basal ones usually subopposite, apically gradually alternate, smaller and closer, lower ones somewhat reduced; stalk 0.2–3 cm long; pinna elongate-triangular or elongate-rhombic, (5–)10–20 cm × (1.5–)3–10 cm, 2–4.5 times as long as wide, base usually with unequal sides, the acroscopic side broader as the pinna is strongly anadromic and this side has longer or less ascending pinnules, apex acuminate, often with 6–8 major, alternating, ascending pinnules to a side; pinnules triangular to rhombic, often twice as long as wide, shortly stalked, acute or acuminate; ultimate free divisions rhombic, asymmetrical, pinnatisect on both sides, the smaller ones cuneate, unequally and shallowly bifid or, if deeply bifid, usually once again bifid, linear spatulate to cuneate, margins of the lobes entire. Sori on the apical margin of the segments; indusium attached to the base and sides, on 1–3(–4) vein ends, brownish and chartaceous when dry; with more or less straight to convex base, adnate, convex sides, and straight, slightly convex or sometimes erose-denticulate free margin, more or less equalling the segment margin, never reflexed at maturity. Spores monolete, ellipsoid, smooth, medium brown.

Odontosoria chinensis (L.) J. Smith – 1, habit; 2, pinnule (var. chinensis); 3, pinnule (var. divaricata); 4, pinnule (var. rheophila).

Growth and development Not much is known about the growth and development of *O. chinensis*. Its gametophytes have hardly been described although it is a widespread fern which easily colo-

nizes. It primarily reproduces by outcrossing but it may also possess a mixed-mating system. On the prothallus several gregarious archegonia develop on the distal centre of the cushion near the sinus. Archegonia have a long neck, 90–100 µm long, bending toward the posterior side; the globose antheridia develop scattered between the archegonia.

Other botanical information Opinions about the correct classification of *O. chinensis* vary extremely. In 'Ferns of Malaya', Holttum placed it in *Dennstaedtiaceae, Lindsaya* subfamily and named it *Sphenomeris chusana* (L.) Copel. In 'Flora Malesiana' it is placed in the *Lindsaea*-group (no family) as *Sphenomeris chinensis* (L.) Maxon; later, however, Kramer moved it to *Dennstaedtiaceae*, changing the name to *Odontosoria chinensis* (L.) J. Smith. In the 'Flora of Thailand' it is placed in *Lindsaeaceae* as *Sphenomeris chinensis*. Regardless of the difficulties in classification, *O. chinensis* is easily recognized by the finely dissected leaves ending in narrow, parallel-sided, entire segments which widen at the apex to accommodate the pocket-shaped, indusiate sori. *O. chinensis* is very variable and 4 varieties have been distinguished which, however, are not quite distinct and overlap in distribution range throughout South-East Asia:

- var. *chinensis*. Lamina of variable length; segments gradually broadened to the apex, apical margin not or scarcely incised; sori often several together to a segment, rarely one except in the upper reduced segments, mostly with 2 or 3 veins; spores 42–48 µm long.
- var. *divaricata* (Christ) Kramer (synonym: *S. chusana* (L.) Copel. var. *tenuifolia* Holttum). Lamina over 20 cm long; segments suddenly spatulate-dilated at the apex to accommodate the sorus, apical margin often incised; sori one or two together in a segment, mostly with one vein; spores mostly 55–60 µm long.
- var. *rheophila* Kramer. Lamina 15–20 cm long; segments stiff, often with more or less revolute margin, gradually broadened to the apex, apical margin entire or sinuate; sori one or two together in a segment, mostly with one vein; spores elongate, bean-shaped, 44–48 µm long, about twice as long as broad.
- var. *rubens* Amoroso & Medecilo. Distinguished in the Philippines for specimens with reddish petiole and rachis.

Ecology *O. chinensis* grows terrestrially and on rocks from 100–2500 m altitude, on river banks, in thickets and open forests, in exposed or lightly shaded locations, often near hollow roads, on slopes, escarpments and on open banks (frequently by path-sides) in the mountains. It is found on infertile, not too dry, badly-drained soils, especially on steep banks. It also occurs in fields with alang-alang (*Imperata cylindrica* (L.) Raeuschel). Locally it can be abundant and behave like a weed.

Husbandry *O. chinensis* grows well in pots in the shade. It needs well-drained soils and adequate watering. It tolerates cool to warm conditions.

Genetic resources and breeding Germplasm collections or breeding programmes for *O. chinensis* are not known to exist. It is unlikely that it is endangered by extinction or genetic erosion because of its wide distribution in a multitude of habitats, but germplasm collection is recommended.

Prospects Since *O. chinensis* is an attractive fern that can also be grown in pots, its potential as an ornamental needs to be investigated. Its dye and medicinal uses require further research to detect the active compounds and the possibilities for commercialization.

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W.P. de Winter

Oleandra neriiformis Cavanilles

Anal. Hist.Nat. 1: 115 (1799) ('*neriformis*').
OLEANDRACEAE
$2n = 82$

Synonyms *Ophiopteris verticillata* Reinw. (1824), *Oleandra pistillaris* (Swartz) C. Chr. (1934), *O. colubrina* (Blanco) Copel. (1958).

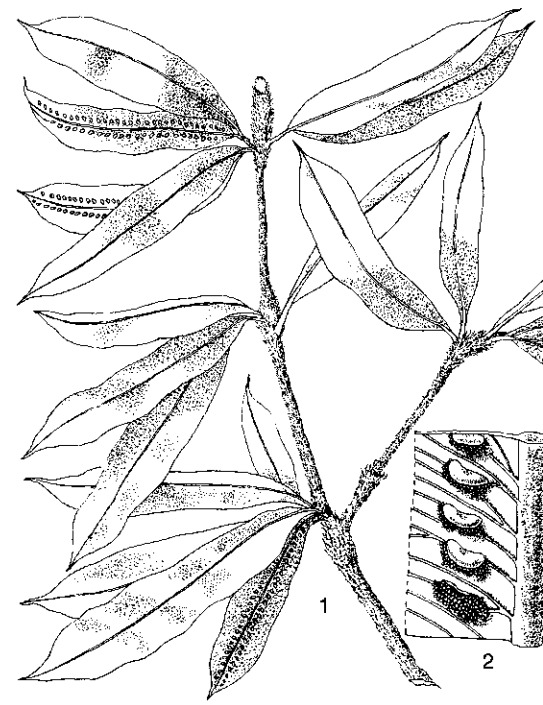
Vernacular names Indonesia: paku areuy (Sundanese), paku korani (Manado), paku sake (Batak). Malaysia: tiaò ch'uèh (Chinese). Philippines: kaliskis ahas, lunas (Tagalog). Thailand: nakkharat (northern, peninsular), phaya ngu (north-eastern), nakho (Malay, peninsular).

Origin and geographic distribution *O. neriiformis* is widespread in the Asian and Pacific Old World tropics and occurs from northern India and south-western China, throughout South-East Asia to Samoa in the Pacific.

Uses In the Philippines a decoction of the petiole of *O. neriiformis* is considered an efficacious medicine for alleviating difficult menstruation. A decoction of the rhizome is believed to counteract poisonous snake bites.

Properties Several compounds have been isolated from *O. neriiformis*: filicene ($C_{30}H_{50}$), n-octacosanol lignocerate, the 4-desmethyl sterols campestersol, stigmasterol, β-sitosterol and a trace of cholesterol, the 4a-methyl sterols cycloeucalenol, citrostadienol and traces of 24-methylen lophenol, the dimethyl sterols cycloartenol and 24-methylene cycloartenol, the triterpene alcohol nerifoliol, neriifoloxide, a triterpene epoxide ($C_{30}H_{50}O$) and the triterpene 29-ethoxyhopane ($C_{32}H_{56}O$). Histochemical tests in the Philippines showed abundant amygdalin and saponin in rhizomes and pinnae, and formic and tartaric acid in aerial stems. The related species *O. wallichii* (Hook.) C. Presl (occurring from northern India and southern China to Thailand, northern Vietnam and Taiwan) contains the triterpenoids hop-17(21)-ene and neohop-13(18)-ene, which greatly inhibit Epstein-Barr virus activation induced by the tumour promoter 12-O-tetradecanoylphorbol-13-acetate (TPA). Hop-17(21)-ene and neohop-13(18)-ene exhibit remarkable anti-tumour promoting effects against mouse skin tumour promotion in an in-vivo 2-stage carcinogenesis test using 7,12-dimethylbenz[a]anthracene as an initiator and TPA as a promoter.

Description A terrestrial thicket-forming fern, up to 2 m tall, with a branching shrublike habit, easily mistaken for a flowering plant, sometimes climbing-epiphytic. Rhizome stiff, erect or suberect, up to 10 mm in diameter, acting as an aerial stem, densely covered with scales; scales appressed, imbricating, the peltate basal part 1–1.5 mm wide, dark brown to black, narrowed abruptly into the up to 3.5 mm long apical part which is ciliate when young; aerial stem branched, straight, 1–1.5(–2) m tall, with few or no rhizophores, the leaves close together in pseudowhorls of 4–14, the whorls separated by 2–10 cm long internodes. Leaves simple, clustered, more or less coriaceous, on 2–5 mm long phyllopodia borne on all sides of the aerial stem; petiole 0.5–10 mm long, scaly; lamina oblanceolate, up to 40 cm × 3.5(–7.5) cm but often narrower, base attenuate, margins entire, apex caudate-acuminate, midrib scaly when young, glabrous or pilose; veins close together, simple or once forked, straight, at a broad angle to the midrib. Sori in one irregular row on each side of the midrib, usually 0–3 mm from the midrib; indusium reniform, up to 2 mm wide. Spores monolete, ellipsoid to spheroid, with irregularly toothed wings.



Oleandra neriiformis Cavanilles – 1, habit of a branch; 2, part of leaf showing veins and sori.

Growth and development The gametophyte of *O. neriiformis* is cordate, often hairy, sometimes bearing short-stalked antheridia. When terrestrial the sporophyte has a shrublike habit with erect growth, when growing as an hemi-epiphyte it is straggling.

Other botanical information The taxonomy of the genus *Oleandra* Cavanilles is confused and various authors have stressed the need for a worldwide revision. For a long time about 40 species were known, but the descriptions were based on too few collections. Tryon revised the

genus for the American tropics and reduced the number of species to 4. For Africa he estimated the presence of 5 species and for the Asiatic and Pacific tropics 6 species. Formerly ill-defined species became synonyms of *O. neriiformis* and, in addition to the ones mentioned above, the following names are also considered synonymous: *O. angusta* Copel., *O. archbaldii* Copel., *O. bantamense* (Blume) Kunze, *O. ciliata* Kuhn, *O. cuspidata* Baker, *O. herrei* Copel., *O. hirtella* Kunze, *O. maquilingensis* Copel., *O. mollis* C. Presl, *O. nitida* (Copel.) Copel., and many more are mentioned in the literature. Although *O. neriiformis* is the most abundant and most widespread species of the genus, it does not occur in Australia (records refer to *O. musifolia* (Blume) Kunze), Africa or South America (records are due to misapplications of the name). *O. neriiformis* is a very variable species (hence the many names) but overall distinctive characteristics are the similar fertile and sterile leaves and the sori closer to the midrib than to the margin. A distinctive characteristic of the family *Oleandraceae* is the articulate petiole (often on a phyllopodium, an outgrowth of the stem) in simple leaved species or articulate pinnae in pinnate ones.

Ecology *O. neriiformis* is found from sea-level up to 2200 m altitude but mostly above 1000 m, Usually it forms straggling shrubs to thickets in mountain forest. Sometimes it is found between other epiphytes high in the crowns of mossy trees, occasionally on trunks of palms that retain their leaf bases, but also on rocks or lava.

Propagation and planting *O. neriiformis* is hardly cultivated. Though it is easily propagated by spores, propagation by rhizome cuttings is easier and faster. Rhizome fragments can be grown in pots with sandy loam and a thin layer of humus, but they can also be attached to a tree trunk (e.g. of a tree fern).Young plants grown from spores can be transplanted to pots, logs or tree fern trunks.

Husbandry Plants of *O. neriiformis* should be watered every day without getting the soil too wet. Chemical fertilizer can be given once a month, while direct sunlight may damage young plants.

Harvesting About 2 years after sowing from spores, the rhizomes of *O. neriiformis* are big enough to be collected for medicinal use. When it is propagated by rhizome cuttings, the harvest will be earlier. After collecting, the rhizomes are cleaned of roots and dust, cut into small pieces, dried and stored until needed. Petioles can be collected any time when needed.

Genetic resources and breeding Germplasm collections or breeding programmes are not known to exist for *O. neriiformis*. Given its great variability, germplasm collection is recommended in order to avoid genetic erosion.

Prospects The medicinal properties of *O. neriiformis* seem interesting because of the available bio-active constituents. Further research may reveal new applications and commercial possibilities. Investigation of the ornamental possibilities of this unique shrubby fern is recommended.

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J.J. Afriastini

Onychium siliculosum (Desv.) C. Chr.

Index filic.: 468 (1906).
PTERIDACEAE
$2n = 58$

Synonyms *Pteris siliculosa* Desv. (1811), *Onychium auratum* Kaulf. (1824), *O. tenue* Christ (1901).

Vernacular names Philippines: pakong-anuang, dila-dila, buhok-virgin (Tagalog). Laos: ko kout pha.

Origin and geographic distribution *O. siliculosum* is distributed from India, the Himalayas, Burma (Myanmar), Thailand, Indo-China to south-western China (Yunan), Taiwan, the Philippines, Java and New Guinea to Polynesia.

Uses In the Philippines, juice from the crushed leaves of *O. siliculosum* is said to be a good preventive for baldness. A decoction of the leaves is used as a remedy for dysentery in the Philippines although from other areas it has been recorded as having laxative properties. *O. siliculosum* is also used as an ornamental.

Production and international trade There is no international trade or commercial cultivation of *O. siliculosum*. It is collected from the wild for home use only.

Properties *O. siliculosum* contains onitin, a phenolic illidoid sesquiterpene, and a farinaceous exudate from stalked glands occurs prominently on the undersurface of the leaves.

Description A terrestrial fern, up to about 1 m tall. Rhizome short, ascending or creeping, densely covered with scales; scales linear, subulate, 5–7 mm long, thin but firm, entire, concolorous brown, spreading. Leaves 3–4-pinnate at the base, dimorphous; petiole stout, 10–46 cm long, stramineous to pale brown, glabrous but scaly at base; sterile lamina oblong-ovate to lanceolate deltoid, up to 48 cm × 7–20 cm, round at base, acuminate at apex, herbaceous, glabrous on both sides but with stalked glands at underside, green to yellow-green; rachis glabrous, adaxially sulcate; pinnae gradually reducing in size, the basal ones oblong-subdeltoid, up to 8 cm × 20 cm, petiolate, caudately acuminate at apex; pinnules and secondary pinnules distinctly petiolate; ultimate segments spatulate, oblique, sometimes slightly falcate, 5–10 mm × 1–2.5 mm, the base cuneate, margins with a few narrow, acute, entire lobes, acute at apex; fertile lamina with the segments pod-like and larger, 5–25 mm × 1–2.5 mm, the terminal ones longer making the pinnae caudate. Sori covering the abaxial side, completely protected by reflexed marginal flaps, densely coated with golden-yellow wax. Spores tetrahedral-globose, 30 µm × 35 µm, with a prominent equatorial flange and coarse adjacent ridges.

Onychium siliculosum (Desv.) C. Chr. – 1, habit; 2, rhizome scale; 3, sterile pinnule; 4, fertile pinnule.

Growth and development The gametophyte of *O. siliculosum* is initially spatulate with a lateral meristem, later developing lobes with additional meristems. Old gametophytes are asymmetrically cordate or irregularly lobed with archegonia and antheridia variously distributed.

Other botanical information *Onychium* Kaulf. is currently classified in the subfamily *Taeniti-doideae* of the *Pteridaceae* and comprises about 8 species distributed in the Old World tropics. In taxonomic literature it has variously been classified, e.g. in *Parkeriaceae* and *Polypodiaceae*. *O. japonicum* (Thunb.) Kunze, occurring from the Philippines and Java north to Korea at much higher altitudes than *O. siliculosum*, does not have yellow wax on the fertile segments and has brown sori; it also has a shorter petiole, more clustered leaves, longer ultimate pinnules and marginal attachment of the indusia. It has antimicrobial activity. A putative carcinogen, ptaquiloside,

was detected in an unidentified *Onychium* species.

Ecology *O. siliculosum* is found on exposed steep sites, such as fairly dry banks of new roads in open locations, around 600 m altitude near the equator but at 800–1000 m further north.

Propagation and planting Propagation of *O. siliculosum* is by spores.

Genetic resources and breeding No germplasm collections or breeding programmes for *O. siliculosum* are known to exist. It is widely distributed and does not seem to be in danger of genetic erosion but germplasm collection is recommended.

Prospects Little is known about the possibly bioactive constituents of *O. siliculosum* and further research is needed to evaluate its potential.

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Dedy Darnaedi & Titien Ngatinem Praptosuwiryo

Ophioglossum pendulum L.

Sp. pl. ed. 2: 1518 (1763).

OPHIOGLOSSACEAE

n = 120–660 ($2n$ = unknown; *Ophioglossum*: x = 30, level of ploidy is unknown)

Synonyms *Ophioderma pendula* (L.) Presl (1845), *Ophioglossum moultonii* Copel. (1912), *O. falcatum* Fowler (1940).

Vernacular names Adder's-tongue fern, hanging adder's-tongue fern, ribbon fern (En). Indonesia: simbar gadang (Javanese), kumpai lubang (Sundanese), daun rambut (Malay, Moluccas); Thailand: teen mue nok khao.

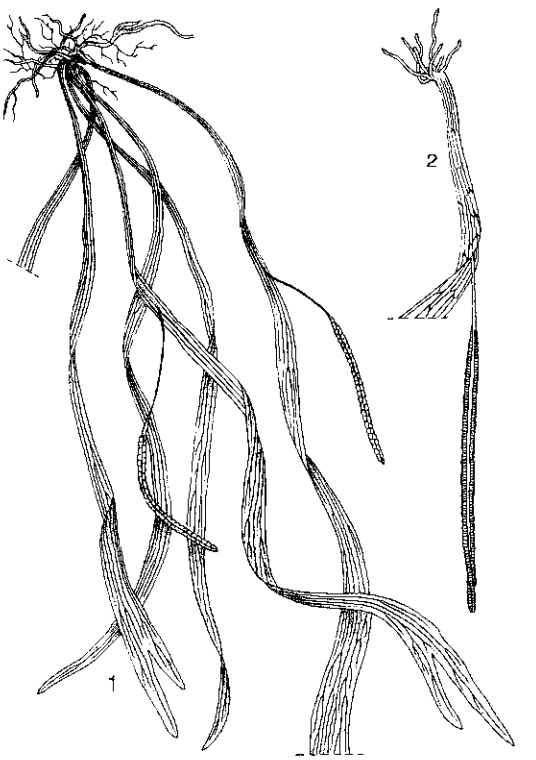
Origin and geographic distribution *O. pendulum* is widespread in the Old World tropics, from Madagascar and the Seychelles eastwards throughout tropical Asia, including South-East Asia, tropical Australia to Polynesia and Hawaii. It is quite rare in the Philippines. It has become naturalized in Florida (United States).

Uses Young leaves of *O. pendulum* are eaten as a vegetable. In the Moluccas (Indonesia), leaves shredded and mixed with coconut oil are used as an ointment to treat hair. In Mindanao (the Philippines) an infusion of the leaves is used as a cough remedy and the spores are administered to newborn babies to rid them of meconium. *O. pendulum* is also grown as an ornamental.

Production and international trade *O. pendulum* is collected from the wild. No international trade exists and it is not in commercial cultivation.

Properties The ribbon-like, fleshy leaves of *O. pendulum* are tough and stringy when broken and they taste sweet.

Description An epiphytic fern with ribbon-like, pendulous leaves and the sporangia in a stalked, spike-like sporophyte. Rhizome small, 1–3 cm long, creeping, fleshy, without scales, bearing



Ophioglossum pendulum L. – 1, habit; 2, venation and spike.

many fleshy roots and a few leaves. Leaves 1–6 clustered, pendulous, linear, often one or more times furcate, 0.3–1.5(–4) m × 1–7(–9) cm, base narrowed gradually to a fleshy terete petiole of indefinite length, margin entire and slightly bent backwards, apex obtuse, limp, fleshy or coriaceous; veins forming a series of long narrow areoles, formed by slender oblique cross-veins connecting a series of more or less straight longitudinal veins, the longitudinal veins near the middle of the leaf blade thicker than those near the margin, no midrib beyond the attachment of the spike. Strobilus spike-like on a stalk 0.5–10 cm long, attached near the base of the leaf blade, cylindrical, 2–45 cm × 5 mm, simple, bearing two rows of sporangia which are almost completely fused; sporangia opening by a transverse slit, releasing numerous creamy white spores. Spores globose, trilete, about 50 µm in diameter, finely irregularly rugose.

Growth and development The tuberous non-green prothalli of *O. pendulum* are subterranean saprophytes and dependent on a mycorrhizal fungus. The apices are white, the lower parts greyish, yellowish, or brownish. The prothalli are long-lived perennials of indeterminate growth and each may give rise to one or several sporophytes. The completion of the life cycle may take several years. Experiments with the related fern genus *Botrychium* Sw. suggest that the gametophytes can develop a sporophyte when grown in an axenic (sterile) culture-medium with additional sugar.

Other botanical information The *Ophioglossaceae* is the most isolated family of the ferns and some authors consider it more closely related to a lineage of progymnosperms or cycadophytes than to typical modern ferns. Evidence from fossils to back up speculations, however, is lacking. The sporophore is unique and not found in other fern families. *O. pendulum* belongs to subgenus *Ophioderma* (Blume) Clausen of the genus *Ophioglossum* L. which is considered by some to be a separate genus, differing from *Ophioglossum* by the stalk of the spike clearly adnate to the leaf, no clear separation between stalk of spike and spike and a fertile spike apex. If *Ophioderma* is considered a separate genus the correct name for the species is *Ophioderma pendula* (L.) Presl. *O. pendulum* is a rather variable species, and based on differences in leaf form and habit (e.g. leaves more falcate, pendulous or not, venation visible or not, dwarf habit), several forms, varieties or species have been distinguished. However, because many intermediates exist these distinctions are without practical value and fall within the wide variability, not deserving separate naming.

Ecology *O. pendulum* is a pendulous epiphyte on palms (particularly oil palm and sago palm because of the long persisting leaf bases), tree ferns and trees, sometimes indirectly by growing among the roots, leaves and humic nests of other epiphytic ferns such as *Asplenium nidus* L. or *Platycerium coronarium* (Koenig) Desv., sometimes on rocks, in the lowlands and hills. When they grow abundantly they may eventually deplete water and nutrients from the nest to such an extent that the hosting fern dies. Old nests of dying or dead *Platycerium coronarium* with vigorous bunches of *O. pendulum* used to be quite common in Malesia. *O. pendulum* normally grows in the shade under humid conditions. Plants from exposed sites have narrower and more branched leaves whereas plants from higher altitudes have broader and shorter leaves than those from the lowland.

Propagation and planting *O. pendulum* can be propagated by spores and by rhizome parts. Plants collected from the wild may be grown as epiphytes on palm trunks or in hanging pots and baskets. *O. pendulum* can be raised in pots like orchids or on dead or living tree trunks, on a soil medium of fern roots, sphagnum moss or coconut fibres. Although partial shading is generally required, the plants must be kept warm and damp at all times.

Diseases and pests Natural stands of *O. pendulum* do not show signs of any serious disease or pest. However, bacteria may cause leaf deformations and rotting, and insects may cause some damage as well.

Harvesting *O. pendulum* plants grown from spores can be harvested when 2–3 years old. When grown from plantlets taken from the wild, harvesting of leaves may start 6 months after planting.

Genetic resources and breeding *O. pendulum* is quite common and widespread and seems not to be liable to genetic erosion. Intraspecific genetic diversity within the *Ophioglossaceae* has proven to be remarkably low, probably due to self-fertilization of the subterraneous gametophytes. Germplasm collections or breeding programmes are not known to exist.

Prospects Since *O. pendulum* can easily be grown on oil-palm trunks there is a potential to increase the production of young leaves as a vegetable. The combined cultivation of *O. pendulum* and oil palm in existing plantations improves the productivity of the land and increases product diversity. Therefore, the development of plants pro-

ducing numerous young leaves of a high nutritional value should be taken into consideration.

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H.C. Ong & Norma O. Aguilar

Ophioglossum reticulatum L.

Sp. pl.: 1063 (1753).

OPHIOGLOSSACEAE

n = 120, 240, 360, 480, 510, 630 + 10 fragments, 720; the latter counts, corresponding with chromosome numbers of 1260–1440 in the sporophyte, are the highest found in any living organism; various cytotypes have been found coexisting in a single population

Synonyms *Ophioglossum petiolatum* Hooker (1823), *O. moluccanum* Schltdl. (1825), *O. pedunculosum* sensu auct. plur., non Desv.

Vernacular names Adder's-tongue fern (En). Indonesia: jukut siraru (Sundanese), daun saleh (Moluccas), jumu tufa (Ternate). Philippines: ground-adder's tongue fern.

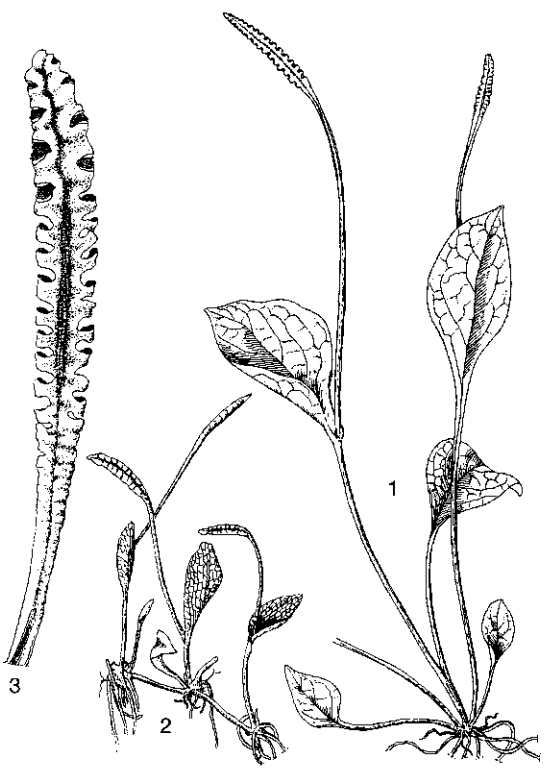
Origin and geographic distribution *O. reticulatum* is distributed pantropically, both in the tropics and subtropics, including South-East Asia.

Uses In Indonesia, *O. reticulatum* is an appreciated vegetable, collected sedulously wherever it is common. It is eaten fresh as salad, or cooked, alone or mixed with other vegetables. The leaves should be cooked gently, otherwise they turn completely into slime. In South Africa (Natal) and India the leaves are used as a substitute for spinach. In the Philippines, it is used as a herbal medicine which is anti-inflammatory and anti-swelling. Leaves boiled in oil are a remedy for wounds.

Production and international trade *O. reticulatum* is collected from the wild and traded only locally; statistics are not available.

Properties Young leaves of *O. reticulatum* taste sweet. The presence of alkaloids, arbutin, amygdalin, saponin, formic acid and oxalic acid in most plant parts has been shown through histochemical tests in the Philippines.

Description A small, terrestrial, erect, herbaceous fern with a single spike and few entire leaves. Rhizome subterranean, short cylindrical to



Ophioglossum reticulatum L. – 1, habit; 2, plants connected by stolons; 3, spike.

subglobose, 10–22 mm × 2 mm, sometimes stoloniferous, resulting in the formation of colonies, carnose, glabrous, bearing rather thick roots and 1–2(–8) leaves. Leaves entire with a long-petiolate spike; petiole terete, (0–)2–16 cm long, green; sterile lamina very variable, ovate to lanceolate, reniform, deltoid or orbicular, rarely obovate or trullate, (0.8–)1–8(–10.5) cm × 0.5–5 cm, base attenuate to cordate, margin entire, apex acuminate to obtuse, green, carnose, thin or coriaceous when dry; venation obscure to conspicuously reticulate, lax with few free-ending veinlets to rather dense and with many free veinlets without or with a few areolulae. Strobilus spike-like on a 1–20 cm long stalk which arises from lamina base, (1–)5–6(–8) cm long, sterile apex 0.5–1.5 mm long; sporangia 20–45 pairs in two rows, connate and sunken into the tissue, yellow-green, opening by a transverse slit. Spores trilete, subglobose, surface finely reticulate but seemingly smooth, blackish.

Growth and development The tuberous, fleshy, non-green prothalli of *O. reticulatum* grow buried in the soil and depend on a mycorrhizal fungus. The apices are whitish, the lower parts greyish, yellowish, or brownish. The prothalli are long-lived perennials of indeterminate growth and each may give rise to one or several sporophytes. The completion of the life cycle may take 1–20 years (the fastest gametophyte maturation recorded for *Ophioglossum* sp. in culture is 8 months). Gametophytes can develop a sporophyte when grown in an sterile culture medium with nutrients including ammonia and supplements of sugar. The antheridia and archegonia occur together in various stages of development, arising from cells on the surface, but at maturity they are largely sunken in it. The sporophytes have fleshy rhizomes and roots which can penetrate deep into the soil. In a dry season, aboveground parts may die; growth is resumed at the beginning of the rainy season.

Other botanical information The *Ophioglossaceae* is the most isolated family of the ferns and some authors consider it more closely related to a lineage of progymnosperms or cycadophytes than to typical modern ferns. Evidence from fossils to back up speculations, however, is lacking. The sporophore is unique and not found in other fern families. Within the genus *Ophioglossum* L., *O. reticulatum* belongs to subgenus *Ophioglossum*, with 4 closely related species in South-East Asia; they are all terrestrial, there is a good demarcation between petiole and lamina, the stalk of the spike is not or only at the base adnate to the lamina and the spike has a sterile apex. The other members of subg. *Ophioglossum* are: *O. costatum* R. Br. (Old World tropics), *O. gramineum* Willd. (pantropical) and *O. nudicaule* L.f. (pantropical). The differences with *O. reticulatum* are small and concern mainly the size and form of the rhizome and the leaf blade. *O. reticulatum* is spread pantropically and is very variable. Mainly based on leaf characteristics, it has been subdivided into species, subspecies, varieties and formas, causing confusion in the literature on its identity. The presence of many intermediates makes those subdivisions rather useless and it seems better to accept one widespread polymorphic species.

O. petiolatum Hooker from South America, treated as a synonym here, is often considered as a different species. It is not sure whether what has been identified as *O. petiolatum* in Asia is identical to the original *O. petiolatum* and thus it is uncertain if it is identical to *O. reticulatum*.

In addition to *O. pedunculosum*, also *O. pedunculatum* has been used as a synonym. This is based on a type-error by Poiret (1816) and persistently copied since. Poiret wrote *O. pedunculatum* instead of *O. pedunculosum* and many authors have confused both names with *O. reticulatum*.

The closely related northern temperate *O. vulgatum* L. has been widely used for various medicinal purposes. In traditional European medicine, an ointment made from the leaves was used as a general treatment for wounds. The juice was a constituent of eyewashes. In Belgium *O. vulgatum* was applied to snake bites. In Chinese medicine *O. vulgatum* is turned into general tonics and reported to be emetic, antiscrofulous, and useful for dropsy, vomiting and hiccough; fresh leaves are used as a poultice for ulcers.

Ecology *O. reticulatum* can be found in humid, mostly shaded but also sunny sites, from sea-level up to 2200 m altitude. It often grows in a colony above the ground surface and on bare soil that is not easily water permeable because of a rocky base, a termite nest, or on a well-trodden place (for example along paths, roads and houses). Its presence may indicate poor soil. Sometimes it grows in humid grassland vegetation. The plant is usually only visible in the rainy season. In agriculture it can become a harmless weed.

Propagation and planting *O. reticulatum* can be propagated by spores or rhizome cuttings. Because of its stoloniferous habit it can develop rather extensive colonies. Commercial cultivation is not practised, but for its medicinal properties it is often grown in pots. When grown from spores,

1–2-year-old plants can be harvested for their leaves; when grown from plants collected from the wild, harvesting may start after about 6 months.

Genetic resources and breeding *O. reticulatum* is widespread and there seems to be no danger of extinction. The conservation status of its various cytotypes and varieties, however, is largely unknown. Collection of germplasm is recommended to safe the wide variability. Neither germplasm collections, nor breeding programmes are known to exist.

Prospects Because *O. reticulatum* has nutritional, medicinal and ornamental value, it seems worthwhile investigating further its properties and possibilities for cultivation and breeding.

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V.B. Amoroso & H.C. Ong

Pityrogramma calomelanos (L.) Link

Handbuch 3: 20 (1833).

PTERIDACEAE

$2n = 232$ (tetraploid)

Synonyms *Acrostichum calomelanos* L. (1753), *Pellaea calomelanos* (L.) Link (1841).

Vernacular names Silver fern, silverback fern (En). Indonesia: pakis perak (Javanese), paku perak (Sundanese), pakis wulung (Sumatra). Malaysia: paku hijau (Malay), fen yèh ch'uèh (Chinese). Philippines: pakong-gubat (Tagalog), elecho de plata (Tagalog), pakong-kalabao (Tagalog). Thailand: chon nok khao (Yala), chon rung (Pattani), foen ngoen (Bangkok). Vietnam: cho chanh.

Origin and geographic distribution *P. calomelanos* originates from tropical and subtropical America but has spread throughout the tropics, including South-East Asia. It has been cultivated for a long time and its current, almost pantropical distribution may have been induced by deliberate introductions. Its spread throughout the Old World tropics went by roads and plantations. If its current distribution is not due to man directly, then at least *P. calomelanos* takes advantage of the many open habitats created by human activities.

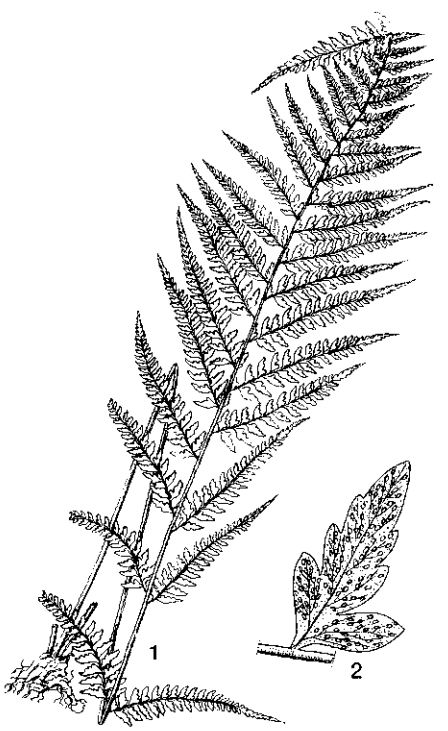
Uses In the Philippines, a decoction of the leaves of *P. calomelanos*, with the roots of *Cynodon dactylon* (L.) Pers. and styles of *Zea mays* L., is considered an effective remedy for kidney trouble. A decoction of the roots of *P. calomelanos* is drunk to treat dysentery. To cure malaria, the leaves are pounded and rubbed on the back and placed under a sleeping mat. *P. calomelanos* is also used medicinally by Chinese Malaysians and is often cultivated as an ornamental in gardens and greenhouses.

Production and international trade Although *P. calomelanos* is a plant cultivated worldwide no statistics on production or trade are available.

Properties *P. calomelanos* produces a conspicuous white waxy resinous substance on the lower leaf surface, as do a number of other species in the *Pteridaceae*. The major components of this wax are flavonoids (chalcones, dihydrochalcones, flavanones, dihydroflavonols, flavones, flavonols), some of them with a complex substitution pattern, including esters, C-methyl derivatives and biflavonoids. Diterpenoids and triterpenoids are also present sometimes. The wax of *P. calomelanos* contains complex flavonoids such as calomelanol A (8-[3-(4-methoxyphenylpropionyl)]-5,7-dihydroxydihydroneoflavone), calomelanol B (8-[3-(4-hydroxyphenylpropionyl)]-5,7-dihydroxydihydroneoflavone), calomelanol C (8-(3-phenylpropionyl)-5,7,4'-trihydroxydihydroneoflavone), 8-(3-phenylpropionyl)-5,7-dihydroxyneoflavanone, 8-(2-carboxy-1-phenylethyl)-5,7-dihydroxyflavone δ-lactone

and seven others called calomelanol D–J. The wax also contains a cytotoxic component (2'6'-dihydroxy-4'4-dimethoxy dihydrochalcone). In tests on mice injected with Ehrlich ascites cells, the life span was increased by 52% and 57% when a liposome preparation of the chalcone was administered at 5 mg/kg and 25 mg/kg, respectively. The leaves of *P. calomelanos* contain the sesquiterpenes pterosin Z and calomelanolactone. In the Philippines, histochemical tests on *P. calomelanos* revealed the presence of alkaloids, amygdalin, saponin, oxalic acid, arbutin, tannin, formic acid and tartaric acid.

Description A terrestrial, closely tufted, rhizomatous fern up to about 1 m tall. Rhizome short, ascending to erect, covered with scales; scales lanceolate, 4–5 mm long, dark golden brown, thin, entire, the apex filamentous. Leaves 2–4-pinnate; petiole 10–50 cm long, lustrous dark purple, with a few scales near the base, glabrous upwards, covered with white waxy powder when young; lamina lanceolate to oblong-deltate, 20–95 cm × 10–30 cm, the apex acuminate, herbaceous to coriaceous, light green and glabrous above, underside with a white (more rarely pale yellow or pink) waxy covering exuded by glandular hairs; rachis grooved on upper surface; pinnae linear-subtriangular, up to 13 cm × 1–4 cm, gradually smaller upwards, or longer near the middle, the lower ones petiolate, cuneate-truncate at base, the apex acuminate, the costa grooved, grooves decurrent to those on the rachis; pinnules oblong-lanceolate, up to 2.2 cm × 0.5 cm, cuneate at base, acute to acuminate at apex, lobed or pinnatisect in larger ones; lobes oblanceolate to spatulate, acute and dentate at apical portion; veins free, pinnate in larger ones, to several times forked, obscure. Sori along veins throughout the lower surface and often concealing it, exindusiate. Spores subtriangular, prominently ridged, 39–54 µm.



Pityrogramma calomelanos (L.) Link – 1, habit; 2, pinnule.

Other botanical information *Pityrogramma* Link comprises about 16–20 species, with most species in tropical America. *Pityrogramma* is now usually classified in *Pteridaceae*, but in the literature it can also be found under *Adiantaceae*, *Gymnogrammaceae*, *Parkeriaceae* and *Sinopteridaceae*. *P. calomelanos* is very variable and, based on the type and colour of the indumentum, 3 major varieties have been distinguished but much confusion exists:

- var. *austroamericana* (Domin) Farwell. Characterized by a cover of glandular hairs exuding a yellow farinose wax at underside of leaves. Mainly occurring from Costa Rica to Brazil, but occasionally also in tropical Asia. Contrary to var. *calomelanos*, this variety is more widely distributed in the subtropics and warm-temperate regions than in the humid tropics. Some authors consider this taxon as a separate species: *P. austroamericana* Domin (synonyms: *P. calomelanos* var. *austroamericana* (Domin) Farwell, *P. calomelanos* var. *aureo-flava* auct. non (Hook.) Weatherby ex Bailey, *P. chrysophylla* auct. non (Sw.) Link). It is a popular ornamental, known as golden fern or gold-dust fern, with bright yellow to orange powder on the leaf underside.
- var. *calomelanos*. Characterized by a cover of glandular hairs exuding a white farinose wax on underside of leaves. Occurring naturally in tropical America. Elsewhere often cultivated in greenhouses and gardens and often escaped and naturalized, for example in Africa and tropical Asia. In tropical South-East Asia, var. *calomelanos* is the most common form and this paper mainly refers to this variety.
- var. *ochracea* (C. Presl) R.M. Tryon. Characterized by scattered trichomes instead of glandular hairs at underside of leaves. Occurring from Honduras to Bolivia, and not in South-East

Asia. Some authors consider this taxon as a separate species: *P. ochracea* (C. Presl) Domin.

The subdivision of *P. calomelanos* into varieties is difficult because the characteristics are not constant and escapes from cultivation and possibly hybridization occur.

P. chrysophylla (Sw.) Link (synonym: *P. calomelanos* var. *aureo-flava* (Hook.) Weatherby ex Bailey), originating from the West Indies, is another popular ornamental pot plant in South-East Asia with a golden powdery covering on the underside of the leaves and is also named golden fern.

Ecology *P. calomelanos* occurs on open mountain slopes in recently felled areas or along new roads at low or medium altitudes, in open forest, savanna woodland and rainforest margins. It is distinctly tropical, apparently preferring non-calcareous fine sands. After volcanic eruptions it may be one of the first or even the most important species recolonizing the area, both from spores and from remaining rhizomes.

Propagation and planting *P. calomelanos* can be propagated by spores and by rhizome cuttings.

Husbandry *P. calomelanos* prefers slightly drier conditions than most ferns and the plants are easy to grow. It requires a well-drained potting mix and should be exposed to moderate sunshine.

Genetic resources and breeding *P. calomelanos* is widespread and common, and not in danger of genetic erosion. Germplasm collections or breeding programmes are not known to exist.

Prospects *P. calomelanos* contains many specific chemical constituents, especially in the waxy exudates. Little is known about the medicinal and other properties of these substances and research is recommended. Similar to *Pteris vittata* L. (see the treatment on *Pteris* L.) it is tolerant of high concentrations of heavy metals and it hyperaccumulates arsenic. However, phytoremediation of arsenic contaminated soils with the aid of ferns is a very recent development in which *Pityrogramma* has so far received much less attention than *Pteris*, although it is called equally promising. Its ornamental value will remain important and further research is needed into the possibilities for commercial production in South-East Asia.

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Dedy Darnaedi & Titien Ngatinem Praptosuwiryo

Platycerium bifurcatum (Cav.) C. Chr.

Index filic.: 496 (1906).

POLYPODIACEAE

$2n = 74$ (subsp. *bifurcatum*)

Synonyms *Platycerium willinckii* T. Moore (1875), *P. hillii* T. Moore (1878), *Alcicornium veitchii* Underw. (1905).

Vernacular names Staghorn fern, elkhorn fern (En). Indonesia: paku uncal (Sundanese), simbar agung (West Kalimantan), simbar menjangan (Javanese, Balinese). Philippines: dapong repolyo (Tagalog).

Origin and geographic distribution *P. bifurcatum*, in the wide sense used here, is found from Java, through the Lesser Sunda Islands and New Guinea to eastern Australia. As an ornamental it is cultivated all over the world.

Uses *P. bifurcatum* is a valuable ornamental. The leaves were used as poultice to treat fevers in the belly. In Java, the leaves were ground with *Foeniculum vulgare* Miller (fennel, 'adas'), *Alyxia reinwardtii* Blume ('pulasari') and red onion and applied to swellings.

Production and international trade There is high demand for *P. bifurcatum* as an ornamental species in Europe, Australia and the United

States, and as a result there is large scale production of the plant in these areas.

Description Epiphytic fern with fleshy, repeatedly forked foliage leaves and round base leaves, appressed to the substratum. Rhizome short, hidden, with basally attached or peltate scales; scales 1.5–11 mm × 0.3–1.3 mm. Leaves dimorphic, closely clustered; sterile base leaves sessile, not articulated to the rhizome, withering soon but long persistent, erect or appressed, 18–60 cm × 8–45 cm, the apical margin entire to lobed, greyish-green but soon turning brown; fertile and sterile foliage leaves ascending to pendulous, articulated to the rhizome, 0.25–1 m long, the base narrowly wedge-shaped, margins entire, apex 2–5 times bifurcate, the first fork usually occurring at or below the middle of the leaf, one division often remaining undivided following the forking of the leaf, the latter thus appearing to divide in three, the upper surface green, sparsely to densely covered with stellate hairs, the lower surface greyish-green, densely covered with stellate hairs; ultimate divisions elongate, commonly 0.5–2.5 cm broad, sometimes wider. Sporangia in 1–10 soral patches, borne over the greater part of the lower surface of the ultimate segments of the fertile leaves, sometimes reaching around the sinus of the first fork, sometimes not reaching the apex, with shortly stalked paraphyses.

Platycerium bifurcatum (Cav.) C. Chr. - habit.

Other botanical information *Platycerium* Desv. comprises about 15 species, 6 in Africa, 8 in Asia, 1 in South America. In Malesia 6 species are found. *Platycerium* is closely related to *Pyrrosia* Mirbel with which it forms a monophyletic group.

In *P. bifurcatum* 3 subspecies are distinguished:

- subsp. *bifurcatum*: rhizome scales up to 11 mm long, base leaves up to 50 cm long, foliage leaves erect, spreading or pendulous. Within this subspecies, two varieties are distinguished:
  - var. *bifurcatum*: upper part of the base leaves more or less sinuate, foliage leaves mostly spreading, asymmetrical, densely hairy; occurring in eastern Australia;
  - var. *hillii* T. Moore: upper margin of the base leaves entire, foliage leaves erect, more or less symmetrical, sparsely hairy; occurring in New Guinea and eastern Australia.
- subsp. *veitchii* Underw.: occurring in eastern Australia.
- subsp. *willinckii* T. Moore: rhizome scales short, up to 5 mm long, base leaves up to 70 cm long with lobed upper margins, foliage leaves pendulous; occurring in Java and the lesser Sunda Islands.

All these infraspecific taxa have often been treated as different species, but in cultivation they easily hybridize, producing many different intermediate forms.

P. coronarium (König ex Müller) Desv. is a species with long, pendulous foliage leaves, reniform fertile lobes and base leaves with a deeply lobed upper part. It is found in Indo-China, Peninsular Malaysia, Sumatra, Java, Borneo and the Philippines and was used in Malaysia to enlarge the spleen by rubbing the ashes over the body. It is also commonly cultivated in gardens in South-East Asia.

Ecology *P. bifurcatum* grows as an epiphyte in various kinds of forest and open vegetation. Locally it can be the dominant epiphytic species. It is found from sea-level up to 2000 m altitude. It is well adapted to dry conditions. The base leaves of *Platycerium* form a receptacle for litter, which develops into a peat-like substance that is both moist and well drained. The host sometimes produces aerial roots in this substrate.

Propagation and planting *P. bifurcatum* can be easily grown from spores. Mature plants develop additional growth centres ('pups') which can be severed and planted apart. Mass propagation is done by tissue culture or gametophyte production

on agar. Optimal growth of gametophytes can be obtained on modified Miller medium supplemented with 4% sucrose, 0–0.6% agar and the pH adjusted to 5.5.

Husbandry *Platycerium* is very drought resistant and easily overwatered, which causes the roots to rot. The plants must be rooted in a well-aerated growing medium, or attached to a tree trunk or mounted on a piece of wood.

Genetic resources and breeding Germplasm collections of *P. bifurcatum* are not known to exist. Many breeding programmes for *P. bifurcatum* exist and numerous ornamental cultivars have been released.

Prospects *P. bifurcatum* is an important ornamental, suitable for a wide range of ecological conditions, including the artificially heated indoor environment. No decline of its popularity is foreseen at present. Other species of *Platycerium* gradually penetrating the market do not seem to be competitors yet. Little is known about the medicinal properties of *P. bifurcatum* and further research into this field should be encouraged.

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Dedy Darnaedi & Titien Ngatinem Praptosuwiryo

Pleocnemia irregularis (C. Presl) Holttum

Kew Bull. 29: 347 (1974).

DRYOPTERIDACEAE

$2n = 82$

Synonyms *Dictyopteris irregularis* (C. Presl) C. Presl (1836), *D. difformis* (Blume) T. Moore (1858), *Tectaria irregularis* (C. Presl) Copel. (1908), *Arcypteris irregularis* (C. Presl) Ching (1940).

Vernacular names Indonesia: paku andam (Malay), paku kapal, paku kebo (Sundanese). Malaysia: paku siar.

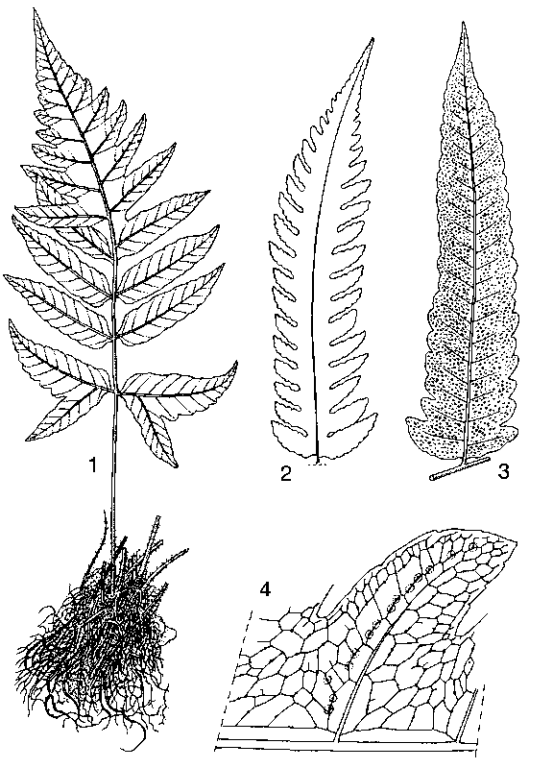
Origin and geographic distribution *P. irregularis* is distributed from southern Burma (Myanmar) throughout South-East Asia to the Caroline Islands, Solomon Islands and Fiji.

Uses In South-East Asia the succulent, young and still not unfolded leaves of *P. irregularis* are eaten raw as a salad or steamed as a vegetable. As a steamed vegetable, mixed with diverse pounded spices and grated coconut, is considered one of the most savoury Indian dishes. A poultice of crushed roots and rhizomes is applied to scabies-infected skin, while a poultice of pounded leaves and shoots for rubbing on the body against (malaria) fever. An infusion of the leaves in hot water is said to be effective against diarrhoea. The woolly scales may be used as a styptic instead of the hairs of *Cibotium barometz* (L.) J. Smith.

Production and international trade *P. irregularis* is not cultivated commercially and no international trade exists. Young leaves are collected from the wild and locally consumed as a vegetable, or offered for sale on local markets. Parts of the scaly rhizomes and petiole bases of *P. irregularis* are also offered for sale locally, e.g. in Indonesia as 'penawar jambe' for the woolly styptic scales.

Properties The uncooked leaves of *P. irregularis* are slightly astringent and somewhat musty. It tastes better when mixed with other salad material since it is rather sweet.

Description A large, terrestrial, bipinnatifid fern, up to 2.5 m tall, with remarkably large basal pinnules. Rhizome short, erect or suberect but not arborescent, its apex and the bases of the petioles densely covered with scales; scales thin, linear or lanceolate, 3–4 cm × 2 mm, margins crispate or irregularly dentate, apex long acuminate, dark brown. Leaves deeply bipinnatifid or pinnate towards base; petiole stout, 30–80 cm long, green when living and pale when dry, dark at the base, glabrescent except for the scales at the base; lamina lanceolate, 50–200 cm × 60–70 cm, firm, herbaceous, rather light green, drying brown-olivaceous, when young conspicuously pale, firmly herbaceous, glabrous; pinnae opposite, numerous, the basal pair the largest; basal pinnae asymmetrically subdeltoid with a basal basiscopic pinnule up to 12–20 cm × 6 cm, free, sessile, deeply lobed, usually much longer than the next ones; supra-



Pleocnemia irregularis (C. Presl) Holttum – 1, young leaf; 2, a middle pinna; 3, pinna with sori; 4, enlarged lobe to show venation and sori.

basal pinnae lanceolate-oblong, up to 40 cm × 12 cm, petiolate, on large leaves pinnate at the base with few pairs of sessile and usually more or less adnate pinnules, the distal part deeply lobed, apex acute to acuminate; lobes falcate, usually about 1 cm wide, the longest with crenate margins and acute apex, the shorter more distal lobes entire with blunt apex, proximal sinuses rounded at the base, distal sinuses narrowly angled with a broad tooth in the angle; distal pinnae gradually less deeply lobed, the uppermost grading into the petiolate, pinnatifid, deltoid apex of the lamina; rachis and base of costae adaxially with short hairs, costules, veins, distal part of the costae, and surface above glabrous, rachis and costae abaxially glabrescent or bearing rather stiff multicellular hairs up to 1 mm long, costules and veins usually hairless but with small round red glands similar to those in the sori. Veins forming a single narrow row of areoles along either side of costae and shorter areoles on either side of costules, the whole of the rest of the lamina filled with more or less elongated 4–6-sided areoles, sometimes with an included free veinlet. Sori round or often extending along the veins and sometimes confluent, small, close, usually scattered irregularly, exindusiate; sporangia often bearing round red glands either near annulus or on a hair attached to the stalk.

Other botanical information Within *Dryopteridaceae*, *Pleocnemia* C. Presl belongs to the tribe *Dryopteridoideae*. In the literature *Pleocnemia* has been variously classified in *Aspidiaceae*, *Athyriaceae*, *Polypodiaceae* and *Tectariaceae*. In Flora Malesiana *Pleocnemia* is classified into the so-called *Tectaria* group, without a further family classification. *Pleocnemia* comprises about 19 species, distributed in the Asian Old World tropics and subtropics. Species of *Pleocnemia* without indusia have also been placed in the genera *Dictyopteris* C. Presl and *Arcypteris* Underw.

In South-East Asia 2 species closely related to *P. irregularis* are similarly used as a vegetable:

- *P. macrodonta* (Fée) Holttum (synonyms *Tectaria cumingiana* (Hook.) C. Chr., *T. irregularis* auct.). Distributed in Sarawak, the Philippines, eastern New Guinea, Admirality Islands and New Britain. It differs from *P. irregularis* by scales up to 2 cm long and wider than 1 mm; pinnae conspicuously pinnate, pinnules sessile and mostly adnate, base unequally cuneate, margins lobed to or more than one third towards the midrib; sori in 2 close rows on either side of each costule, often somewhat confluent, with additional sori near the sinuses in the broader pinnules. In Thailand and Vietnam very large plants of *P. irregularis* occur which have more fully bipinnate leaves than those in Malesia; these plants have been erroneously identified as *P. macrodonta* but they are much less fully bipinnate and their sori are arranged differently.
- *P. brongniartii* (Bory) Holttum (synonym: *Dictyopteris pteroides* C. Presl). Distributed in New Guinea and the Philippines. It differs from *P. irregularis* by size and branching of the leaves, and the shape of the pinnules is similar to *P. macrodonta*; the sori, however, are all near the margins of the lobes of pinnules or of pinnae near the leaf apex.

Ecology *P. irregularis* is common in partial shade in lowland forest and on the edge of forested hills, especially on slopes. It is found in the inner corners of winding roads, around villages and in plantations. It grows on heavy clays, calcareous clays or stony humus-rich soils, from sea-level up to about 800 m altitude, sometimes in clusters. It tolerates drier conditions than many other terres-

trial forest ferns. In Thailand it is recorded on rather dry slopes in dense forest.

Propagation and planting *P. irregularis* is easily propagated by spores. Vegetative propagation is possible by rhizome parts.

Husbandry *P. irregularis* is not cultivated commercially. When planted, it needs light shade and it seems to be tolerant of regular pruning.

Harvesting Croziers and other young leaves of *P. irregularis* are collected from the wild for own consumption. When sold on the local market they are often bundled with a bamboo strip.

Genetic resources *P. irregularis* does not seem in danger of genetic erosion due to its wide distribution and common occurrence. Germplasm collections are not known to exist.

Breeding A natural hybrid of *P. irregularis* and an unknown, large bipinnate species (possibly *P. olivacea* (Copel.) Holttum from western Malesia) has been found in Sarawak and named *Pleocnemia ×intermedia* Holttum.

Prospects In South-East Asia *P. irregularis* will continue to be used as a vegetable and as a medicine. Further research on its chemical properties, followed by research toward possibilities for domestication and marketing are worth consideration.

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Dedy Darnaedi & Titien Ngatinem Praptosuwiryo

Pteridium aquilinum (L.) Kuhn

Cryptogamae vasculares. In: C.C. von der Decken, Reisen in Ost-Afrika 3(3): 11 (1879).

DENNSTAEDTIACEAE

$2n = 52$ (diploid), 104 (tetraploid, most common), 208 (octoploid)

Synonyms *Pteris aquilina* L. (1753), *Pteris esculenta* Forst. (1786), *Pteridium esculentum* (Forst.) Nakai (1825).

Vernacular names Bracken (fern), pasture brake, eagle fern (En). Fougère aigle (Fr). Indonesia: andam dangdeur, paku geulis (Sundanese), pakis gemblung (Javanese). Malaysia: pakis gila. Philippines: anamam (Tukukan, Bontoc), sigpang (southern). Thailand: kut kia, kut kin (northern), chon yai (peninsular). Vietnam: quy[ees]t.

Origin and geographic distribution The origin of *P. aquilinum* is thought to be in the tropics. Now it is found worldwide in all temperate and tropical regions and is one of the most widely distributed vascular plants. It is absent in hot or cold desert-like regions, but on farmed land in temperate regions (e.g. United Kingdom) it has become a troublesome weed.

Uses *P. aquilinum* is the fern with the most diverse uses, although its positive economic importance lies one or two centuries back (at least in Europe), now being (again in Europe, particularly in United Kingdom) an economic nuisance as a persistent weed in pastures. In South-East Asia it can be a weed in tea and other plantation crops. Due to this weed aspect, bracken is also one of the best investigated ferns of the world. Nevertheless, its various uses are worth mentioning, because in most parts of the world (including South-East Asia) it is not often a common troublesome weed. The young tender leaves and rhizomes are used as food and feed. The rhizomes were favoured by the New Zealand Maoris, who soaked and pounded them to obtain a starchy material, resembling that of arrowroot. In other countries, the raw or dried and ground rhizomes are eaten after roasting or baked into a poor-quality bread in times of food scarcity. The young, still curled leaves

('croziers' or 'fiddleheads') are eaten as a vegetable in many countries. They are regarded as a delicacy in Japan where canned croziers are sold ('warabi' or 'zenmai'). Leaves and rhizomes mixed with grass are eaten by livestock. Silage is also possible. However, cases of bracken fern poisoning of livestock and human stomach cancer make the food value of rhizomes and leaves questionable.

The ash, having a high potash content, was formerly used extensively in Europe for glass and soap production. Bracken ash was particularly useful for making clear colourless glass. For soap, the potash is combined with oils and fats. Wettened bracken ash was sold in balls to wash clothes and to bleach linen.

Leaves are used as fuel, for thatching, as litter and as compost. The thatch was praised because it is naturally dry and not apt to ferment like straw, whereas the use as litter for livestock has perhaps been the most important application of bracken. The litter provides a warm bedding with high absorbency and decomposes more slowly than straw and may be used as compost. In Java, leaves are placed over nurseries of *Cinchona* and other plants for protection against the sun. This shelter decays slowly with the increasing growth of *Cinchona* and gradually disappears.

Bracken has also numerous medicinal uses. In Europe the dried and powdered rhizome or a decoction of the fresh rhizome is taken as an anthelmintic, has diuretic and sedative activity and activates blood circulation. A decoction of the leaves is taken against whooping cough, tuberculosis, bronchitis and costal pain. Leaf juice is given to women in labour to promote uterus contractions and the entire or powdered leaf is used as a dressing to cure wounds. Decoctions of rhizome and leaves are also used against chronic disorders arising from obstruction of the intestines and against melancholy. A bed of green leaves was believed to be a sovereign cure for rickets in children. In China, a tincture made from a decoction of the rhizome and petiole base in wine is drunk against rheumatism. In Indo-China and Thailand, roasted and powdered rhizomes mixed with sesame oil or *Selaginella*, are used to treat snake bite. In Papua New Guinea, petiole juice is applied against toothache and mouth infections.

In Europe, *P. aquilinum* rhizomes have been used as a substitute for hops in beer brewing (one third rhizome, two thirds malt) and in leather tanning. Leaves were used to protect plants against frost and to pack and store fruits. Petioles have been applied as fibre to make cord and paper. In Kalimantan (Indonesia) fiddle-strings have been made from the petioles.

As a dye bracken has been variously used: an olive-green dye was made from leaf tops mordanted with alum (double sulphate of aluminium and potassium); wool is coloured light green in Ireland by cooking young bracken tops for 20 minutes and after adding the wool, simmering for 40 minutes; in France, silk was dyed grey-green using bracken croziers; in the United States weavers and Indians obtained a brown or black dye with the rhizome and a yellow-green or lime-green dye with the croziers.

Hairs on the rhizome and crozier have been used for stuffing pillows, and a decoction of the leaves was an effective insecticide in roses. In China, water in which bracken has been soaked is applied as a vegetable pesticide. In the Philippines, leaves are used as body covering by women working in pond fields during rain; leaves are also used by women as a carrying-pad on the head. Smoke of burning bracken is an effective insect repellent.

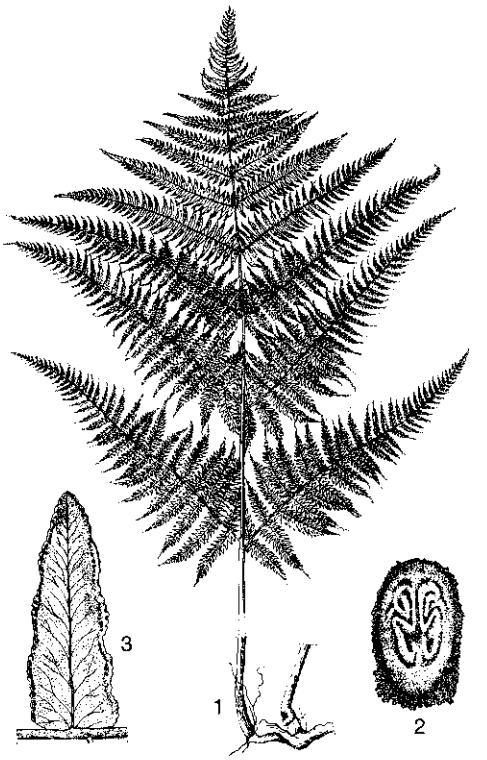
Bracken has many superstitious uses as well. In the Philippines bracken leaves are worn in the hair or attached to a load believing they protect against lightning. In Europe, the bracken spores were believed to enable people to become invisible and burning of bracken was believed to attract rain.

Production and international trade Statistics are scarce on production and trade of *P. aquilinum*. In 1970 over 300 t bracken croziers were consumed in Tokyo alone and in the whole of Japan annual consumption may have reached several thousand t. For other uses the importance of bracken is mainly local and often only historical. At present all attention and research in the United Kingdom is focused on the eradication and control of bracken.

Properties Starch from the rhizomes of *P. aquilinum* for consumption requires careful preparation and adequate washing to remove its bitterness. The nutritional value of rhizomes is poor since they contain much tannin, mucilage and indigestible fibre. Dry rhizomes contain about 40–70% soluble carbohydrates and 2–20% albuminoids, but amounts vary strongly with the season, being highest in the (winter) rest stage. The curled young leaves are said to have a peppery taste and to be slimy and stringy, only the hairs are sometimes problematic. In Japan it is a popular food but it is suspected that it contributes to a high incidence of stomach cancer. Particularly older leaves, reaching the spore stage, are thought to

be poisonous and are also the cause of much poisoning of livestock. In general, all parts of bracken (including the spores) may contain a wide range of secondary plant substances as well as flavonoids which are important for the production of tannins. The secondary substances include sesquiterpenoids (ptaquiloside and related substances, in general called pterosins, having insecticidal and carcinogenic activity), ecdysones (terpenoid compound, identical to the moulting hormone of insects), cyanogenic glycosides (same function as alkaloids), tannins (broad spectrum antibiotic by inhibiting a large number of enzymes) and phenolic acids (acting as fungicide, insecticide and playing a role in protection against other plants by allelopathy). All these constituents may have some activity as a feeding deterrent, affecting predators such as man, animal and other plants. Shikimic acid has also been found in all parts of bracken, especially in the rhizome. It has carcinogenic activity and may explain the occurrence of a fatal haemorrhagic syndrome in cattle and stomach cancer in man after eating bracken foliage. In cattle also thiaminase I, present in bracken, is responsible for neurotic syndromes because it destroys thiamine. Flavonol glycosides isolated from *P. aquilinum* include: rhamnetin 3-O-β-laminaribioside, isorhamnetin 3-O-β-laminaribioside, quercetin 3-O-fructoside, quercetin 3-O-β-laminaribioside and isoquercitrin, kaempferol 3-O-β-(6-caffeoylglucoside), kaempferol 7-O-rhamnoside-4-O-glucoside and the acylated flavonol glycoside kaempferol 3-O-(5-feruloylapioside). The occurrence and concentrations of the various chemical constituents vary with the subspecies and varieties. Air-dried bracken contains about 5.9% ash, of which 43% K_2O, 5% Na_2O, 6% SiO_2 and 14% CaO.

Description Terrestrial fern, with up to 2.5 m tall, finely divided leaves. Rhizome long, creeping deep in the soil, repeatedly branched, covered with fine, pale brown hairs, vascular system of two concentric, complex dissected solenosteles. Leaves alternate, appearing on short rhizome branches, never very close together; petiole thick, up to more than 1 m long, pale, in cross-section showing a horse-shoe pattern of vascular bundles; lamina large, in outline ovate-triangular, up to 2 m × 1 m, 2–4-pinnate and pinnatifid; all axes grooved on upper surface and often hairy; basal pinnae usually subopposite, the larger with a dark callose spot on the rachis near the base which in developing leaves serves as a nectary; basal pair of pinnae up to 70 cm × 40 cm, upper pinnae and



Pteridium aquilinum (L.) Kuhn – 1, habit; 2, cross section rhizome; 3, fertile leaf segment.

pinnules gradually reduced and confluent; ultimate divisions pinnately compound or lobed, often with a long, entire, apical portion; segments oblong, obtuse, adnate, often with winged expansions at base, often interspersed with smaller and short lobes; leaf tissue firm, hairy to glabrescent; veins close, free, forked, raised beneath, hairy; margin entire, always revolute. Sori submarginal, linear, mostly continuous on marginal vein connecting the lateral vein ends; sporangia borne between the outer indusium consisting of the reflexed segment margin and the thin inner indusium attached just below the receptacles. Spores trilete, tetrahedral-globose, 23–35 mm in diameter, irregularly granulate.

Growth and development Spores of *P. aquilinum* germinate in almost any light intensity, nearly always in newly exposed open virgin habitats such as fire damaged sites or after forest logging, but never in closed vegetation including its own canopy. The role of spores seems to be invasion rather than maintaining an existing population since maintenance is by rhizome growth. Once prothalli are established young sporophytes

may appear within 2 months and growth is rapid. Within one year a clump of 0.5 m in diameter can be formed with numerous leaves and extended rhizomes. The development of a leaf is characteristic of bracken: the pinnae unroll completely one by one, starting at the base of the lamina, and in this way the apex of leaves grows for a considerable period of time and a developing lamina may show segments treacherously resembling those of other fern species. At the base of the lower pinnae nectaries are present and exude droplets of petiole sap, attracting ants; they are only active in leaves that are developing and their function is unknown. *P. aquilinum* shows a gradual decrease in fertility with an increasing degree of shade, although vegetative growth is not visibly hampered by heavy shade. Other factors that affect spore formation are not well known but might include ecological stress, age and maturity of a clone. When fertile, however, spore production can be enormous, up to 1 g spores per leaf (about 300 million spores). When mature, spores are mechanically ejected 1–2 cm in the air during dry weather and further carried and dispersed by wind currents and often deposited with the first rain thereafter. *P. aquilinum* is known as a colonizer, e.g. of areas of cooled lava after volcano eruptions such as Krakatau in Indonesia. Here 11 fern species, including *P. aquilinum*, had become firmly established within 3 years after the eruption, later largely displaced by other plants which caused too much shade and competition for *P. aquilinum*.

Other botanical information A cross-section of the rhizome of *P. aquilinum* shows, with some imagination, 2 spread eagles, hence 'aquilina', the Latin name for eagle, given by Linnaeus to this fern. Because of its wide distribution, the history of *P. aquilinum* is long and shows great variability, resulting in numerous names and subdivisions. Only Tryon made a worldwide taxonomic revision and survey of *Pteridium*, whose opinion will be followed here. Tryon accepts only one species, *P. aquilinum*, which he subdivides into 2 subspecies:

- subsp. *aquilinum*. Ultimate segments adnate or equally decurrent and surcurrent, without a farinaceous appearance below, pubescence of the lower surface absent or woolly, mainly in the northern (temperate) hemisphere and in Africa.
- subsp. *caudatum* (L.) Bonap. Ultimate segments mostly decurrent, underside with farinaceous appearance with straight, appressed or arachnoid pubescence, mainly in the southern hemisphere, but not in Africa.

In subsp. *aquilinum* 8 varieties and 4 in subsp. *caudatum* have been distinguished, mainly based on characters of the rhizome hairs, hairiness of the rachis and leaf underside, hair density, angle of pinnules to their mid-vein, dissection of the leaf lamina, shape of the ultimate segments, their division and mode of attachment, the relative sizes of the indusia and the sequence of the unrolling of the leaf lamina. In South-East Asia only 2 varieties occur:

- subsp. *aquilinum*: var. *wightianum* (Ag.) Tryon (synonyms: *Pteris revoluta* Blume, *Pteris recurvata* Wall. ex Ag. var. *wightiana* Ag., *Pteridium revolutum* (Blume) Nakai). Pinnules sessile, segments contiguous, terminal lobes small or indistinct, rachis hairy in the groove above; distributed from the Himalayas throughout South-East Asia to Taiwan, in South-East Asia mainly at higher altitudes.
- subsp. *caudatum*: var. *yarrabense* Domin (synonyms: *Pteris aquilina* L. var. *esculenta* (Forster) Bedd., *Pteridium esculentum* (Forster) Nakai). Pinnules shortly stalked, segments rather widely spaced, terminal lobes distinct, rachis subglabrous; distributed from the Himalayas throughout South-East Asia to Australia, in South-East Asia mainly in the lowland.

Many authors do not agree with the one species concept and distinguish several species. For example in Australia 2 species (*P. esculentum* found all over, *P. revolutum* in northern Australia only) and an intermediate hybrid (var. *yarrabense* from above) are distinguished.

Ecology In Europe, *P. aquilinum* has been a camp-follower of man and often it is an indicator of old forest. Deforestation promoted bracken in competition with other communities which have replaced forest and share similar habitats with bracken, notably grassland and moorland. Bracken is generally inhibited by bog, marsh, clay or waterlogged soils, probably due to the lack of oxygen. Leaves and superficial rhizome buds do not withstand frost, so in many regions the duration of the growing season may be determined by early and late frosts. Bracken is characteristically found on acid, nutrient-deficient, deep soils and is usually absent on nutrient-rich and calcareous soils. In areas where bracken dominates and the gain of litter continues to exceed the loss, bracken will ultimately degenerate and create possibilities for other species to take over. In woodland an equilibrium is often maintained between bracken growth and the environment. In South-East Asia, *P. aquilinum* is never present in rain forest, but is

common particularly as var. *wightianum*, usually at higher altitudes (var. *yarrabense* occurs from sea-level up to 2500 m altitude), in clearings, open areas and forest edges. It needs a deep soil, and this is not provided where the soil has been cultivated and abandoned. In hilly country in Borneo, var. *wightianum* survives the periodic burning of secondary growth and there it can grow abundantly; in the Philippines it grows between 800–2000 m in open locations; in Java between 1800–2800 m on exposed mountain flanks in open *Casuarina junghuhniana* Miq. (synonym *C. montana* Jungh. ex Miq.) forest; in New Guinea it occurs on Mount Wilhelm at 2600–3400 m. The 2 varieties sometimes grow side by side in Thailand, where it is common in pine forest but rather rare on limestone soils. In Peninsular Malaysia var. *yarrabense* is restricted to the lowlands.

Propagation and planting Propagation of *P. aquilinum* is mainly by the creeping, underground rhizome, but in favourable localities (not too dry, not too dark), propagation by spores and subsequently sexual reproduction can be common and effective. Spores are easily transported by wind over long distances to new areas which explains its worldwide distribution.

Husbandry *P. aquilinum* is not cultivated commercially. If planted as a garden plant, it should preferably be on poor, barren, sandy soil, half in the shade. In Scotland, spraying of 4.4 kg/ha asulam (methyl (4-aminobenzenesulphonyl) carbamate) on the foliage is an effective means of controlling bracken.

Diseases and pests *Corticium anceps, Fusarium* spp. and *Septoria aquilina* are parasitic fungi found on *P. aquilinum*. On the Canary Islands *Orobanche* species grow parasitically on *P. aquilinum* rhizomes. Bracken has almost no serious insect enemies because it contains ecdysone which interferes with the growth processes (causing moulting) of insects. In Vermont (United States) the Japanese beetle *Popillia japonica* attacks bracken.

Harvesting For any use, *P. aquilinum* is harvested when needed and when possible. In temperate climates, leaves can only be harvested in spring and summer.

Yield Only a few statistical data are available on the yield of *P. aquilinum*. There is one estimate that annual rhizome production for animal feed may amount to 17 t/ha. For fertilizer use of the ash, it has been calculated that 50 t of dried bracken are required to produce one t of potash.

Genetic resources and breeding *P. aquilinum* is so widespread that it does not seem to be in danger of genetic erosion. Germplasm collections and breeding programmes are not known to exist.

Prospects *P. aquilinum* has the most varied uses of all the ferns. Because of its carcinogenic activity, human and livestock consumption of rhizomes and leaves should be discouraged. The medicinal and pesticidal qualities need further investigation. Its uses as a dye, fertilizer, thatch and litter most probably will remain of local importance only.

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Titien Ngatinem Praptosuwiryo & P.C.M. Jansen

Pteris L.

Sp. pl.: 1073 (1753).

PTERIDACEAE

$x = 29$; *P. cretica*: $2n = 58$ (diploid), 87 (triploid), 116 (tetraploid), reproduction apogamous; *P. ensiformis*, *P. multifida*, *P. semipinnata*, *P. vittata*: normally $2n = 116$ (tetraploid), reproduction sexual, but other ploidy levels and counts exist as well

Major species and synonyms

- *Pteris cretica* L., Mant. pl. 1: 130 (1767).
- *Pteris ensiformis* Burm.f., Fl. indica.: 230 (1768), synonym: *P. crenata* Swartz (1801).
- *Pteris multifida* Poir., Encycl. 5(1): 714 (1804).
- *Pteris semipinnata* L., Sp. pl.: 1076 (1753).
- *Pteris vittata* L., Sp. pl.: 1074 (1753), synonyms: *P. longifolia* auct. non Retz. (1883), *P. longifolia* L. var. *brevipinna* Domin. (1913).

Vernacular names

- *P. cretica*. Cretan brake (En). Thailand: kut phi sue (northern), foen ngoen (Bangkok). Vietnam: r[as]ng ch[aa]n x[if] hy l[aj]p.
- *P. ensiformis*. Sword brake, slender brake, laurel fern (En). Malaysia: paku padang, paku mega, paku mukut. Philippines: pakong parang. Singapore: chièn yèh fèng weich'uéh. Thailand: foen ngoen. Vietnam: r[as]ng ch[aa]n x[if] h[if]nh g[uw][owj]m.
- *P. multifida*. Spider brake, huguenot fern, Chinese brake (En, Am).Vietnam: ph[uw][owj]ng v[if] th[ar]o, seo ga, theo ga.
- *P. semipinnata*. Malaysia: paku medang, paku pelandok.
- *P. vittata*. Rusty brake, ladder brake, Chinese ladder brake (En, Am). Malaysia: paku uban bukit. Singapore: líng kaì fèng weich'uèh. Thailand: kaching duphae, kut tat, kut mak (northern). Trade name: *Pteris longifolia*.

Origin and geographic distribution *Pteris* comprises an estimated number of 240–300 species and is distributed worldwide in tropical and temperate moist areas. About 80 species are found in South-East Asia.

- *P. cretica* occurs almost pantropically and in many subtropical areas. Since it has been widely cultivated and freely naturalized, the origin is uncertain.
- *P. ensiformis* naturally occurs in Sri Lanka, India, China, throughout South-East Asia to northern Australia and Polynesia, and is widely naturalized elsewhere.
- *P. multifida* occurs from Japan to Indo-China and Singapore and is naturalized in various locations in the Americas.
- *P. semipinnata* is distributed from southern Japan and southern China throughout South-East Asia. The natural southern limit is uncertain but it is naturalized in northern Australia.
- *P. vittata* is very widespread in the warm tropical and temperate Old World: from Japan to northern Australia, Polynesia, Yemen, the Comoros and Mascarene Islands, from Spain to South Africa, and is naturalized in South America, for example in the Caribbean.

Uses Various species of *Pteris* are used as ornamental plants (e.g. *P. cretica*, *P. ensiformis*, *P. quadriaurita* Retz., *P. semipinnata*, *P. tripartita* Swartz, *P. vittata*). The leaves of *P. ensiformis* possess astringent properties, and a decoction of the fresh leaves is given in dysentery. In Malaysia the juice of young leaves is applied to clean unhealthy tongues of young children, while the juice of the rhizome has an application for glandular swellings of the neck. In New Guinea the juice is used for boils, ulcers, and wounds. The use for controlling menstruation is also reported from Papua New Guinea. *P. moluccana* Blume is used as a vegetable or to wrap food in Papua New Guinea while the salted raw shoots are given to children as a tonic. A decoction of roots and leaves of *P. multifida* is applied medicinally in Vietnam to treat diarrhoea and dysentery, and as an anthelmintic. The ground dried roots and leaves boiled in sesame oil are used to treat skin diseases in children. The raw leaves of *P. tripartita* and the closely related *P. wallichiana* J. Agardh are used during childbirth in Bougainville and Papua New Guinea. The roasted white pith of the petiole is applied as an anthelmintic to treat round worms. A number of species is used in Chinese medicine. *P. altissima* Poir. is used in Honduras as a skin cleanser and to alleviate insect bites. Stands of *P. vittata* have been suggested to remedy arsenic contaminated soils but no field test results are available yet.

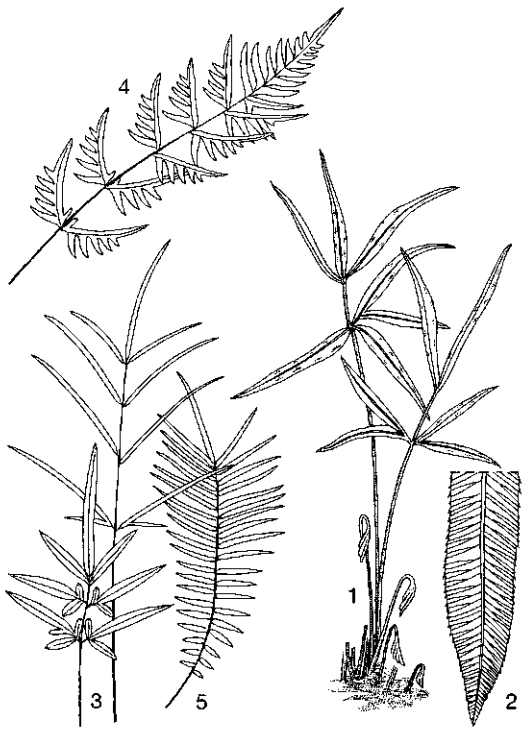
Production and international trade An extensive trade exists in various species, varieties and cultivars of *Pteris*, but no statistics are available.

Properties *P. vittata* accumulates metallic ions (As, Cd, Cu, Fe, Mn, Pb and Zn) from the soil and the uptake of arsenic is especially prominent. *P. vittata* actually profits from soil arsenic concentrations up to 100 ppm as compared to clean soil, and a biomass increase of up to 107% has already been observed at around 50 ppm. At soil arsenic concentrations exceeding 500 ppm the growth is reduced, although the plants may survive a much higher pollution. Bioaccumulation factors up to 142 are found (a total accumulation of arsenic over 22 500 mg/kg on a dry weight basis) with 75–98% of the element accumulated in the above-ground parts of the fern, thus removing up to 26% of the arsenic in the soil. Little difference in solubility exists among the various arsenic compounds except for $FeAsO_4$ and $AlAsO_4$, which are less soluble. In addition to arsenic, *P. vittata* is also effective in accumulating phosphorus; depending on the soil phosphorus concentration, accumulation factors up to 55 have been found.

Three unnamed compounds of *P. semipinnata* (A, 5F, and especially 6F) inhibit the activities of DNA topoisomerase I and II, and show strong cytotoxic activity against human cancerous cell lines. At low concentrations compound 6F enhances the cytotoxicity of genistein against a cancerous cell line by factor 2.60 to 4.65. Two diterpenes from the aerial parts of *P. multifida* showed a moderate cytotoxicity to Ehrlich ascites tumour cells. On the other hand, extracts of spores from *P. vittata* induced DNA damage in human cells in vitro. Ptaquiloside, the sesquiterpenoid carcinogen of *Pteridium aquilinum* (L.) Kuhn, was isolated from *P. cretica*. Antimicrobial activity against *Candida utilis*, *Micrococcus luteus* and *Staphylococcus aureus* has been demonstrated for alcohol extracts of *P. ensiformis*, and against *Bacillus subtilis* for *P. inaequalis* Bak. Water extracts of the rhizomes and leaves of *P. vittata* inhibit germination of spores and growth of *Alternaria brassicicola* and *Aspergillus niger*. Luteolin, apigenin, β-sitosterol and daucosterol were isolated from the acetone-methanol extract of the aerial parts of *P. multifida*. Luteolin inhibited the growth of *Bacillus subtilis* and *Candida albicans*. The presence of the anti-allergic compound asperglaucide has also been demonstrated. Essential oils were isolated from *P. cretica* and *P. multifida*. The components included in both oils were quite similar, the major common compounds found being hexanal, vanillin, 4-hexen-1-ol, 1-hepten-3-ol, 3-hydroxy-2,2,4-trimethylpentyl-isobutyrate, carbonyl compounds, alcohols and esters such as heptanal, isobutyl-isobutyrate, and ethyl-cinnamate. Both oils possessed a green and seaweed odour. Pterosin derivatives are found in *P. semipinnata* and *P. wallichiana*. Pterosins have been shown to inhibit calcium contractures of potassium-depolarised smooth muscle of guinea-pig ileum by both histamine and acetylcholine. A diterpene and 2 indanone sesquiterpenes are found in *P. angustipinna* Tagawa, *P. cretica*, *P. dactylina* Hook., *P. grevilleana* Wall. ex J. Agardh, *P. multifida* and *P. tremula* R. Br. Four more ent-kaurane-glycosides were isolated from the leaves of *P. cretica*. A C-glycosyl-flavone-O-glycoside from aerial parts of *P. cretica* was characterised as luteolin-8-C-rhamnoside-7-O-rhamnoside. The flavone glycosides luteolin-7-O-robinobioside, luteolin-7-O- rutinoside, luteolin-7-O-glucoside, luteolin-7-O-β-sophoroside and luteolin-7-O-β-gentiobioside were isolated and identified in this plant material. The flavonoids 3-C- (6'''-O-acetyl-β cellobiosyl)-apigenin and 6-C-β-cellobiosylisoscutellarein-8-methy-ether are found in *P. vittata*.

Description Terrestrial or epilithic, small to very large ferns with linear, marginal sori. Rhizome erect or short-creeping, slender to massive, often stout; scales always present, elongate or narrow, entire or rarely dentate, brownish to blackish, sometimes with a pale margin, glabrous, often sclerotic, non-clathrate, attached by a broad base, often also with hairs. Leaves closely spaced, 1–2(–5)- pinnate, sometimes tripartite, palmate or pedate, monomorphic or dimorphic; petiole adaxially grooved, stramineous, reddish, brown to purple, or dark and lustrous, the basis with scales and hairs like the rhizome, with one or less often two vascular bundles; lamina apex often similar to a pinna, thin-herbaceous to coriaceous, glabrous or less often variously hairy, the basal pinnae often branched and strongly produced basiscopically, seemingly bifurcate; rachis deeply grooved continuous into the costae, frequently alate, especially the distal part; costae with the groove margins frequently interrupted and producing teeth or spines; venation entirely catadromous, or the basal pinnae anadromous, free or areolate. Sori linear, marginal to submarginal, when young covered by a false indusium formed by the deflexed margin of the segment; paraphyses usually present, then often in great number. Spores tetrahedral or globose, rugose, reticulate or papillose, pale to almost black.

– *P. cretica*. Rhizome short creeping; scales minute, dark brown, entire. Leaves once pinnate, except for the basal pinnae that are forked once or



Pteris. P. cretica L. – 1, habit; 2, pinna segment. P. ensiformis Burm.f. – 3, fertile and sterile leaves. P. semipinnata L. – 4, leaf. P. vittata L. – 5, leaf.

twice, dimorphic; petiole slender, 10–50 cm long, stramineous to purple, nearly black at the base, glabrous or puberulous; lamina oblong, 15–40 cm × 6–35 cm, pinnae up to 7 pairs, up to 23 cm × 2 cm, fertile pinnae up to 1.2 cm wide; pinnae margins serrate; veins free.

– *P. ensiformis.* Rhizome slender, creeping or suberect, bearing leaves close together; scales dark brown, concolorous, entire. Leaves distinctly dimorphic; petiole 5–30 cm long, pale green or stramineous, glabrous; sterile lamina oblong, 7–30 cm long, with usually pinnate lower pinnae, apical part simple, below tripinnatifid or pinnate with 1–3 lobes or pinnules; fertile leaves taller, bipinnate, pinnae of fertile leaves forked once near the base only, the lobes much narrower than in sterile pinnae, up to 40 cm long, with simple terminal segment, 15–25 cm long, below this about 3 pairs of oblique ascending pinnae, each shaped like the terminal segment but usually with a short branch on the basiscopic side near the base; veins free.

– *P. multifida.* Rhizome short-creeping; scales small, blackish-brown. Leaves bipinnate with long, rarely forked pinnules, dimorphic; petiole slender, 4–25 cm long, stramineous, darker at the base, glabrous; lamina ovate, 20–30(–45) cm × 15–25 cm, rachis alate by the decurrent pinnae bases; pinnae about 4 pairs, up to 10–15 cm × 3–10 mm; fertile leaves more divided and with narrower segments; veins free.

– *P. semipinnata.* Rhizome short, erect; scales narrow, dark brown, entire. Leaves pinnately pinnatifid, monomorphic; petiole slender, 10–40 cm long, dark purplish, glabrous; lamina deltoid, 30–40 cm long, pinnae 6–12 pairs, up to 5–10 cm long, basiscopically dissected into 3–more lobes, acroscopic margin entire; fertile pinnae narrower than the sterile pinnae; veins free.

– *P. vittata.* Rhizome short, erect to suberect, covered with concolorous, brownish, entire scales. Leaves pinnate, monomorphic; petiole 5–50 cm long, green, scaly throughout when young; lamina oblanceolate, (15–)25–50(–80) cm × (6–)13–25 cm with much longer terminal segment; pinnae up to 15 cm × 7–10 mm; sterile and fertile leaves only slightly different; veins free.

Other botanical information *Pteris* is a large, morphogically diverse genus, comprising 240–300 temperate to tropical species, including numerous complexes varying from a few to several dozen species. Polyploidy occurs in 55% of its species and apogamy in 35%. The genus is in need of a modern revision. From detailed karyological studies in *P. vittata* it is clear that it is a coenospecies or species complex having five cytotypes (diploid to hexaploid). The diploid and tetraploid types are sexual with normal divisions whereas the triploid, pentaploid and hexaploid ones are natural hybrids and have arisen in nature from hybridization between different genotypes. *P. vittata* was formerly confused with the neotropical *P. longifolia* L. and in trade it still persists under this name. The American *P. longifolia* differs from the Asiatic species in a number of aspects including the articulate and deciduous pinnae.

The popularity of the genus as ornamentals has given rise to a great number of cultivars (e.g. about 250 for *P. cretica*), often with variegated or strongly divided leaves.

Ecology *Pteris* occurs worldwide in tropical and warm-temperate areas but is either absent in very dry regions or poorly represented in regions with periodic drought. It grows terrestrially in more or less shaded locations, from sea-level up to high in the mountains, less often in open places, on all kinds of soils. Garden ornamentals have become established far outside their natural ranges. *P.*

cretica is found on mountain slopes and forests. *P. ensiformis* is not uncommon and is mostly found in shady places under rocks, in crevices, or old, wet walls. *P. semipinnata* occurs in lightly shaded locations in the lowlands, not in heavily shaded forest. *P. vittata* is a common fern of the lowlands, in open sunny sites, sometimes on walls, varying much in size. Other species of the genus are common in primary and secondary vegetation. *P. vittata* grows in central Florida (United States) on soils contaminated with up to 1600 ppm chromated copper arsenate, whereas in Thailand it has been found on mine tailings with As concentrations of up to 15 600 ppm, and transplanted plants survived on contaminated soil from Hunan with 23 400 ppm As. *P. melanocaulon* Fée of the Philippines does not grow well where soil copper levels are below 300 ppm and becomes more vigorous with higher concentrations. Both species accumulate the contamination in their tissue that end up having higher concentrations of pollution compounds than the soil.

Propagation and planting All *Pteris* species grow easily from spores, and this is their preferred method of propagation, although it is possible to propagate from rhizome cuttings and by separation of plantlets. The best germination and rhizoidal and protonemal growth was observed following storage of the spores at 20°C. Spores stored at 20°C contained the highest content of total soluble sugars, free amino acids and total proteins. Fresh spores contained the highest content of amino acids, proteins and sugars. An optimum medium for spore germination and growth of *P. ensiformis* is Peace River peat, with addition of dolomite at 3–6 kg/m^3 to the optimum soil pH of 4.8–5.8, with 300–400 ppm soluble salts and optimum light intensity 4450 lux.

The sporophyte production can be enhanced by transplanting the three-month-old sporophytes grown on Murashige and Skoog solid medium to a medium supplemented with benzyladenine acid (4.4 µm). After a month the rhizomes become swollen with multiple growth centres. Homogenized and plated on a hormone-free medium, 1 g of rhizome can give rise to about 1000 sporophytes.

If planted in gardens, the soil should be poor and well drained for all *Pteris* species. *P. ensiformis* and *P. semipinnata* prefer wet, shady conditions while other species may also grow in more sunny sites.

Husbandry *Pteris* is mainly cultivated for ornamental use while leaves and rhizomes are collected from the wild for other uses. Experimental trials have been carried out with the aim of evaluating *P. tremula* for cut foliage production. Under the climatic conditions of the Riviera Liguriari (Italy) it can be grown in a greenhouse with a maximum irradiance level of 25 000 lux in summer. The plants were grown in a 30 cm organic substrate layer, composed of an equal mixture of fallen beech leaves and peat moss.

Diseases and pests In India the mould *Colletotrichum gloeosporioides* (*Glomerella cingulata*) has been recorded on *P. vittata*, and the pentatomid *Coptosoma siamica* as a pest of *P. quadriaurata* above 1400 m altitude. The nematode *Aphelenchoides fragariae* sometimes heavily infects *Pteris* species. Soil drenches with the nematicides aldicarb or methomyl, as well as nemagon used as a preventive dressing on young plants, resulted in improved growth and absence of nematodes 10 weeks after treatment.

Harvesting *Pteris* plants grown from spores are large enough to produce leaves for ornamental use after 1 year.

Yield In Italy, the annual yield of leaves of *P. tremula* with a length of 40 cm was 336 leaves per m^2 at a density of 11.1 plants per m^2 and 364 leaves at a density of 16.7 plants. Yield was high in spring and summer but a minimum yield of nearly 1 leaf per plant per month was obtained in January at a minimum temperature of 8°C.

Handling after harvest Minimum vase life of *P. tremula* was 15 days, even after dry storage at 18°C and 90–95% relative humidity for 3 days, or after dry storage at 5°C for 5 days.

Genetic resources Germplasm collections of *Pteris* are numerous, particularly where commercial breeding activities for new ornamental cultivars exist.

Breeding *Pteris* has the greatest range of morphological features of any fern genus. Many species hybridize easily and several of these hybrids are sexually fertile, or have become so, after polyploidisation, or can be propagated asexually. Although some *Pteris* species have been cultivated for over 200 years, relatively few new forms have arisen that could be propagated as cultivars. With *P. ensiformis* though, some successful variegated cultivars have been produced. The variegated character is due to a dominant gene. However, in the true-breeding of apogamous species, breeding is directed towards creating superior strains by hybridization or by selection from the wild.

Prospects In Indonesia, Malaysia, the Philippines and Papua New Guinea, only the use of *Pteris* as an ornamental is common. Their effec-

tiveness as medicines and the active substances are being investigated with promising results. *Pteris* is well known for the occurrence of hybrids and apogamous species that may contribute to their success in commercial cultivation as ornamental plants.

At present, *P. vittata* is a focus of interest as a potential agent for phytoremediation of arsenic contaminated soils. Phytoremediation is the process of employing plants to decontaminate soils by utilising their ability to accumulate certain soil compounds. Phytoextraction attempts to remove contaminants from the rhizosphere through plant uptake and accumulation in roots, leaves or stems. The plants are then harvested and the contaminants reclaimed from the plant biomass or the plants are disposed of at a waste facility. Its ability to grow on arsenic-contaminated sites and to accumulate the pollutant make *P. vittata* a most promising candidate. However, the practicability of using it to clean soils under field conditions has yet to be proven.

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H. Schneider & G. Rusea

Pyrrosia Mirbel

Hist. Nat. Gen. 4: 70 (1803).

POLYPODIACEAE

x = 37; *P. lingua, P. nummulariifolia, P. piloselloides*: 2*n* = 74; *P. lanceolata*: 2*n* = 74, ca. 144, 216

Major species and synonyms

- *Pyrrosia lanceolata* (L.) Farwell, Amer. Midl. Natur. 12: 245 (1930), synonyms: *Cyclophorus adnascens* (Swartz) Desv. (1811), *Cyclophorus lanceolatus* (L.) Alston (1931), *P. adnascens* (Swartz) Ching (1935).
- *Pyrrosia lingua* (Thunb.) Farwell, Amer. Midl. Natur. 12: 302 (1931), synonyms: *Cyclophorus lingua* (Thunb.) Desv. (1827), *Pyrrosia heteractis* (Thunb.) Ching (1935), *P. caudifrons* Ching, Boufford & K.H. Shing (1983).
- *Pyrrosia longifolia* (Burm.f.) C.V. Morton, J. Wash. Acad. Sci. 36: 168 (1946), synonyms: *Polypodium acrostichoides* G. Forster (1786), *Cyclophorus acrostichoides* (G. Forster) C. Presl (1851), *Pyrrosia acrostichoides* (G. Forster) Ching (1935).
- *Pyrrosia nummulariifolia* (Swartz) Ching, Bull. Chin. Bot. Soc. 1: 52 (1935), synonyms: *Niphobolus nummularifolius* (Swartz) J. Smith (1841), *Cyclophorus nummularifolius* (Swartz) C. Chr. (1906).
- *Pyrrosia piloselloides* (L.) M.G. Price, Kalikasan 3: 176 (1974), synonyms: *Drymoglossum piloselloides* (L.) C. Presl (1836), *Drymoglossum heterophyllum* auct. non (L.) Trimen (1887).

Vernacular names

- *P. lanceolata*: Indonesia: paku tamaga (Javanese). Malaysia: kapal (Sandakan), tetumpang (Perak), sakat batu. Philippines: humang anapatpat, holog, apatpat an dodologapdi (Luzon). Papua New Guinea: ilofilifeh, tarawalla, rumbaro. Laos: ueang pae. Thailand: tjakweikjon (Karieng), phak peek kai (Chiang Rai).

- *P. lingua*: Japanese felt fern (En). Thailand: thao hin (north-eastern). Vietnam: c[aa]y th[aj]ch v[ex], kim tinh th[ar]o.
- *P. longifolia*: Indonesia: kadaka (Sundanese), paku waceh (Prapat, Sumatra), sungwengto (Halmahera). Malaysia: soloio, suloi (Sakai), janglu (Batek). Papua New Guinea: tobonallingu, bunu, momabo. Thailand: samong (Malay-Yala).
- *P. nummulariifolia*: Indonesia: picisan (Javanese), paku duduitan (Sundanese). Malaysia: paku berenas jantan.
- *P. piloselloides*: Dragon's-scale fern (En). Indonesia: sisik naga (general), pakis duwitan (Javanese), sakat ribu-ribu (Sumatra western coast). Malaysia: picisan, sisik naga. Philippines: pagong-pagongan.

Origin and geographic distribution *Pyrrosia* extends from central Africa through South and East Asia to Oceania (Henderson Island) and New Zealand, but is absent from Hawaii and western and central Australia. The highest diversity is found in the eastern Himalaya and in Sumatra with 12 species each. *P. lanceolata* is the most widespread species, extending towards Africa and far into the Pacific. *P. lingua* is a more northern species, found from Korea through Indo-China and Thailand to Nepal and northern India. It is the most frequently cultivated species outside its natural area of distribution, e.g. in the United States. *P. longifolia* is found throughout South-East Asia, extending to Australia and the Pacific. *P. nummulariifolia* ranges from the Himalayas, through continental South-East Asia to the Philippines, Borneo, Sumatra, Java, Lesser Sunda Islands and Sulawesi. *P. piloselloides* extends from north-eastern India throughout South-East Asia.

Uses *Pyrrosia* species are mainly used medicinally and some are also used as an ornamental. Most species listed here have succulent leaves (only the leaves of *P. lingua* are leathery), the juice of which is applied locally for various purposes. The juice of *P. lanceolata* is used in Malaysia against dysentery and mixed with seeds of *Nigella sativa* L. ('jintan hitam') and onion, it is applied externally against headache. In the Pacific, leaves are used as a poultice on wounds. The juice of *P. longifolia* is applied in labour. The juice of *P. nummulariifolia* is administered internally against cough and stomach pains. *P. piloselloides* is used internally against cough, dysentery and gonorrhoea; it is chewed as a remedy against purulent inflammation of the gums and tooth sockets, often leading to loosening of the teeth (pyorrhoea). Externally, it is used in the Philippines as a styptic for coagulating blood of capillary haemorrhages and for eczema. *P. lingua* is the best known *Pyrrosia* species cultivated as an ornamental and is grown in pots and baskets or as ground cover. Antiviral activity has been detected in *P. lingua*. In China and Japan, a decoction of *P. lingua* has been known for thousands of years as a diuretic for treatment of various disorders of the urinary tract. Together with *P. petiolosa* (H. Christ) Ching it is sold as the Korean crude drug 'suk wi'. Leaves of *Pyrrosia* species constitute the Chinese medicine 'shi-wei', or 'Folium Pyrrosiae'. *P. sheareri* (Baker) Ching, found in China, is used on a large scale to treat bacillary dysentery.

Production and international trade The species of *Pyrrosia* mentioned are not available commercially but they are fairly widespread in cultivation in fern collections and spores are listed in several spore banks. Dried leaves collected for herbal medicines are traded locally.

Properties *P. lanceolata* and *P. piloselloides* contain alkaloids, arbutin, amygdalin, tannin, saponin, formic acid, oxalic acid and tartaric acid. Several other compounds have been isolated from some Chinese species of *Pyrrosia*, among which mangiferin, isomangiferin, sucrose, β-sitosterol and diploptene, the concentrations varying per species.

Extracts of *P. lingua* show a moderate inhibition of the angiotensin-inverting enzyme (ACE) which plays a role in the build up of high blood pressure. The methanolic extract has a moderate inhibiting effect on xanthine oxidase which catalyzes in the conversion of hypoxanthine via xanthine to uric acid, which plays a crucial role in gout. The herb was found highly effective against type 1 herpes simplex virus. In clinical tests, among the 78 cases of herpetic keratitis due to HSV1 treated by aqueous extracts of *P. lingua* and *Prunella vulgaris L.* in eye drops, 38 were cured, 37 improved and 3 showed no benefit.

Isolated from *P. lingua* were: five hopane derivatives (22,28-epoxyhopane, 22,28-epoxyhopan-30-ol, hopane-22,30-diol, hop-22(29)-en-30-ol and hop-22(29)-en-28-ol) and the dammarane triterpenoids: octanordammarane, (18S)-18-hydroxydammar-21-ene, (18S)-pyrrosialactone, (18S)-pyrrosialactol, 3-deoxyocotillol, and dammara-18(28), 21-21-diene. Furthermore cyclohopenol and cyclohopanediol, two hexacyclic hopane derivatives, (28S)-28,29-cyclohop-22(30)-en-28-ol and (22R, 28S)-28,29-cyclohopane-22,28-diol, along with hop-

22(29)-en-28-al were isolated from the rhizomes. The major compounds found in the essential oil are hexanal, vanillin, 4-hexen-1-ol, 1-hepten-3-ol, and 3-hydroxy-2,2,4-trimethylpentyl-isobutyrate. The oil has a greenish and fatty acid-like odour.

P. serpens (Forster) Ching, found in Oceania, predominantly accumulates naringenin and eriodictyol-7-neohesperidosides. A range of apigenin and luteolin O- and C-glycosides are also accumulated together with the flavonol glycoside kaempferol-3-sophoroside-7-α-L-arabinofuranoside.

Description Mainly epiphytic ferns. Rhizome creeping, branched, mostly growing exposed on top of the substrate, covered with peltate scales, dorsally bearing leaves at intervals of 1–7 cm. Leaves simple, petiolate, articulated to the rootstock, mono- or dimorphic, often succulent, covered with stellate hairs. Sterile leaves (if present) shorter and wider than the fertile ones. Sori naked, round, elongate or forming a longitudinal coenosorus along the margin of the lamina.

- *P. lanceolata*. Small, glossy green, thin-fleshy fern, clambering over tree trunks and rocks by its slender creeping rhizome. Rhizome 1–2 mm thick, wiry. Scales up to 3 mm long, appressed, dark, with a dentate, scarious margin. Leaves dimorphic; sterile leaves ovate-elliptical to narrowly ovate, 2–12 cm × 0.4–2 cm; fertile leaves linear, 3.5–29 cm × 0.3–1.3 cm, the apical fertile part often distinctly narrower than the sterile basal part; stellate hairs monomorphic, with appressed, straight rays only, forming a sparse to dense, thin cover on the undersides of the leaves. Sori circular, 0.5–1 mm across, with a tuft of stellate hairs in the centre, in several rows between midrib and margin.
- *P. lingua*. Full-foliaged looking fern with a slender, creeping, amply branching rhizome 1.2–3.7 mm thick. Scales up to 9.5 mm long, lustrous light brown, with curly marginal or superficial cilia. Fertile leaves with the petiole 1.5–25 cm long, lamina ovate-elliptic to narrowly ovate-elliptic, 5–25 cm × 0.8–5 cm, the apex rounded to acuminate, occasionally apiculate; sterile leaves wider, up to 7.2 cm broad; stellate hairs mono- or dimorphic, persistent. Sori circular, 0.5–2 mm across, approximate, often confluent along the veins.
- *P. longifolia*. Fern with very thick-fleshy, long narrow leaves. Rhizome 1.8–2.7 mm thick, often rather brittle. Scales elliptical, up to 1.5 mm long, appressed, dark with an entire, scarious margin, rather resembling scale insects. All leaves similar, strap-shaped, 20–100 cm × 0.5–4.5 cm, occasionally longer; stellate hairs monomorphic, with appressed, straight rays only, forming a mostly rather sparse, thin cover on the underside of the leaves. Sori circular, 0.5–1 mm across, with a tuft of stellate hairs in the centre, in several rows between midrib and margin.
- *P. nummulariifolia*. Small, wide-creeping fern with fleshy leaves. Rhizome filiform or wiry, 0.6–1.6 mm thick. Scales up to 5.7 mm long, brown, margin ciliate in the upper part. Leaves dimorphic; sterile leaves sessile or with petioles up to 2.5 cm, lamina round to elliptical, 0.8–5 cm × 0.6–2 cm; fertile leaves with petiole up to 2.5 mm long, lamina elliptical to linear, 1.5–12.5 cm × 0.3–1 cm; stellate hairs dimorphic, hairs with mainly straight, acicular rays separated from a dense layer of hairs with mainly crisped rays, together forming a thick cover especially on the undersides of the leaves. Sori round, 1–1.5 mm across, mostly hidden in the stellate hairs.
- *P. piloselloides*. Small fern with thick fleshy, glossy green leaves and a wide-creeping rhizome. Rhizome filiform, up to 1 mm thick. Scales roundish-ovate, up to 1 mm long, dark in the centre with a dentate-ciliate scarious margin.

Pyrrosia piloselloides (L.) M.G. Price – habit.

Leaves dimorphic; sterile leaves sessile or short-petiolate, often appressed to the substrate, lamina round to elliptical, 1–7 cm × 1–2 cm; fertile leaves with petiole to 0.5 cm long, lamina linear, 4–16 cm × 0.3–1.5 cm; stellate hairs monomorphic, all with acicular rays, forming a sparse, appressed layer. Sori linear, running along the margin of the leaf.

Growth and development The gametophyte of *Pyrrosia* is cordate, with a thin median midrib and a glandular margin. Archegonia and antheridia are formed on the same prothallus. In some species the prothalli may pass through a stage during which they are elongated and relatively narrow and only bear antheridia. Most *Pyrrosia* species are slow growers.

Other botanical information *Pyrrosia* comprises about 50 species, including those formerly referred to as *Drymoglossum* C. Presl and *Saxiglossum* Ching. Characteristic of *Pyrrosia* are the peculiar stellate hairs, a sclerenchyma sheath in the rhizome and the absence of pinnate divisions of the leaves. *P. lanceolata* is very variable; the description given here applies to the form usually identified as *P. adnascens*, which is the most common form at low altitudes in South-East Asia. Other forms of *P. lanceolata* vary mainly in the shape and size of the sterile leaves and the degree of leaf-dimorphism. In South-East Asia the names *P. nuda* (Giesenh.) Ching and *P. varia* (Kaulf.) Farw. refer to such forms. In *P. lingua*, two varieties are distinguished: var. *heteractis* Hovenkamp: indumentum dimorphic, a dense persistent mat of whitish to greyish-brown hairs in an upper layer with boot-shaped rays and a lower layer with mainly woolly rays; some authors consider this taxon as a separate species; and var. *lingua*: indumentum monomorphic, a thin mat of persistent, light to greyish-brown hairs with boot-shaped rays. Small forms of *P. lingua* are often misidentified as *P. petiolosa*. *P. lingua* is a popular ornamental fern because it is attractive and easy to grow, tolerating irregular watering and surviving moderately low temperatures. In cultivation the leaves may reach 50 cm length. Numerous cultivars have been developed, mostly differing in their peculiar leaf forms, e.g. 'Cristata' (crested tongue fern with the leaf tips several times irregularly forked) and 'Monstrifera' (lacerate pyrrosia because the leaf margins have irregular fringe-like lacerations). Contrary to Linnaeus, a number of authors have confused *P. piloselloides* with or considered it conspecific with *P. heterophylla* (L.) M. Price, a closely similar species restricted to southern India, Sri Lanka and the Seychelles. All references to *P. heterophylla* or its synonyms for South-East Asia should be taken as referring to *P. piloselloides*. *P. piloselloides* has also been confused with *P. nummulariifolia*, from which it can easily be distinguished by its short, appressed, dentate scales on the rhizome and the much sparser cover of hairs on the leaves. The epithet *nummulariifolia* is often written as *nummularifolia*, following the original spelling by Swartz. However, this is a compound form derived from *nummularia* and *folius*, and as such the form without the second (connecting) – i should be treated as an error to be corrected.

Ecology All *Pyrrosia* species are fairly common, often rather hardy epiphytes throughout the South-East Asian tropical lowlands. *P. lanceolata* is common on all kinds of sites, mostly at low altitudes, but sometimes up to 1500 m altitude. *P. lingua* grows as an epiphytic and epilithic, and sometimes as a terrestrial, in sheltered to exposed sites, from sea-level up to 3000 m altitude. It can tolerate some frost. *P. longifolia* is a common epiphyte, frequent in exposed locations, often in the littoral zone, at low altitudes. *P. nummulariifolia* is often found as an epilithic, on limestone. As an epiphyte, it often grows in the crown of trees. *P. piloselloides* is often found colonizing bare bark on tree trunks and can cover entire trees, including the thin twigs. It grows from sea-level up to 1000 m altitude. Its gametophyte is able to tolerate up to 50 days of drought. Upon rehydration, the cells recovering from water stress are capable of forming new gametophytes.

Propagation and planting All *Pyrrosia* species are easily propagated by rhizome cuttings and by layering. Rhizome segments to be transplanted should contain at least one actively-growing apex and should be firmly fixed to a moist substrate until the plant is established.

Husbandry *Pyrrosia* species are not cultivated commercially on a large scale. The species described here can be easily maintained in gardens or greenhouses under conditions resembling their natural habitats. *P. lingua* is a slow grower. *P. piloselloides* is potentially a pest in plantations and could easily be grown and harvested in large quantities.

Genetic resources and breeding Germplasm collections or breeding programmes are not known to exist for *Pyrrosia*. None of the used species are rare or in danger of genetic erosion.

Prospects The available evidence suggests that several *Pyrrosia* species contain useful active compounds with coagulant, laxative or antiviral prop-

erties. More research is needed to discover the best sources for special medicinal preparations.

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P.H. Hovenkamp

Rumohra adiantiformis (G. Forst.) Ching

Sinensia 5: 70 (1934).
DRYOPTERIDACEAE
$2n = 82$

Synonyms *Polystichum adiantiforme* (G. Forst.) J. Sm. (1875), *Dryopteris adiantiformis* (G. Forst.) Kuntze (1898).

Vernacular names Leatherleaf fern, climbing shield fern (En).

Origin and geographic distribution Originally, *R. adiantiformis* is a species of the southern hemisphere and is found in Papua New Guinea, Australia, New Zealand, Polynesia, South America, southern Africa, the Comoros and Mascarene Islands and Madagascar. It is cultivated all over the world with the United States and Costa Rica as the main producers.

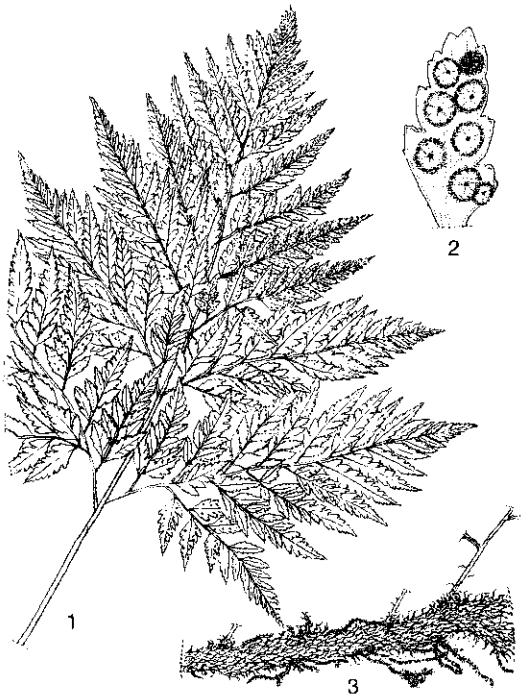
Uses *R. adiantiformis* is one of the most prominent sources of cut foliage. From the 1960s onwards it has been slowly displacing floral arrangements with *Asparagus* sp. as filler and background material. This change is due primarily to its better keeping quality. It is also sold as an ornamental for gardens and hanging baskets.

Production and international trade Statistics on global production and trade of *R. adiantiformis* have not been compiled, but some national statistics include the species. In 1997 the planted area in the United States totalled about 1750 ha, with a production value of 60 million US$, mainly sold on the domestic market. In 1999, the production of the state Florida alone reached a total value of 62.6 million US$, an increase of 7% compared with the previous year. The increase of the sales value is at a lower rate than that of the production since the wholesale price per bunch of leaves has been declining over time. Costa Rica is a major producer with an estimated planted area of about 1000 ha managed by approximately 40 fern growers, dominated by 5 leading companies controlling the largest share of the export market. Many independent growers sell their product to larger companies for export to the main markets in the United States, the Caribbean, Canada, the European Union (The Netherlands, Germany, Norway, Denmark, France, United Kingdom) and Japan. The total Costa Rican export value was about 50 million US$ in 1995, with an annual increase of about 20%. Other Central American exporters include Honduras.

Entire fern plants are sold as landscape ground cover to subtropical areas and for starting cut foliage ferneries. These sales are of far less value than those of the leaves sold to florists.

Properties Continuous contact with the leaves of *R. adiantiformis* might induce allergic contact dermatitis.

Description A terrestrial and epiphytic fern with finely divided, plastic-like leaves. Rhizome long-creeping, (0.5–)1–1.5 cm in diameter, densely scaly; scales attached at the sinus or peltate, cordate, 6–16 mm × 2–5.5 mm, entire, denticulate or erose, acuminate, pale to dark brown. Leaves 3-



Rumohra adiantiformis (G. Forst.) Ching – 1, leaf; 2, pinnule segment with sori; 3, rhizome.

pinnate-pinnatifid, monomorphous, about 20 mm apart; petiole 14–50 cm long, sulcate, with peltate scales near the base, light brown, decurrent on the rhizome; lamina broadly ovate to deltoid, 10–50 cm × 7–40 cm, the basal pinnae may be basiscopically more produced, the apex acuminate, lustrous bright to dark green above, paler and dull beneath; rachis with an entire central ridge and 2 adaxial grooves; veins free, simple or forked; pinnae approximate, petiolate, acuminate; ultimate segments oblong, crenate to bluntly lobate. Sori circular, 2 mm in diameter, usually one per lobe and black at maturity; indusium circular, peltate, entire, with a dark centre. Spores monolete, ellipsoid, 30–38 μm.

Other botanical information The taxonomic position of the genus *Rumohra* Raddi has caused some discussion, chiefly as whether to include it either in the *Davalliaceae*, on the basis of the similarity of the rhizome and leaves, or in the *Dryopteridaceae*. The scales and round indusia, however, suggest affinity with *Polystichum* Roth and *Arachnoides* Blume, a viewpoint that is supported by the perispore structure. Some examples of cultivars are:

– 'Davis': with slightly contracted pinnules, and

– 'Underhill': characterized by its upright and outwardly arching plant habit; moderate vigor and rapid growth rate; dark burgundy-coloured rachis that is durable and strong; numerous pinnules per leaf that are medium green, glossy, with finely and deeply serrate margins and acute apices which give a fringed lacy appearance to the leaf; overlapping pinnules which give a full and dense appearance to the leaf that bears no spores.

Ecology *R. adiantiformis* is particularly common in cooler, temperate areas. Depending on the latitude, the preferred altitude ranges from near sea-level to well over 2000 m. It grows on shaded mountain forest floors, in forest margins, scrub forest, or more rarely on more open stony sites. Usually it grows as an epiphyte, but it is also found as a terrestrial and, for example, on boulders, scree and humus-filled pockets in limestone ledges. In moist forests it can be found as an epiphyte on tree ferns, rotting trunks and logs. Commercially *R. adiantiformis* is grown under shade, predominantly on well-drained sandy soils with a low water- and nutrient-retaining capacity. It is tolerant of a wide range of soil pH and rarely visibly suffers from micro-element deficiencies. The maximum levels of photosynthetic active radiation (PAR) range from 470–670 $\mu E/m^2.s$ or approximately 73% shade.

Propagation and planting The propagation of *R. adiantiformis* is predominantly vegetative by rhizome cuttings. Site preparation prior to planting is simple: the land is cleared and the soil is rototilled. Terminal rhizome pieces 10–15 cm long are planted in 3 or 4 rows in a bed 1.2 m wide.

Husbandry When grown commercially *R. adiantiformis* is shaded by trees or by artificial shading with polypropylene shade fabric. Weeds are a nuisance requiring extensive hand labour. Growth and productivity are reduced by water stress and therefore irrigation is often applied using overhead sprinklers. NPK fertilizer is applied, the amount and frequency depend on the type of soil. Typical application rates per ha in commercial cultivation in Florida (United States) are for N: 112–392 kg, P as P_2O_5: 134–168 kg and K as K_2O 112–392 kg. Lower nutrient application rates should be used for newly planted leatherleaf fern. Applications should not start until feeder roots start developing on the transplanted rhizomes. Nutrients should be applied in small amounts or in controlled or slow release forms to minimize leaching and other losses.

Diseases and pests In the United States and

Central America the most dangerous fungus in *R. adiantiformis* cultivation is *Colletotrichum* sp., which causes severe anthracnose. Symptoms consist of necrosis of the outermost portions of unfurling croziers. When the infected leaf grows and expands, it appears severely burned or scorched and cannot develop normally. Lesions may appear at or near the base of petioles. Under natural conditions the pathogen is incapable of rhizome infection and mature fern foliage does not appear to be susceptible either. The pathogen apparently spreads easily and the disease is very difficult to control once it becomes established. The spread of this pathogen into uninfected ferneries should be prevented because the yield of marketable leaves from infected areas may drop to nothing. The best strategy is to prevent movement of this pathogen into uninfected ferneries by limiting access and implementing strict decontamination procedures to delay or prevent infection, especially in isolated ferneries. Uninfected areas should not be visited after infected areas. Activity in the latter should be scheduled for the end of the work day. Infected areas should be well marked and avoided by personnel and vehicles except when applying fungicides or other disease management practices. It is most important to decontaminate personnel, equipment and vehicles when traveling between ferneries. Quaternary ammonium detergent-disinfectants mixed with water are recommended to inactivate anthracnose inoculum on tools and equipment, cloth and footwear. Products such as Galloway GX 1027 hand soap-disinfectant can be used for skin decontamination.

Other fungal pathogens are *Cylindrocladium* sp. and *Rhizoctonia* sp. which require preventive fungicide applications to control the fungi in the field. *Cylindrocladium* leaf spot causes reddish to greyish-brown spots that vary from pinpoint to 2.5 cm long. They can be water soaked and coalesce to encompass much of the leaf. The disease is most severe in periods of high temperatures. *Rhizoctonia* aerial blight causes dark brown to greyish spots all over the plants and sometimes covering entire leaves. The mycelium of the fungus frequently spreads up the petioles onto the leaf blades, especially in the moister centre of the plants. This disease is also correlated with higher temperatures. Many other cut foliage crops are hosts of *Rhizoctonia* spp. and the disease can readily spread from one crop to another. Plants treated year after year with a fungicide may develop optimum soil conditions around the roots for growth of certain bacteria that produce phytotoxic chemicals, resulting in distorted and off-colour fern leaves.

When the fernery has poor drainage and excessive rains or other excessive applications of water, *Pythium* root rot may affect the plants, which become greyish-green or chlorotic and may wilt. Roots are brown, mushy and stunted. Several fungicides are labelled for this disease on *R. adiantiformis*, but providing adequate drainage is a better way of preventing root rot.

The Florida fern caterpillar (*Callopistria floridensis*), the leatherleaf fern borer (*Undulambia polystichalis*) and leaf hoppers (*Eupterix* spp.) are the most important insect pests. Currently, in addition to rotation to control the Florida fern caterpillar, growers depend heavily on diflubenzuron and *Bacillus thuringiensis* (*Bt*)-based products.

High temperatures may cause the frond curl syndrome (FCS), resulting in leaves wilting rapidly after harvesting through desiccation.

Harvesting The leaves of *R. adiantiformis* are harvested with clippers and tied with rubber bands into bunches of 20–25 leaves.

Yield In Florida (United States) the annual yield of *R. adiantiformis* averages over a million leaves per ha.

Handling after harvest The leaf bunches of *R. adiantiformis* are dipped in or sprayed with water, packed in corrugated fibreboard cartons and stored or shipped at 4°C. Packed this way, the leaves may be stored for a month and still have a vase life of 1–3 weeks. Preventive application of fungicides may be beneficial prior to storage to control post-harvest decay. The leaves can be preserved with glycerine and may also be dyed various colours. No effective means of extending the vase life of good quality leaves has been found yet, though the durability of leaves with a short vase life may be increased by up to 75% using commercial dip treatments.

Genetic resources and breeding Almost all *R. adiantiformis* grown for cut foliage is propagated vegetatively, but the origin of current cultured plant material is unclear. Germplasm collections are not known to exist, but may become increasingly important to select disease-resistant material. Relatively few cultivars are offered for sale.

Prospects Opportunities exist for setting up ferneries for the production of cut foliage of *R. adiantiformis* for local and export markets, especially at higher altitudes since the frond curl syndrome might cause serious problems in warm tropical areas. Research is required to develop wilt and pest-resistant cultivars.

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W.P. de Winter

Schizaea dichotoma (L.) J.E. Smith

Mem. Acad. Roy. Sci. (Turin) 5: 422, t. 9 (1793).
SCHIZAEACEAE
$2n = 144$ (New Zealand)

Synonyms *Acrostichum dichotomum* L. (1753), *Schizaea biroi* Richter (1911), *S. copelandica* Richter (1911).

Vernacular names Branched comb fern, fan fern (En). Indonesia: paku cakar ayam (Bangka), rumput bulu merak (Belitung), silaju (Sumatra western coast). Malaysia: paku tombak, paku jarum (Malay), pirangas (Murut). Papua New Guinea: umiar, biak. Thailand: tan klom, mimsa rima (peninsular), ya hang ma ba (south-eastern).

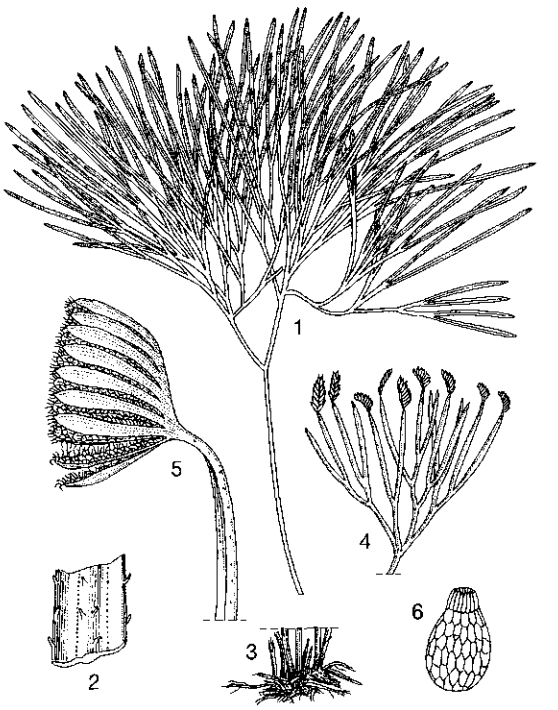
Origin and geographic distribution *S. dichotoma* is found from Sri Lanka and southern India throughout South-East Asia to Australia, New Zealand and Tahiti.

Uses In Indonesia (Belitung) the root of *S. dichotoma* is applied as a medicine for cough and other throat troubles and as a tonic for women after childbirth. In Malaysia a decoction of the roots is used to treat cough and, in a mixture with other herbs, to treat kidney problems and impotency.

Production and international trade *S. dichotoma* is not cultivated commercially and only locally used.

Properties Little is known about the properties of *S. dichotoma*. Two phytoecdysteroids have been isolated from the leaves, namely schizaeasterones A (20R,22R,24R)-3-β,11-β,14-α,20,22-pentahydroxy-24-methyl-5-β-cholest-7-en-6-one) and schizaeasterones B, (20R,22R,24xi,25xi)-3-β,11-α,14-α, 20,22,26-hexahydroxy-24-ethyl-5-β-cholest-7-en-6-one).

Description A small terrestrial fern, with re-



Schizaea dichotoma (L.) J.E. Smith – 1, leaf; 2, part of lower surface of leaf; 3, rhizome; 4, fertile segments on ultimate leaf divisions; 5, sorophores; 6, sporangium.

peatedly forked leaves whose lobes end in sorophores. Rhizomes short creeping, up to 6 cm long, covered with coarse, lustrous, brown hairs 2–3 mm long. Leaves dichotomously branched; petiole (10–)15–30(–50) cm long, narrowly alate towards the top; lamina flabellate, 2–8 times dichotomously branched, the lower branches narrowly alate like the petiole, the upper ones gradually changing into more flattened surfaces by wider wings and less prominent costa; ultimate lobes 1–1.5 mm wide; fertile segments (sorophores) in small groups of about 5–10 pinnately arranged pairs at the apices of the branches, folded together, the lowest 3–4 mm long. Sporangia in two rows on each lobe, mixed with long brown hairs, opening by a crown of annulus cells on their top. Spores smooth to minutely granular.

Growth and development *Schizaea* species have subterranean gametophytes with a modified filamentous or pseudo-axial organization. The archegonia and antheridia are borne on short branches. Some cells are associated with an endophytic fungus. The time between embryo emergence from the archegonium and the first leaf production is quite long. It could be that the sporeling lives for several years as an entirely underground saprophyte before the first leaf emerges.

Other botanical information *Schizaea* J.E. Smith comprises about 30 species, distributed mainly pantropically and in temperate regions of the southern hemisphere. In Malesia 7 species occur. Some populations of *S. dichotoma* consist predominantly of smaller plants, where sporogenous leaves may be as small as 3.5 cm. Such specimens have been named *S. copelandica* and *S. biroi* by Richter. There is, however, no sharp distinction between these forms and typical *S. dichotoma*.

Ecology Like most *Schizaea* species, *S. dichotoma* is almost exclusively found on drier sandy soils in lowland areas up to 1000 m altitude above sea-level, in lightly shaded localities, in forest, scrubland and coastal heathland. It is also commonly found in rubber plantations.

Propagation and planting Little is known about the propagation of *S. dichotoma*. As it has a creeping rhizome, cutting the rhizome for propagation might be possible. It requires cool, shady and rather dry soils.

Genetic resources and breeding No germplasm collections or breeding programmes of *S. dichotoma* are known to exist. It has a wide distribution and though it is rather uncommon, it does not seem to be endangered.

Prospects *S. dichotoma* was traditionally only used locally as a herb and not extensively in Indonesia and Malaysia. More research on its chemical content and properties is desirable to evaluate its medicinal potential.

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Cheksum Supiah Tawan & W. Somprasong

Selaginella Pal. Beauv.

Mag. Encycl. Paris 9(5): 478 (1804).

SELAGINELLACEAE

x = 7, 8, 9, 10 (in South-East Asian species counted so far); 11, 12 (also recorded from elsewhere); *S. doederleinii*: $2n$ = 16, 18; *S. tamariscina*: $2n$ = 20

Major species and synonyms

- *Selaginella doederleinii* Hieron., Hedwigia 43(1): 41–42 (1904).
- *Selaginella plana* (Desv.) Hieron., in Engl. & Prantl, Nat. Pfl. 1 (4): 703, number 363 (1902).
- *Selaginella tamariscina* (Pal. Beauv.) Spring, Bull. Acad. Brux. 10: 136, number 9 (1843).

Vernacular names General: selaginella, moss fern, spikemoss (En, Am, Aus).

- *S. doederleinii*. Greater selaginella (En). Herba selaginellae doederleinii (Latin). Shi shang bai (Chinese).
- *S. plana*. Indonesia: tapak doro (Javanese), paku rane biru (Sudanese), rutu rutu (Moluccas). Malaysia: sondotnulogo (Murut, Sabah).
- *S. tamariscina*. Chinese resurrection plant (En). Juan bai, chüan pai, huan hun ts'ao (Chinese).

Philippines: pakong-tulog, pakongcipres (Tagalog), pakaunkung (Iloko). Thailand: dok hin (northern). Vietnam: mong lung rong, cay chan vit, thach bachi.

Note: For many *Selaginella* species vernacular and botanical names have become very confused.

Origin and geographic distribution *Selaginella* as a genus (comprising more than 400 species) has an almost worldwide distribution. The subgenera (see under Other botanical information) however, have more limited ranges. The subgenus *Selaginella* is found throughout the northern hemisphere; subgenus *Ericetorum* has a southern range in Australia, Tasmania and South-Africa; subgenus *Tetragonostachys* has species in the Americas, Africa, and from Sri Lanka, northern India and north-eastern China to Japan and Kamchatka (Russia); subgenera *Stachygynandrum* and *Heterostachys* are pantropical. *S. doederleinii* is a northern species found from India, China and Japan to Malaysia. *S. plana* is found in Indonesia (Sumatra, Java, Lesser Sunda Islands, Moluccas) and is also commonly cultivated. *S. tamariscina* occurs from Thailand to China and Korea, in the Philippines and Indonesia (Lombok, Java, Sulawesi).

Uses In general, *Selaginella* species are used as food, medicinally, for handicrafts and as ornamentals. *S. doederleinii* is applied in Chinese traditional medicine as a bactericide in the treatment of cardiovascular diseases and of smaller body cancers in nose, throat, lung and liver. It is said to be helpful in the treatment of malignant hydatidiform moles and accelerates cancer remissions when used with chemotherapy and radiation (e.g. applied in lung cancer, nasopharyngeal carcinoma, chorionic epithelioma and tumour of the digestive tract). As a broad spectrum medicine it has many applications. It is applied to cure fever, promote blood circulation and remove blood stasis, for jaundice of dampness-heat type and abdominal mass, for acute and chronic hepatitis, cirrhosis, cholecystitis, diarrhoea, dysentery and leucorrhagia of dampness-heat type, cough of lung-heat type, sore throat, silicosis, for haematemesis, haemafecia, haemoptysis, epistaxis and externally to stop bleeding after trauma and after separation of the umbilical cord. *S. plana* is used to staunch blood from cuts by applying finely chewed branches as a plaster below a bandage and left until bleeding has stopped and the wound healed. It has also been used as a blood-cleanser and as stomach medicine. In Sabah, the Murut people use *S. plana* against fever by bathing in a decoction. In New Guinea, cooked young shoots of *S. tamariscina* are consumed. In Vietnam the whole plant of *S. tamariscina* has been used to treat jaundice, hepatitis, burns and as an infusion for respiratory diseases and haemorrhoids. In Malaysia and the Philippines it is applied against cough, prolapse of the rectum, haemoptysis, gastro-intestinal haemorrhage, haematosuria, excessive menstrual flow and gravel. The whole plant is boiled to a concentrated decoction and drunk. Used as a styptic, the wound is powdered or dressed with the granulated herb. In combination with *Thuja* L., the ground herbs are drunk in an infusion with warm water against blood in the faeces due to a boil in the anal region (so the patient cannot sit) or for extra-menstrual bleeding of the uterus. In traditional Chinese medicine *S. tamariscina* is used in therapy of advanced cancer. The whole plant is astringent and haemostatic. A decoction is applied in the treatment of traumatic bleeding, haemoptysis in pulmonary disease, gastro-intestinal bleeding, metrorrhagia, haematuria, persistence of post-partum lochial discharge, rectal prolapse and leucorrhoea. In combination with acupuncture, it forms part of the treatment of diabetes. In Germany a beauty tea is prepared from a mixture of plants including *S. tamariscina* against fragile and brittle finger nails.

Production and international trade Although *Selaginella* is quite important in traditional Chinese medicine both in and outside China, production and trade statistics are not available. It is known that *S. tamariscina* is exported from China to Peninsular Malaysia and Germany but no statistics are available.

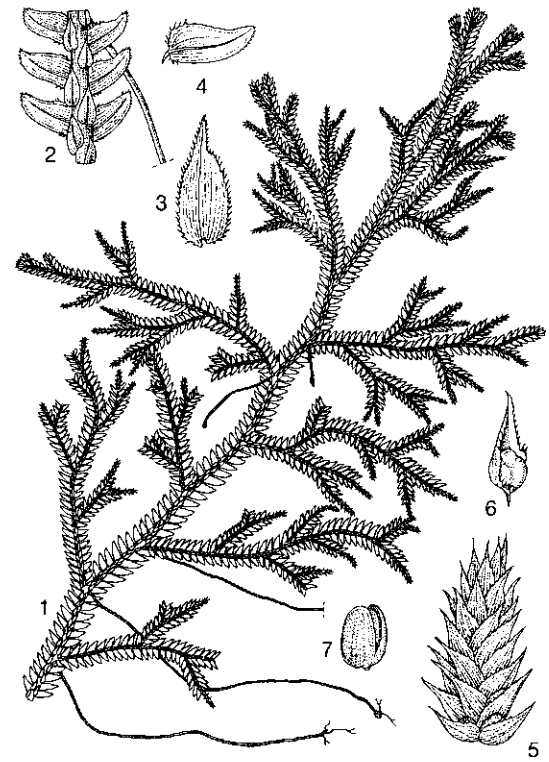
Properties Mice inoculated with granuloma-180 and injected with *S. doederleinii* showed 40–50% tumour inhibition. Mice with hepatic cancer lived significantly longer than the control group. From the ethanolic extract of *S. doederleinii* 11 phenolic compounds have been isolated: 5 lignans: (−)-lirioresinol A, lirioresinol B, (+)-wikstromol, (−)-nortracheloside and matairesinol; 2 phenylpropanones: 3-hydroxy-1(3-methoxy-4-hydroxyphenyl)-propan-1-one, 3-hydroxy-1-(3,5-dimethoxy-4-hydroxyphenyl)-propan-1-one, and 4 biflavonoids: amentoflavone, 7,7"-di-O-methylamentoflavone, 7,4',7",4"'-tetra-O-methylamentoflavone and heveaflavone. The cytotoxic activity of the lignans against L929 murine cells accounts for the use of the plant in traditional Chinese medicine as an anticancer agent. However, after taking *S. doederleinii* as an alternative anticancer treatment, severe bone marrow suppression has been

observed. Extracts of *S. tamariscina* inhibited human mesangial cell proliferation activated by interleukin-1β and interleukin-6; they also showed significant tumoricidal effects against cultured human leukaemia cells, whereas these fractions did not affect normal human lymphocytes. The extracts possess a strong antioxidant property. In experiments with diabetes induced by alloxan in rats, the *S. tamariscina*-complex injection given intraperitoneally (25g/kg) for 12 days lowered the levels of blood sugar and serum lipid peroxide, as well as increasing the concentration of serum insulin. Histologic observation revealed the repair of the structure of pancreatic inlet B cells injured by alloxan. It is claimed to promote the adrenocortical function in mice, the metabolism and reticuloendothelial function but there are no scientific references.

Amentoflavone, a biflavonoid, showed cytotoxic activity and significantly suppressed the growth of Raji and Calu-1 tumour cell lines. It is found in a number of species, including *S. doederleinii* and *S. tamariscina*. It was shown to have an inhibitory effect on the group II phospholipase A2 activity and to inhibit cyclo-oxygenase from guinea-pig epidermis without affecting lipoxygenase, to inhibit phospholipase C γ-1 activity and the formation of total inositol phosphates (IPt). It showed also potent antiviral activity against respiratory syncytial virus with an IC50 of 5.5 μg/ml and potent anti-inflammatory activity. It shows inhibitory activity against influenza A and B viruses. However, amentoflavone did not show significant inhibitory activity against rat adjuvant-induced arthritis, a chronic inflammatory model. In addition, amentoflavone was found to possess potent analgesic activity. Robustaflavone, a biflavonoid found in *S. denticulata* (L.) Spring, *S. lepidophylla* (Hook. & Grev.) Spring and *S. willdenowii* (Desv. ex Poir.) Baker, is a potent in-vitro inhibitor of the hepatitis B virus, a strong inhibitor of HIV-1 and influenza A and B viruses, and a moderate inhibitor of HSV-1 and -2. Its usage and purification is patented in the United States as an inhibitor of viral activity.

The composition of the mixture from which a German beauty tea is prepared (powdered mixture 15 minutes in 0.25 l boiling water) is: 30 g *Achillea clavennae* L., 30 g *Anthemis nobilis* L., 20 g leaves of *Fragaria* sp., 30 g leaves of *Rubus fruticosus* L., 20 g leaves of *Rubus idaeus* L., 30 g *S. tamariscina* and 20 g *Urtica* sp.

Description Herbaceous, creeping, erect or sprawling plants with a characteristic branching pattern. Main stems either far-creeping, often much-branched and of indefinite growth or short-creeping and then becoming erect, often with a distinct unbranched region below and with variously arranged leaf-like flattened branch systems (pseudo-leaves) of finite growth above; further growth arising only from basal branches; sometimes exhibiting a scrambling or climbing habit, from 10 cm up to 6 m long; naked dichotomously branching rhizophores ('roots') emerge from stem branch axes. Leaves simple, ligulate, very small, usually much less than 10 mm long, with a midrib but no lateral veins, arranged in four ranks (in all South-East Asian species) with two lateral rows of larger leaves spreading from the branch and two rows of smaller median leaves dorsally appressed along the branch axis; an axillary leaf present at every branching point. Strobili usually terminal on ultimate branches, compact, or occasionally more spread out along secondary branches; sporophylls leaf-like in four ranks, uniform or dimorphic; sporangia on the adaxial surface in the axils



Selaginella doederleinii Hieron. – 1, habit; 2, part of stem with leaves and rhizophore; 3, median branch leaf; 4, lateral branch leaf; 5, strobilus; 6, megasporophyll; 7, microsporangium.

of the sporophylls; sporangium stalked, of two kinds: megasporangia assuming a shape determined by the megaspores; microsporangia globose or somewhat wider than long, thin-walled with areas of thickened cells which aid dehiscence.

- *S. doederleinii*. Main stem erect from a decumbent base, 8–10 cm × 12–35 cm, with long rhizophores, alternately branched. Leaves dimorphic; lateral leaves oblong, unequilateral, spreading, the margins ciliate adaxially, subentire abaxially; median leaves ovate, equilateral, imbricate, aristate. Strobili terminal and lateral on the lateral branches, 5–12 mm long; sporophylls monomorphic, ovate, carinate, the margins ciliate, the apex aristate.
- *S. plana*. Main stem procumbent, ascending from a more or less trailing base, or erect, up to 60(–120) cm long, the basal part unbranched to 45 cm, woody, the distal part pinnately compound. Pinnae ovate, pinnate (up to 3-pinnate), the branches rather irregular. Leaves dimorphic, entire, distant, erect and appressed to stem; lateral leaves oblong-linear, conspicuous free auricle at base of outer side, margin entire; median leaves lanceolate, conspicuous free auricle at base of outer side, apex acuminate, margin entire. Strobili tetragonous, up to 2.3 cm long; sporophylls monomorphic, lanceolate, apex acuminate, margin broadly pellucid and denticulate.
- *S. tamariscina*. Flat, circular rosettes of branches on a pseudo-trunk. Main stem densely tufted, short and stout, with many equal sized branches, the basal part covered with roots. Lateral and median leaves only slightly different, in four rows, ovate, inequilateral, basally narrowed, marginate, ciliate, cuspidate, abaxially pale, the upper side dark green. Strobili terminal, tetragonous, those with microspores long, with megaspores very short; sporophylls monomorphic, ovate, ciliate, the apex acuminate.

Growth and development Gametophytes of *Selaginella* develop endosporously and the gametophyte is well developed by the time the spores are shed; those of the microspores develop antheridia that produce 100 biflagellate antherozoids, those of the megaspores develop archegonia containing egg cells. A film of moisture is necessary for fertilization to take place. The embryology is endoscopic, the embryo emerges from the upper surface of the gametophyte and the young plant grows quickly into the adult form.

Other botanical information *Selaginella* is subdivided into five subgenera which are well distinct:

- *Selaginella*. 2 species. Leaves monomorphic, spirally arranged.
- *Ericetorum*. 3 species. Leaves monomorphic, spirally arranged.
- *Tetragonostachys*. About 50 species. Leaves monomorphic, spirally arranged. Strobili with the sporophylls in four rows so that the spikes are square in transverse section.
- *Stachygynandrum*. About 600 species, including some of the South-East Asian ones. Primary stems erect, only rooting at the base, or semi-prostrate, rooting in the axils of the dichotomies; branches often compound and often forming a pseudopinnate leaf-like growth form in one plane; they are flattened with larger lateral leaves. Strobili in cross-section square or terete, never flattened, often many on the branch-tips maturing simultaneously; sporophylls in four rows, monomorphic. Analysis of the DNA-sequence of the chloroplast rbcL-gene has revealed that *Stachygynandrum* is polyphyletic.
- *Heterostachys*. About 60 species, including some of the South-East Asian ones. Primary stems creeping and copiously branched, or secondary branches erect and shrubby. Branches flattened with larger lateral leaves. Strobili flattened with dimorphic sporophylls. Analysis of the DNA-sequence of the chloroplast rbcL-gene has revealed that *Heterostachys* is polyphyletic.

Many of the several hundreds of species superficially resemble each other and must be distinguished by a number of microscopic characters in combination. A dozen other species have been or are used in South-East Asia. Although their properties are not interchangeable, it requires specialist knowledge to identify *Selaginella* to the species level. Some other species used are:

- *S. caudata* (Desv.) Spring. Vernacular names: Indonesia: tapak doro, cakar ayam (Javanese), paku rane (Sundanese). Malaysia: paku merak. *S. caudata* is similar to *S. usteri* Hieron. in general habit, leaves with entire margins and terete strobili. Differences: Stem becoming scandent, up to 3 m long. 3–5 pinnate. All leaves lack conspicuous free auricles; median leaves ovate, apex acute; axillary leaves obovate, apex obtuse. Sporophylls lanceolate, apex acute, margin without conspicuous pellucid border and entire. Occurring in the Moluccas and in New Guinea. Young leaves of *S. caudata* are eaten as a vegetable in Java but also as a depurative or stomachic. *S. caudata* is also used as a poultice for vertigo and to staunch blood from cuts by applying finely chewed branches as a plaster under a

bandage and left until bleeding has stopped and the wound healed. Whole plant material of *S. caudata* contains 0.05% alkaloids (on dry weight basis).

- *S. intermedia* (Blume) Spring. Synonyms: *S. atroviridis* (Wall.) Spring, *S. ascendens* Alderw. (excl. var. *ciliaris* Spring), *S. plumea* Spring. Vernacular names: Malaysia: jambol merak, ekor merak, daun ekor merak. Main stem scrambling or suberect, up to 30 cm or more long, rooting in the lower half, up to 14 mm broad including leaves. Leaves dimorphous; lateral leaves of main stem spreading, usually crowded, up to 3-pinnate; branching irregular, pinnae outline deltate to linear; lateral leaves oblong lanceolate, one false vein on either side of main vein, upper margin denticulate; median leaves lanceolate, outer side auriculate, apex aristate with arista about half the lamina length, margins denticulate; axillary leaves ovate, apex acute, margins denticulate. Strobilus terete. Sporophylls uniform, lanceolate, apex acute, margins denticulate with a conspicuous white border. An eastern species, not known from the Moluccas and New Guinea. *S. intermedia* is given in decoction for stomach ache and is applied as a poultice over the whole body for asthma. Pounded with *Cleome viscosa* L. or *Achyranthes aspera* L. it has been applied as a poultice for rheumatism and pounded with *Cardiospermum halicacabum* L. for buboes in the groin. *S. intermedia* is cultivated around Bogor (West Java) and used to make small pots and sold in the form of plates.
- *S. opaca* Warb. Main stem creeping, up to 30 cm or more long, rooting at intervals, up to 6 mm broad including leaves. Leaves dimorphic throughout; lateral leaves of main stem spreading, usually crowded, up to 3-pinnate; branches distant, pinnae outline ovate to linear; lateral leaves oblong-lanceolate, shortly ciliate on upper margin; median leaves ovate, apex abruptly aristate, arista usually more than half lamina length, margins shortly ciliate; axillary leaves ovate, apex acute, margins shortly ciliate. Strobilus flattened. Sporophylls slightly dimorphic, ovate-lanceolate, margins shortly ciliate. *S. opaca* is widespread, but not known from Borneo or continental Asia. Young leaves of *S. opaca* are eaten boiled in the Chimbu and Jimi areas of Papua New Guinea.
- *S. ornata* (Hook. & Grev.) Spring. Synonyms: *S. fimbriata* Spring, *S. ornata* sensu Alston, p.p. Vernacular names: Indonesia: lumut, pakis lumut (Javanese), rane biru. *S. ornata* is similar in general habit to *S. intermedia*. Differences: Main stem up to 8 mm broad including leaves. Pinnae outline linear to ovate; lateral leaves oblong-linear, no false veins, upper margin dentate at base; median leaves apex acute to shortly aristate; axillary leaves deltate, apex rounded-acute, margins dentate. Strobilus flattened. Sporophylls dimorphic, ovate-lanceolate, shortly aristate-acute, dentate. *S. ornata* is widespread throughout South-East Asia, but is not known from the Moluccas or New Guinea. Young leaves of *S. ornata* are eaten as a vegetable in Java but also as a depurative or stomachic. *S. ornata* is also used as ornamental ground cover.
- *S. padangensis* Hieron. Vernacular names: Malaysia: paku merak, pagau (Dusun Rungus, northern Borneo). *S. padangensis* is similar to *S. caudata* in general habit but leaves lacking conspicuous free auricles and with entire margins, and terete strobili. Differences: median leaves lanceolate, apex acute. Sporophylls deltate. *S. padangensis* occurs in Indonesia (Sumatra, Kalimantan) and Malaysia. *S. padangensis* is used as a poultice for the treatment of vertigo and as a medicine for toothache. Dried leaves of *S. padangensis* are smoked like tobacco in northern Borneo.
- *S. stipulata* (Blume) Spring. Synonyms: *S. permutata* Hieron., *S. illustris* Ridley, *S. polystachya* and *S. permutata* sensu Alston. Vernacular names: Malaysia: ekor merak, paku batu. *S. stipulata* is very similar to *S. wallichii* in general habit and appearance. Differences: Leaves of main stem larger than those of branches and very conspicuous on upper part of main stem; median leaves lanceolate, aristate; axillary leaves ovate, apex obtuse. Strobili sometimes in pairs. Sporophylls uniform, ovate-lanceolate, apex acute to acuminate, margin entire. *S. stipulata* occurs in Indonesia (Sumatra) and Peninsular Malaysia. *S. stipulata* is used in decoction as protective medicine after childbirth.
- *S. usteri* Hieron. Similar to *S. plana* in general habit, auriculate leaves with entire margins and terete strobili. Differences: stem up to 1m long; branches regular, linear-lanceolate in outline; median leaves lanceolate, apex acute; axillary leaves lanceolate, apex acute. Sporophylls lanceolate, apex acuminate, margin narrowly pellucid and minutely denticulate. *S. usteri* occurs in the Philippines. Baskets decorated with *S. usteri* (and probably other species) are exported from the Philippines. Plants grow wild but often also as ground cover in plantations.

- *S. wallichii* (Hook. & Grev.) Spring. Vernacular names: Malaysia: paku merak, paku beranas. Singapore: paku berenas. *S. wallichii* is similar to *S. caudata* in general habit, leaves lacking conspicuous free auricles and with entire margins and terete strobili. Differences: Main stem erect, up to 1 m long, 2-pinnate, branches regular, pinnae linear-lanceolate in outline. Median leaves lanceolate, outer base very rounded, apex acuminate; axillary leaves lanceolate, base somewhat auriculate, apex acute. Sporophylls lanceolate, margin very narrowly pellucid, apex long acute. *S. caudata* occurs in Thailand, Peninsular Malaysia and Indonesia (Sumatra). In decoction *S. wallichii* is used as a protective medicine after childbirth.
- *S. willdenowii* (Desv.) Baker. Vernacular names: Indonesia: rane halus (Sundanese), lingonai (Minangkabau), sikili batu (Sumatra west coast). Malaysia: paku merak, paku selemah, paku tanjong. Singapore: paku salumah, paku lumut, paku tanjong. Thailand: rang kai (peninsular). *S. willdenowii* is similar to *S. plana* in general habit, auriculate leaves with entire margins and terete strobili. Differences: The stem becomes scrambling, reaching several m in length. The leaves are iridescent blue-green. Branches regular, deltate in outline; median leaves lanceolate, apex acute; axillary leaves oblong, apex obtuse. Sporophylls ovate, apex acute. *S. willdenowii* occurs in Indo-China, Peninsular Malaysia and Indonesia (Sumatra, Java). Young leaves of *S. willdenowii* are eaten as a vegetable in Java but are also used as a depurative or stomachic. *S. willdenowii* is used in decoction as a protective medicine after childbirth and as an ingredient of tonics. It is also used to treat skin diseases such as itches and ringworm by pounding the plant finely with *Alyxia reinwardtii* Blume and *Foeniculum vulgare* Miller ('adas pulasari') and made into an ointment. Sometimes a little incense derived from gum benzoin, resin of *Stryrax* spp. (kemenyan) is also included in the mixture. In Peninsular Malaysia *S. willdenowii* has also been given internally as an infusion in cold water with *Bridelia tomentosa* Blume, *Dicranopteris linearis* (Burm.f.) Underw., *Merremia vitifolia* (Burm.f.) H. Hallier and *Pericampylus glaucus* (Lamk) Merrill to treat fever, and the ashes have been used in a liniment for backache. Similar uses have been reported from the Andaman and Nicobar Islands. Bioactive constituents of *S. willdenowii* include the biflavones, 4,7'-di-O-methylamentoflavone, isocryptomerin and 7'-O-methylrobustaflavone, which are significantly cytotoxic against a panel of human cancer cell lines. Non-cytotoxic constituents of *S. willdenowii* proved to be bilobetin, robustaflavone and the dihydrobiflavone 2',3'-dihydroisocryptomerin.

In other parts of the world numerous *Selaginella* species are used medicinally, e.g.:

- *S. asperula* Spring is applied on wounds in Colombia.
- *S. exaltata* (Kuntze) Spring is used by the Cuna Indians in Colombia for spleen diseases and stomach aches by taking daily a portion of the cooked rhizome for a prolonged period.
- *S. fissidentoides* (Hook. & Grev.) Spring is applied in Madagascar against cough.
- *S. lepidophylla* (Hook. & Grev.) Spring is used in Mexico as a decoction or infusion to treat kidney stones, gastric ulcers, infections of the stomach, cough, intestinal parasites, diarrhoea, rheumatism, cystitis of the liver, to facilitate the parting and expulsion of the placenta, to purify the blood, to alleviate painful dyspepsia and aching waist or back. The popularity of the plant has resulted in legislation to regulate collection from the wild.
- *S. pallescens* (Presl) Spring is sold in Venezuela and used in decoction, as an emmenagogue and diuretic. In Colombia it is used similarly to *S. articulata* (Kunze) Spring, to treat snake bites. Extracts of *S. pallescens*, used by the Otomi Indians of Queretaro (Mexico) for the treatment of gastro-intestinal disorders, produce a concentration-dependent inhibition of spontaneous ileum contractions.

Ecology The majority of South-East Asian *Selaginella* species grow in organically-rich, moist, well-drained soils in shade or half shade, often near streams, beside trails and at the edge of clearings in lowland to mid-montane primary and secondary forest. *S. tamariscina* grows in dry, rocky habitats. In periods of drought the leaves and branches curl inwards, turning the plant into a ball.

Propagation *Selaginella* can be raised from spores, but vegetative propagation from sections of the stem is easier and faster.

Husbandry The potting mix or garden soil to cultivate *Selaginella* should be well drained and with a fairly high organic component such as loam with added bark or fern fibre, or a very fibrous non-soil mix as for epiphytic orchids. Regular watering and humidity are necessary, but the foliage will rot if it remains sodden for several days at a

time. Light applications of liquid fertilizer at regular intervals promote growth.

Diseases and pests Southern blight (caused by *Sclerotium (Corticium) rolfsii*) has been observed on *S. tamariscina* in Japan. In general, *Selaginella* is mainly damaged by grazing pests such as snails and insects.

Genetic resources and breeding Germplasm collections and breeding programmes for *Selaginella* are not known to exist.

Prospects The confusion in *Selaginella* of scientific and vernacular names requires rigorous investigation to determine whether any medicinal benefit is truly associated with a particular species. *S. tamariscina* could be a promising chemopreventive agent against gastric cancer. Many species show bio-active properties. Especially in the Far East a considerable number of research efforts are currently directed towards the antitumour, antiviral and anti-oxidant properties of various species. Chinese traditional medicine has for centuries taken advantage of these, but wider acceptance may be gained from new scientific publications. *Selaginella* plants also have considerable horticultural value as ornamentals and several species are in commercial production in various parts of the world.

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W.P. de Winter & P.C.M. Jansen

Selliguea feei Bory

Dict. class. d'hist. nat. 6: 588, pl. 41 (1825).
POLYPODIACEAE
$2n = 74$

Synonyms *Grammitis vulcanica* Blume (1828), *Polypodium feei* Mett. (1856), *Pleopeltis feei* Alderw. (1909).

Vernacular names Indonesia: pakis tangkur.

Origin and geographic distribution In South-East Asia, *S. feei* in the strict sense occurs only in Indonesia (Sumatra, Java, Lesser Sunda Islands).

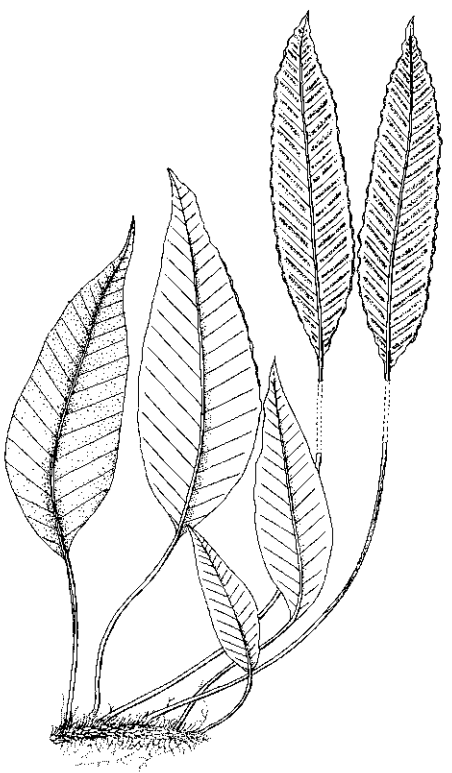
Uses In Java (Indonesia), the rhizome of *S. feei* is traditionally used as a diuretic and as a medicine against rheumatism and hypertension. It is also said to have aphrodisiac properties. *S. feei* is an attractive fern which can also be used as an ornamental, grown in pots and baskets.

Production and international trade *S. feei* is used locally on a small scale only. Standardized extract of the rhizomes is produced commercially on a small scale in West Java (Indonesia) under the name poliponidin. It is beneficial for protection against degenerative diseases such as hypertension, coronary heart disease, diabetes, and rheumatism. No international trade exists.

Properties The following compounds have been isolated from the rhizomes of *S. feei*: selligueain A, selligueain B, (–)-4-β-carboxymethyl-epiafzelechin-(3'-deoxydryopteric acid), (+)-afzelechin-O-β-4'-D-gluco-pyranoside and kaempferol-3-O-β-D-glucopyranoside-7-O-α-L-rhamnopyranoside. Selligueain A is a highly sweet trimeric proanthocyanidin, while selligueain B is a somewhat astringent, sweet-tasting trimeric proanthocyanidin with a doubly linked A unit. The kaempferol-rhamnopyranoside is a very bitter flavonoid glucoside. Selligueain A is non-mutagenic, not acutely toxic to mice and is about 35 times sweet-

er than a 2% sucrose solution in water. In Indonesia, trimeric proanthocyanidin has been tested pharmacologically in mice, especially for its analgesic, anti-inflammatory, anti-oxidant and anti-hypertension activities. Results of the tests showed that proanthocyanidin may have analgesic and anti-inflammatory activity and its mechanism is assumed to be based on the inhibition of prostaglandin biosynthesis, as the compound inhibits cyclo-oxygenase enzyme which has a role in the formation of prostaglandin. Tests on the anti-hypertension activities revealed that proanthocyanidin inhibits angiotensin-converting enzyme (ACE). The role of ACE is to convert angiotensin I into angiotensin II which is known to cause vasoconstriction of the blood vessels. An anti-oxidant investigation using the barbiturate acid method revealed that proanthocyanidin showed an anti-oxidant activity.

Description Rhizome short creeping, 3–8 mm in diameter, densely covered with peltate (rarely pseudopeltate) scales; scales lanceolate-linear, 5–6.5 mm × 1.5–2.5 mm, obtuse or more often acute, golden-brown, evenly coloured, entire to rarely remotely and weakly dentate, appressed or more often spreading; distance between leaves 1–4.5 cm; vascular strands 10–13, with bundle sheath fully sclerified, no sclerenchyma strands. Leaves simple, dimorphic; fertile leaves with the firm petiole 4–30(–55) cm long, glabrous, erect, lustrous pale or brown; lamina lanceolate, 7–25 cm × 2–7 cm, base obtuse, margin cartilaginous, thickened, without or with few notches, apex various, obtuse to acuminate, lustrous bright green, coriaceous, glabrous; sterile leaves usually present, petiole 2.5–45 cm long, lamina ovate-lanceolate, 5–31 cm × 2–10 cm; main veins on adaxial surface raised or not, distinct; veinlets indistinct, free and anastomosing, free veinlets excurrent and recurrent; hydathodes frequent, calcareous scales caducous. Sori mostly confluent across connecting veins into interrupted transverse linear coenosori, 3–5 mm wide, in one row between adjacent costules from the costa to the leaf margin, not quite reaching either the midrib or the margin, superficial. Spores with densely granulose surface.



Selliguea feei Bory – habit.

Other botanical information *S. feei* is the type species of the genus *Selliguea* Bory which is distributed from India to Japan, throughout South-East Asia to Australia and Fiji. *S. feei* has also been recorded in Malaysia, Thailand and Indo-China but these plants should be ascribed to *S. heterocarpa* Blume (which in an authoritative publication has been called. *S. feei* erroneously) and to *S. lateritia* (Baker) Hovenkamp (which at present is still often confused with *S. heterocarpa*). In a strict sense *S. feei* is part of an aggregate of mainly allopatric species, comprising *S. feei* (distributed from Sumatra to Flores), *S. elmeri* (Copel.) Ching (northern Luzon in the Philippines), *S. caudiformis* (Blume) Carruth. (the Philippines, Sulawesi, Moluccas), *S. feeoides* Copel. (Vanuatu, Fiji, Samoa) and *S. plantaginea* Brackenr. and related species (Sulawesi, New Guinea to the Pacific). The allopatric species differ from *S. feei* in the following characteristics: *S. elmeri* has a lamina with an abruptly contracted base and a rounded apex; in *S. caudiformis* the lamina is more distinctly acuminate and the sori are usually separate; in *S. feeoides* the fertile lamina is characteristically ovate-lanceolate, gradually tapering to the apex, with sori in mainly uninterrupted coenosori, not covering the lamina when ripe; *S. plantaginea* has a more widely ovate lamina, the sori ranging from round, separate to fully coenosoroid, and nearly always without hydathodes. Intermediate forms between any two of those species may be found. Specimens of *S. feei*

from Flores have regularly trilobed fronds, a regularly notched margin and sclerenchyma strands in the rhizome. Trilobed forms rarely occur in Java.

Ecology *S. feei* is an epiphytic or epilithic fern, occurring in forest, in open heath, between rocks, on cliffs and roadsides at 900–3150 m altitude. Less often it grows on walls or epiphytically on mossy trunks. In Java it occurs especially on volcanoes, sometimes growing abundantly near craters due to its resistance to volcanic fumes.

Propagation and planting *S. feei* can be propagated by spores and rhizome cuttings.

Husbandry *S. feei* grows well on a medium of a coarse mixture where there is enough shade, humidity and air movement.

Harvesting For medicinal purposes *S. feei* is harvested from the wild when the need arises.

Handling after harvest The rhizomes of *S. feei* can be extracted to prepare pharmaceutical preparations. The returns are 19–20% of the raw material.

Genetic resources and breeding Since the use of *S. feei* is still very limited while it grows abundantly in some locations, it seems the risk of genetic erosion is limited. Neither germplasm collections nor breeding programmes are known to exist.

Prospects Since not much is known about the pharmacological properties of *S. feei*, further research on its chemical contents and clinical tests are necessary. Where industrial prospects for the manufacture of pharmaceutical preparations from *S. feei* are favourable, research on its domestication and cultivation should be considered to guarantee a sustainable supply.

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Dedy Darnaedi & N. Wulijarni-Soetjipto

Stenochlaena palustris (Burm.f.) Bedd.

Suppl. ferns Brit. India: 26 (1876).

BLECHNACEAE

$2n = 148$ (level of ploidy unknown)

Synonyms *Polypodium palustre* Burm.f. (1768), *Acrostichum scandens* (Swartz) Hook. (1864).

Vernacular names Climbing (swamp) fern, liane-fern (En). Indonesia: pakis bang (Javanese), paku hurang (Sundanese), paku merah (Kalimantan, Moluccas). Malaysia: akar paku, paku miding, paku ranu. Philippines: diliman, hagnaya, lanas. Thailand: prong suan, phak kuut daeng (central), lam matheng (eastern and south-western).

Origin and geographic distribution *S. palustris* is distributed from India throughout South-East Asia to Australia and Polynesia. It is sometimes cultivated.

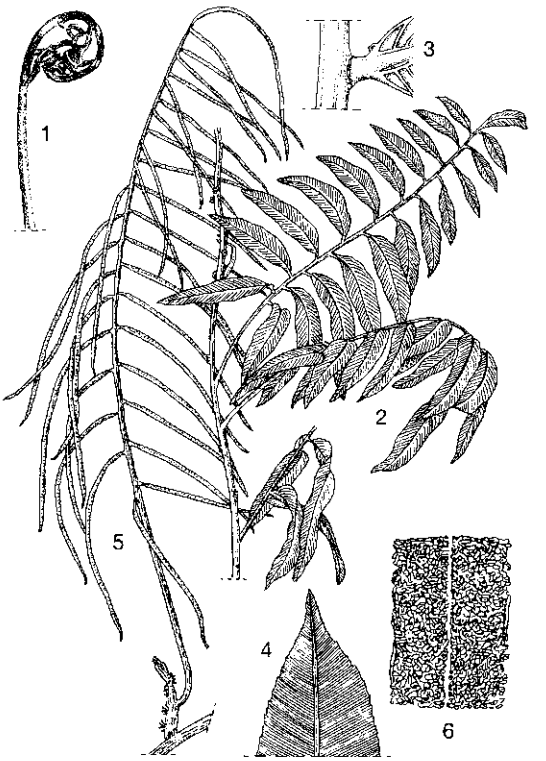
Uses In South-East Asia, crozier and young red leaves of *S. palustris* are relished as a vegetable, and are cooked after having withered. It has a pleasant taste, similar to amaranth, and is therefore found on the menu of local restaurants and throughout Malaysia it is eaten like spinach. *S. palustris* is also used as an ornamental and its black rhizomes are sometimes applied as a wig to supplement thin hair. In general the rhizome is used as an inferior substitute for rattan, e.g. for binding fish-traps, making baskets, ropes and belts. *S. palustris* also has various medicinal uses. In Sumatra, the vegetable is eaten when a gentle laxative is desired. In Malaysia, the young shoots are used to treat diarrhoea while a decoction or the juice is taken internally for fever. Externally

an infusion is used for moistening the head of the person with fever. In Laos it is also applied against fever. In Thailand, the juice is used for skin diseases and in Sabah it is a remedy for swellings. In the Nicobar Islands, *S. palustris* is among the plants used as an abortifacient and contraceptive.

Production and international trade *S. palustris* is not cultivated commercially, but only grown locally on a small scale, usually in a hedge. The used parts are usually collected from the wild when the need arises. The crozier and young leaves are often sold as a vegetable on the local market. In the first half of the 20th Century there was substantial export of dried rhizomes from Karimun Island (Indonesia) to Singapore.

Properties In sea water the rhizomes of *S. palustris* are more durable than rattan, which explains their demand for use in ropes and fishing gear. Five O-acylated flavonol glycosides (stenopalustrosides A-E) have been isolated from the leaves, as well as a glycoside (stenopaluside) (4S',5R')-4-[(9Z)-2,13-di-(O-β-D-glucopyranosyl)-5,9,10-trimethyl-8-oxo-9-tetradecene-5-yl]-3,3,5-trimethylcyclohexanone, a cerebroside 1-O-β-D-glucopyranosyl-(2S',3R',4E,8Z)-2-N-[(2R)-hydroxytetracosanoyl]octadecasphinga-4,8-dienine, the kaempferols 3-O-(3"-O-E-p-coumaroyl)-(6"-O-E-feruloyl)-β-D-glucopyranoside, 3-O-(3",6"-di-O-E-p-coumaroyl)-β-D-glucopyranoside, 3-O-(3"-O-E-p-coumaroyl)-β-D-glucopyranoside, 3-O-(6"-O-E-p-coumaroyl)-β-D-glucopyranoside (tiliroside), 3-O-β-D-glucopyranoside, 3-oxo-4,5-dihydro-α-ionyl β-D-glucopyranoside and β-sitosterol-3-O-β-D-glucopyranoside, 3-formylindole and lutein.
Stenopalustrosides A–D showed significant antibacterial activities against Gram-positive strains (*Bacillus cereus*, *Micrococcus luteus*, *Staphylococcus aureus* and *S. epidermidis*). The minimum inhibition concentration of stenopalustroside A is 2 μg/ml, which is even lower than chloramphenicol (4 μg/ml). A search for alkaloid-containing plants in New Guinea found the leaves to be alkaloid-negative.

Description A wide and upwardly scrambling marsh fern with pinnate leaves of which the fertile ones are remarkably constricted. Rhizome long-creeping, scrambling or climbing on tree-trunks, up to 1 cm in diameter, green; scales peltate, brown, imbricate, absent from the older parts of the rhizome. Leaves well spaced, dimorphic, pinnate; petiole firm, erect, 7–30(–82) cm long, adaxially slightly canaliculate, stramineous to brown, glabrous or with reddish-brown peltate scales; lamina ovate, 17–50(–180) cm × 9–50 cm, bright green, young leaves red, intermediate stages olivaceous, coriaceous and lustrous, glabrous although young plants may have some scales and short pale hairs all over, with 4–14 pairs of alternating pinnae; rachis and costae stramineous to brown, glabrous; sterile pinnae variable in size and shape, short petiolate, articulate to the rachis, lamina narrowly ovate to lanceolate, 5–20 cm × 1–5 cm, the base unequal, cuneately rounded with a small pulvinate gland on the acroscopic side, margins hyaline, sharply irregularly serrate, apex acuminate; veins pellucid, simple or forked, at a broad angle from a row of very narrow costal areoles to the margin, not reduced to the lamina basis but with a few rudimentary pinnae on the petiole below the normal ones; fertile pinnae much constricted, 2–5 mm wide, the margin often protecting the young sori. Sori acrostichoid except for a narrow marginal band, without paraphyses. Spores bilateral, 41 μm × 27 μm,



Stenochlaena palustris (Burm.f.) Bedd. – 1, crozier; 2, part of rhizome and sterile leaves; 3, base of sterile pinna showing gland and joint between pinna stalk and main rachis; 4, apical part of pinna; 5, fertile leaf; 6, segment of fertile pinna.

colourless, translucent, papillose-verrucose.

Growth and development The gametophyte in *Blechnaceae* is cordate, or elongate when mature, with a distinct, often firm midrib. They often bear chlorophyllous hairs. The gametangia are of the common, advanced leptosporangiate type.

Other botanical information *Stenochlaena* J. Smith comprises 6 species in tropical and warm temperate parts of the Old World, 2 in Africa, 4 in Asia, Australia and the Pacific. In anatomical characters *Stenochlaena* is somewhat divergent from the other genera in *Blechnaceae* and therefore it is classified in a separate subfamily *Stenochlaenoideae*. The rhizome bears peltate scales and has a few larger central, and many smaller peripheral vascular bundles; the petiole in cross section has many vascular bundles not in U-shape. In the other subfamily (*Blechnoideae*) the vascular bundles in the petiole form a simple U in cross-section and the stem bears non-peltate scales.

Ecology *S. palustris* is common on rather wet ground such as freshwater swamp forests, sago swamps, behind mangroves or beach vegetation, along rivers, marshes and on floating vegetation. Most commonly it is a scrambling, high-climbing epiphyte in periodically inundated areas, where the lower parts of the rhizome are frequently submerged. It prefers open sites and secondary forest, sometimes fully exposed to the sun but preferring partial shade, and is found in the lowlands and low hills up to 300–400 m in Thailand and New Guinea, and to 900 m in Java. It also occurs in the rain forest and in areas that are never flooded. In rubber plantations it can become a noxious weed. Fertile leaves are infrequently produced, possibly stimulated by a period of dry weather. As a result sporelings are rare but the plants spread rapidly by vegetative means.

Propagation and planting *S. palustris* can be propagated by spores, but more easily by rhizome cuttings.

Husbandry *S. palustris* is very difficult to cultivate ex situ. In warm climates, however, it will grow easily, provided there is enough light and moisture.

Diseases and pests Unidentified leaf spots have been observed on *S. palustris*.

Harvesting The crozier and young leaves of *S. palustris* are collected when the need arises. Rhizomes are collected from the wild for binding material.

Handling after harvest Fresh young leaves of *S. palustris* are tied into bundles and sold as a vegetable on local markets. For binding material, rhizomes are freed of leaves and dried.

Genetic resources and breeding *S. palustris* does not seem to be in danger of genetic erosion since it is rather widely distributed and extraction from the wild still only takes place on a very small scale. No germplasm collections or breeding programmes are known to exist.

Prospects *S. palustris* is an interesting fern which is used as a vegetable, and for fibre and medicine. Further research is needed to evaluate its various uses and properties and its potential for domestication.

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Dedy Darnaedi & Titien Ngatinem Praptosuwiryo

Taenitis blechnoides (Willd.) Swartz

Syn. fil.: 24, 220 (1806).

PTERIDACEAE

$2n = 88, 220$

Synonyms *Pteris blechnoides* Willd. (1794), *Taenitis pteroides* Schkuhr (1804), *T. chinensis* Desv. (1811).

Vernacular names Fillet fern, ribbon fern (En). Indonesia: paku ringin (Java), gugahinigino,

jawa harego (Papua). Malaysia: paku pijai, paku balu, paku pasir. Thailand: kuut prong (south-eastern), prong nuu (peninsular). Vietnam: r[as]ng d[aj]i d[uj]c, c[aa]y rang mu.

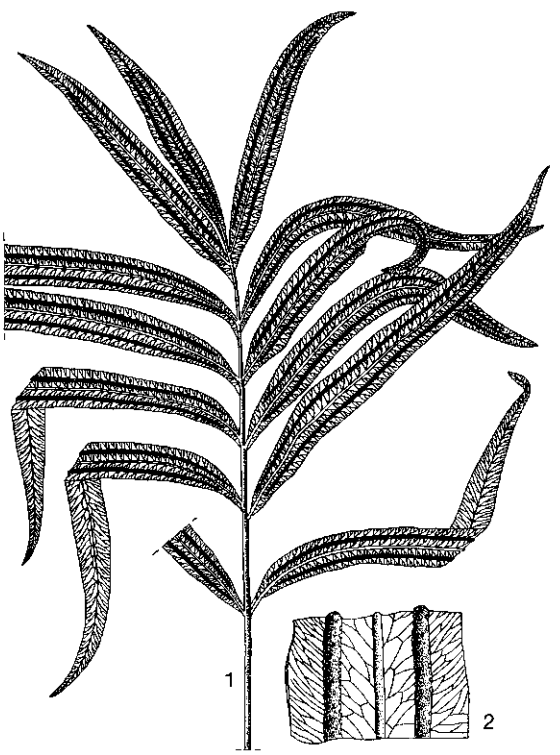
Origin and geographical distribution *T. blechnoides* occurs from Sri Lanka and southern China throughout South-East Asia to north-eastern Australia, Vanuatu and the Fiji Islands.

Uses A decoction of the leaves of *T. blechnoides* is taken as a postnatal protective medicine in Malaysia. The Malay names of the medicine ('meroyan paku' and 'meroyan dawai') suggest that *T. blechnoides* is one of the many wiry ferns used.

Production and international trade *T. blechnoides* is only locally used on a small scale and there is no commercial production or trade.

Properties In the Philippines, water extracts of *T. blechnoides* showed positive antimicrobial activities against *Bacillus subtilis, Candida utilis, Escherichia coli, Micrococcus luteus, Pseudomonas aeruginosa* and *Staphylococcus aureus*.

Description A terrestrial or sometimes epilithic fern with tough, pinnate leaves bearing entire pinnae with linear sori (coenosori) in parallel to the midrib of the pinna. Rhizome short-creeping, 4–5 mm in diameter, the apical part densely covered with lustrous black bristles 2–3 mm long, a bud is present at the base of each leaf. Leaves in two rows about 1 cm apart, pinnate with 1–5(–12) pairs of pinnae and a conform apical pinna, or simple on young plants, not really dimorphic though the fertile pinnae are narrower and usually firmer; petiole 30–60 cm long, grooved near the apex of larger plants, purplish to brown near the base, green to stramineous distally, glabrous; lamina deltoid to elliptical in outline, up to 40 cm × 30 cm, firmly papyraceous to coriaceous, glabrous; rachis grooved; basal pinnae with petiole up to 1 cm long, the distal pinnae sessile; pinnae in sterile leaves narrowly lanceolate, subfalcate, 15–20(–25) cm × 1.5–5 cm, in fertile leaves the pinnae are 0.5–3 cm wide, decreasing slightly in size towards the apex, base cuneate, margins entire, narrowly cartilaginous, gradually narrowing to an acuminate apex; costa abaxially distinctly raised, veins oblique to the costa, copiously areolate without included free veinlets. Sori in 2 continuous median bands parallel to the costa, rarely interrupted, 1–2 mm wide, ferrugineous, with frequent paraphyses. Spores trilete, tetrahedral globose, tuberculate or densely verrucose.



Taenitis blechnoides (Willd.) Swartz – 1, leaf; 2, part of leaf with sori and venation.

Growth and development The gametophyte of the subfamily *Taenitidoideae* of the *Pteridaceae* is initially spatulate with a lateral meristem and develops lobes with additional meristems during its growth. Old gametophytes are asymmetrically cordate or irregularly lobed with archegonia and antheridia variously distributed.

Other botanical information *Taenitis* Willd. ex Sprengel is a complex genus and consists of about 15 species distributed from Thailand throughout the Malesian Archipelago to the Fiji Islands, Samoa and north-eastern Australia. In Malesia 9 species occur in Borneo and 6 in New Guinea, but only one in Java and the Lesser Sunda Islands. It is classified in the subfamily *Taenitidoideae* of the *Pteridaceae* (in which *Pityrogramma* Link is also classified). The genus is, however, often included in the *Adiantaceae*, which, in the classification adhered to here, is considered another subfamily of the *Pteridaceae*. Holttum divided this difficult genus into 4 sections but this is not generally accepted as major characters such as lamina architecture, the flange on the spores and the relation of the sporangia to the venation are insufficiently correlated. *T. blechnoides* comprises a complex of forms differing by slight and

subtle characters which are difficult to distinguish in dried specimens. The common character of all forms is the presence of a longitudinal band of sporangia midway between the midrib and margin of each pinna that is usually continuous but occasionally interrupted.

Ecology *T. blechnoides* is a very common fern, found especially along paths, of lowland to hilly forest up to 750 m altitude, in primary and secondary forest with a preference for slightly shaded conditions. It is rare in heavily shaded forest. It tolerates drier locations than most terrestrial shade ferns though it is common in swampy conditions in the rain forest in Australia. It is also found on rocks and in streambeds, but these specimens are slightly different from the type and classified as varieties.

Propagation and planting *T. blechnoides* can be propagated by spores and by fragmentation of the creeping rhizome, but cultivation is not easy. Young plants may grow on old rotten wood, while old plants may grow on poor well-drained soils in shady conditions.

Genetic resources and breeding *T. blechnoides* is a very common plant facing no risk of genetic erosion. No germplasm collections or breeding programmes are known to exist.

Prospects *T. blechnoides* is only used locally and nothing is known about its medicinal efficiency or active substances. In Malaysia it is considered one of the common weeds occurring in rubber and oil-palm plantations, in gardens and in fields of other crops.

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H. Schneider & Cheksum Supiah Tawan

Tectaria Cav.

Anales Hist. Nat. 1: 115 (1799).

DRYOPTERIDACEAE

$x = 40$; *T. crenata*: $2n = 80$; *T. singaporeana* $2n =$? 80

Major species and synonyms

- *Tectaria crenata* Cav., Descr. pl.: 250 (1802), synonyms: *Aspidium repandum* auct. non Willd. (1810), *A. pachyphyllum* Kunze (1848), *A. grandifolium* Presl (1851).
- *Tectaria singaporeana* (Hook. & Grev.) Copel., Sarawak Mus. J. 2: 368 (1917), synonym: *Aspidium singaporeana* Hook. & Grev. (1827).

Vernacular names

- *T. crenata*. Indonesia & Malaysia: paku kikir.
- *T. singaporeana*. Malaysia: paku todak, paku biawak, paku merak. Thailand: tan loi (peninsular).

Origin and geographic distribution The genus *Tectaria* comprises about 150 species, widely distributed pantropically. *T. crenata* extends from southern Thailand and northern Vietnam throughout Malesia to Polynesia (Marianas, Carolines, Solomons, New Hebrides and Fiji). *T. singaporeana* is found in peninsular Thailand, Peninsular Malaysia, Singapore, Sumatra and Borneo.

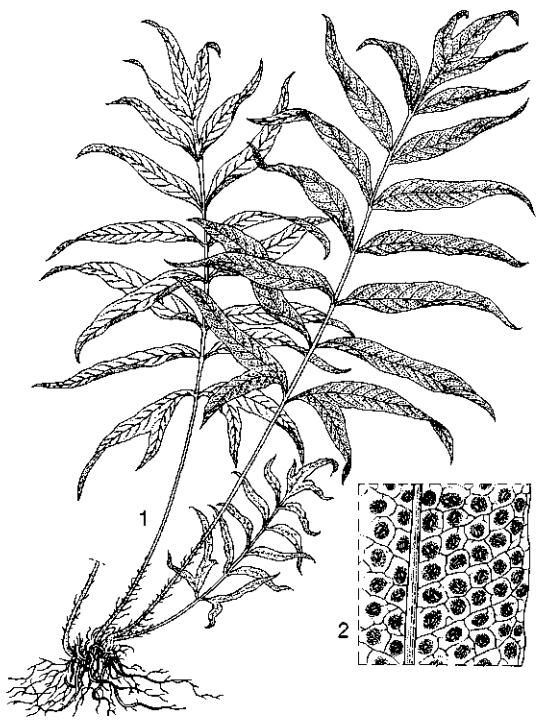
Uses The young leaves of *T. crenata* were eaten in Malaysia as a vegetable when nothing better was available. A decoction of the leaves, along with the roots of *Dracaena angustifolia* Roxb., was used against gonorrhoea. *T. singaporeana* is also known in Malaysia by the vernacular name 'meroyan papan', indicating that it is used after childbirth. It was also applied as a medicine for fever. In India, *T. coadunata* (J. Smith) C. Chr. and *T. polymorpha* (Hook.) Copel. are used medicinally in Madhya Pradesh and Kumaon Himalaya. Some *Tectaria* species are used as ornamentals, e.g. *T. grandidentata* (Ces.) Holtt., *T. griffithii* (Baker) C. Chr., *T. semipinnata* (Roxb.) Morton and *T. vasta* (Blume) Copel.

Properties The chemical properties of *Tectaria* have not been studied well. The phenolics gallic acid, ellagic acid, 2,3-hexahydroxydiphenoyl-D-glucose, (–)-epicatechin, (–)-epigallocatechin, (+)-

gallocatechin, 3,5-di-O-caffeoylquinate-eriodictyol-8-C-β-D-glucopyranoside and 6,7-dihydroxy-1,1-dimethylisochromane have been isolated from the leaves of *T. subtriphylla* (Hook. & Arn.) Copel.

Description Small to rather large, terrestrial or epilithic ferns. Rhizome rather long-creeping to erect, bearing long and narrow, acuminate, often dark brown scales. Leaves often medium-sized to large, monomorphous or dimorphous; petioles remote to clustered, well-developed, stramineous to dark and then often lustrous, often scaly at least near the base, adaxially sulcate, occasionally alate, sometimes hairy, especially in the groove, the hairs short, reddish, articulate, or also with thinner, paler hairs; lamina pinnatifid to bipinnate-pinnatifid, less often lobed or entire and simple, herbaceous to subcoriaceous; basal pinnae segments very often basiscopically produced; rachis like the petiole, rarely dark, usually with reddish, articulate hairs in the adaxial groove, secondary rachis if present sometimes grooved at base, then the groove not joining that of the primary rachis, costae occasionally adaxially with proliferous buds, the leaf apex rarely rooting and proliferous; pinnae sessile or the basal ones short- to long-stalked, or, especially the upper ones adnate and decurrent or also surcurrent, upper pinnae often reduced into a pinnatifid leaf apex, or the apex trilobed, or less often conform; venation catadromous, only the basal pair anadromous, veins more or less anastomosing, usually with some to many free, included veinlets pointing in all directions or not, rarely all veins free; fertile leaves when differing usually more or less contracted. Sori variable in shape and position, with reniform to peltate indusia or without indusia. Spores bilateral and monolete, subellipsoid, with often cristate or echinate wing-like folds, surface usually reticulate-echinate or spinulose.

- *T. crenata*. Caudex suberect; lamina up to 70 cm long, the apical section multilobed, the lower lobes grading into adnate pinnae up to 30 cm long, margins subentire to crenate, basal pinnae distinctly petiolate, producing a large basiscopic lobe. Sori on free veinlets in the areoles, rather large, with a firm, slightly reniform indusium. Spores faintly granulose, with irregular thin fimbriate wings.
- *T. singaporeana*. Caudex erect, up to 10 cm tall; lamina simple, widest below the middle, up to 40 cm × 12 cm, the fertile ones narrower, base abruptly narrowed and short-decurrent, margins entire, apex short-acuminate. Sori up to 6 in a row on either side of a cross-vein, not on the free veinlets, with a subpeltate indusium.



Tectaria crenata Cav. – 1, habit; 2, part of underside leaflet.

Growth and development The gametophyte of *Dryopteridaceae* is fairly constant in shape, being cordate, with simple, derived gametangia. More variation exists in the presence or absence and structure of superficial appendages which may be hair-like, glandular or branched. In natural forest in Peninsular Malaysia, *T. singaporeana* needs at least two years to develop from spores to maturity, bearing the first mature pinnae.

Other botanical information In the literature *Tectaria*, which is a difficult complex of 150 species, can be found classified in many other families, e.g. *Aspidiaceae*, *Dennstaedtiaceae* and *Polypodiaceae*. Flora Malesiana does not designate a family but classifies it in the *Tectaria* group. Here the classification of *Tectaria* in the tribe *Tectarieae*, subfamily *Dryopterioideae* of the large family *Dryopteridaceae* is followed. This same tribe includes, amongst others, the genus *Pleocnemia* C. Presl. T. *crenata* has often been misidentified as *T. reparida* (Willd.) Holttum, usually by the name *Aspidium repandum* Willd. The latter has a more southern occurrence and is not found north of the line Java – the Philippines. *T. repanda* has

a single veinlet in the areoles of the fertile pinnae and peltate indusia, whereas *T. crenata* has mostly forked veinlets and slightly reniform indusia.

Propagation and planting *Tectaria* can be propagated by spores, and in the case of *T. singaporeana* also by buds at the base of pinnae.

Ecology *Tectaria* is usually terrestrial in forest, mostly near streams, not rarely on cliffs, on road banks and also often on rocks and in thickets, rarely in open locations. *T. crenata* is found in lowland and hilly forests. *T. singaporeana* frequents shady lowland forest up to 900 m altitude.

Genetic resources and breeding No extensive germplasm collections or breeding programmes for *Tectaria* are known to exist. In Peninsular Malaysia some small collections are available at the fernarium of the Universiti Kebangsaan Malaysia in Bangi, Selangor.

Prospects Although *Tectaria* is a large genus little is known about its useful properties. The medicinal and ornamental aspects need more investigation before its prospects can be indicated.

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G. Rusea & Norma O. Aguilar

3 Bryophytes (mosses)

3.1 Introduction

3.1.1 Botany

The bryophytes (*Bryophyta*) consist of about 20 000 species, and are divided into 3 groups: *Anthocerotopsida*, *Marchantiopsida* (*Hepaticae*) and *Bryopsida* (*Musci*). The last 2 groups contain the majority of species and are usually called liverworts and mosses, respectively. They are distinguished by their vegetative structure and mode of development of the reproductive organs (gametangia and sporogonia).

3.1.2 Ecology

Bryophytes play important ecological roles in natural ecosystems. In South-East Asia, montane forests, above 1200 m altitude, are richest in bryophytes, most of them being epiphytic. The bryophyte-rich forest reaches an optimum at about 2500 m altitude. Trees in the high mountain forest always have epiphytic bryophytes, which are sometimes very conspicuous, e.g. the hanging garlands of *Aerobryum*. The so-called 'moss forest' is a sure indicator of an everwet (humid) climate, and is often found in depressions on the high mountains, where damp conditions prevail. It is an ecological type of the 'elfin forest', which is the primary forest formation above 2000 m. In the cloud belt of mountains, also the soil, rocks and fallen logs may be carpeted with bryophytes, mostly liverworts. Extensive carpets of hydrophilic terrestrial mosses such as *Sphagnum* are limited to wet localities in the mountains. Lowland forest may be rich in bryophyte species, but the proportion in the total vegetation is usually small.

3.1.3 Uses

A comprehensive review of the worldwide uses of bryophytes is available, including decorative, household and medicinal uses, as soil additives, for horticultural practices and as bio-indicators for environmental degradation (Glime & Saxena, 1991). Species are included that are commonly found in the Old World tropics, e.g. *Herbertus*, *Leucobryum*, *Marchantia*, *Rhodobryum* and *Sphagnum* species.
Compared to the ferns and especially seed plants, bryophytes are little used in South-East Asia. One of the reasons for this is that they are not abundant in lowland rain forest, where human settlements are often located. However, limited use of bryophytes has been documented for a few useful mosses for Peninsular Malaysia: *Calymperes*, *Campylopus* and *Sphagnum* are used for medici-

nal purposes, stuffing mattresses and decoration (Burkill, 1966).
Field observations in remote mountainous areas in South-East Asia have confirmed the tribal usage of large and showy moss plants, such as *Dawsonia*, *Pogonatum* and *Spiridens* species, together with fern allies such as *Huperzia*, *Lycopodiella*, *Lycopodium* and *Selaginella*, as body decoration and to ward off evil spirits.
Sphagnum (peat moss) is sometimes used as nesting material for artificial incubation of eggs in crocodile farms in the Philippines. The use of dried moss material (e.g. *Sphagnum*, *Hypnum* and *Trachypodopsis*) for fuel and house construction, as reported for temperate regions (Pant & Tewari, 1989), has not been observed in South-East Asia.
It appears that the largest market for moss products is in the cities due to the demand of horticulture. Large and small packages of moss mixtures, labeled as 'peat moss', are sold in department stores and supermarkets. They are used in potting mixtures for greenhouses and nurseries and are also employed for soil improvement in gardens. Surveys made in Singapore, Malaysia, Thailand and the Philippines have shown that the moss mixtures sold in markets usually contain large amounts of *Ectropothecium*, *Homaliodendron*, *Neckeropsis*, *Thuidium* and *Vesicularia*, but also liverworts, including *Bazzania*, *Heteroscyphus* and *Pallavicinia*. However, the mosses which are most in demand by orchid growers are *Leucobryum* and *Sphagnum*, both of which can store a large amount of water. In the Cameron Highlands, a major centre of horticulture in Peninsular Malaysia, large bags of *Sphagnum* moss imported from Canada can be purchased.
A newly-developed market for mosses is the trade in aquarium plants. Javan moss (*Taxiphyllum barbieri* (Cardot & Copp.) Z. Iwats.), which is indigenous in South-East Asia, has become a popular aquarium plant for fish hobbyists around the world. Mosses commonly used by bonsai enthusiasts (e.g. in Singapore) to decorate the potted landscape are species of *Bryum* and *Philonotis* and, to a lesser extent, *Isopterygium*, *Vesicularia* and the thalloid liverwort *Riccia*. These bryophytes are often widespread in the region. Recently the introduction of *Ochrobryum kurzianum* Hampe from Thailand has been reported to be used as an ornamental moss in bonsai potting in Singapore (Tan & Tan, 2000).
The custom of building a moss garden, which has been practised for centuries in Japan, has not yet caught on in South-East Asia. Bryophytes are used on a small scale in local handicraft industries manufacturing souvenirs and memorabilia, e.g. postcards, bookmarks and paperweights, using the bryophytes as a motif. Other incidental uses of bryophytes are in packaging, as well as in window-dressing and showcasing gift displays at department stores during the Christmas season.
Although several studies have yielded convincing experimental data for antitumour and anti-microbial properties of bryophytes (Spjut et al., 1986, 1988; Raymundo et al., 1991; Lorimer et al, 1996; Soh and Chan 2001), bryophytes are not prescribed in traditional medicine in South-East Asia. This contrasts with the situation in China, where many folk medicinal uses of bryophytes have been described (Ding, 1982). Several of the species used in China are also found in South-East Asia.

Because of the unique chemistry of liverworts, many species have been exam-

ined for the presence of bioactive compounds (Asakawa 1999). There is an ongoing programme at the Department of Chemistry of the National University of Singapore, where liverwort chemistry is under investigation. Part of this programme is aimed at finding compounds with promising pharmaceutical applications.

3.1.4 Prospects

Trade figures of bryophytes in South-East Asia are not available, but are probably insignificant. All moss products originate directly from the wild. Because of the slow growth of many bryophytes, the quantity harvested needs to be monitored and regulated by the government in regions where collection is common, in order to assure the continued survival of vegetations dominated by bryophytes.

Bryophytes play important ecological roles in natural ecosystems. To realize their commercial potential, more utilization studies are needed. But first of all there is a need to document fully the diversity and species distribution of this poorly known group of plants and understand well its biology and ecology.

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3.2 Alphabetical treatment of moss genera and species

Leucobryum Hampe

Linnaea 13: 42 (1839).
LEUCOBRYACEAE
$x = 11$

Major species and synonyms
- *Leucobryum aduncum* Dozy & Molk., Pl. Jungh. 3: 319 (1854).
- *Leucobryum javense* (Schwaegr.) Mitt., Journ. Linn. Soc. Bot. Suppl. 1: 25 (1859).
- *Leucobryum sanctum* (Brid.) Hampe, Linnaea 13: 42 (1839).

Vernacular names Cushion moss, white moss (En). Indonesia: putih lumut. Malaysia: putih lumut. Philippines: puting lumot (Tagalog).

Origin and geographic distribution *Leucobryum* is a mainly tropical genus of about 150 species. It is pantropical, but some species occur in temperate regions, e.g. *L. glaucum* (Hedw.) Ångstr., which occurs in temperate Europe, Asia and America, and in Hawaii and the Andes. All *Leucobryum* species treated here are widespread and common in South-East Asia, and known also from India, Indo-China, Thailand, China and Japan. *L. sanctum* occurs, in addition, on some Pacific islands.

Uses Because of the capacity to store large amounts of water in the leaves, species of *Leucobryum*, together with *Leucophanes octoblepharioides* Brid. and other members of the family, are used by gardeners or plant growers as a local substitute for peat moss (*Sphagnum*) in potting new plants. According to plant growers in Manila, cushion moss induces good root sprouts in orchid cuttings. Less frequently it is used as filling material for transporting fragile commodities. In parts of Peninsular Malaysia it is used, together with other mosses, such as *Campylopus*, to stuff cushions and mattresses. In Japan, cushion moss is preferred in bonsai landscape design, and in Europe it is commonly used in floral decoration.

Production and international trade *Leucobryum* is sold in local markets and department stores in small packages in many South-East Asian countries. In the Philippines, a kilo of dry, mixed *Leucobryum* material costs about US$ 1 in 1986. It is collected from the wild in nearby mountains. No international trade exists and it is not cultivated commercially.

Properties Laboratory tests showed that water and alcohol extracts of *Leucobryum* have strong anti-microbial activity against bacteria and fungi.

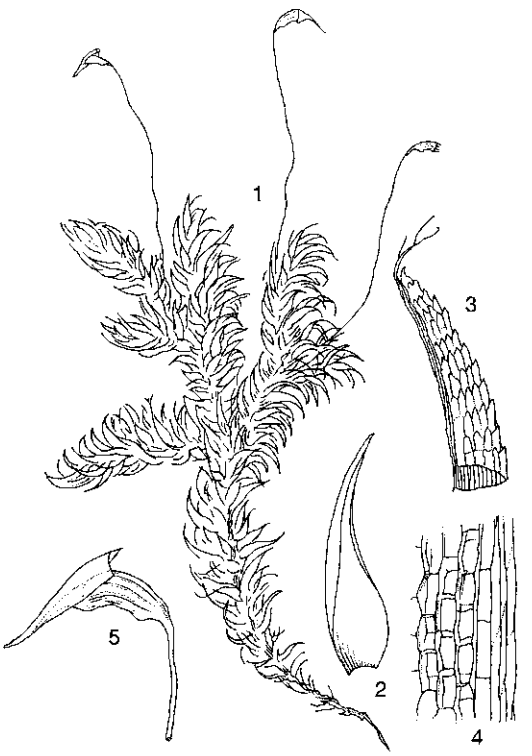
Description Terrestrial mosses, whitish in colour when dry, bluish-green or pale green when wet, forming rounded, compact or more loose cushions, sometimes of considerable size; plants up to 15 cm long, occasionally more. Leaves dense, mostly turned to one side, about 3–10(–15) mm long and 1–1.5 mm wide, thick, composed largely of midrib, with a few rows of narrow, hyaline cells towards the base representing the lamina, several-stratose; midrib in section with 2–several layers of hyaline cells with large circular pores on the inner surface, and with a small central layer of chlorophyllose cells. Sporophytes infrequently present. Capsule erect or inclined, straight or curved, on an often reddish seta, without stomata; peristome teeth 16, bifid, transversely articulated with fine vertical striae between the articulations; operculum with long beak.

Growth and development *Leucobryum* species are usually long lived, slow growing mosses. They are usually dioecious, with male plants in separate clumps or growing in female clumps and then small.

Other botanical information *Leucobryum* is sometimes classified in the family *Dicranaceae*, a somewhat heterogeneous family that is not clearly defined. *Leucobryum* is distinguished by its leaves consisting mainly of midrib composed of 2 or more layers of large hyaline cells.

Ecology Species of *Leucobryum* prefer acidic, wet and humic substrates. Of the three species, *L. aduncum* tolerates more dryness than the other two, which are shade species of the forest floor, trail margins, tree trunks or decaying logs.

Management *Leucobryum* is easily transplant-



Leucobryum aduncum Dozy & Molk. – 1, habit; 2, leaf; 3, leaf apex; 4, cells near leaf margin; 5, capsule with calyptra.

ed from the wild into gardens by transferring whole clumps together with the substrate and placing them under similar conditions as in the wild. Attempts to cultivate and enlarge the clumps by mechanical means have achieved little success.

Genetic resources When the demand becomes too high, populations of *Leucobryum* may easily become endangered. This is already the case locally in Europe, where commercial gathering depleted natural populations of *L. glaucum* in some regions.

Prospects Like *Sphagnum*, *Leucobryum* will remain of limited importance on the market in South-East Asia. Supply from natural populations is limited and large-scale commercial cultivation impossible.

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Benito C. Tan

Sphagnum L.

Sp. pl. 2: 1106 (1753); Gen. pl. ed. 5: 487 (1754).
SPHAGNACEAE
$x = 19$

Major species and synonyms

- *Sphagnum cuspidatum* Hoffm., Deutschl. Fl. 2: 22 (1796), synonym: *S. flaccidifolium* A. Johnson.
- *Sphagnum junghuhnianum* Dozy & Molk., Bryol. Jav. 1: 27 (1854), synonym: *S. gedeanum* Dozy & Molk.
- *Sphagnum perichaetiale* Hampe, Linnaea 20: 66 (1847), synonyms: *S. beccarii* Hampe, *S. holttumii* A. Johnson, *S. japonicum* Warnst. var. *philippinense* Warnst.

Vernacular names Peat moss, bog moss (En). Philippines (Tagalog): lumot.

Origin and geographic distribution *Sphagnum* consists of at least several hundreds of species and is nearly cosmopolitan in range, though usually confined to mountains in the tropics. The three species treated here are widespread in Malesia. *S. cuspidatum* occurs throughout almost all of the northern Hemisphere, *S. junghuhnianum* is widespread in tropical and subtropical Asia, and *S. perichaetiale* has an almost pantropical distribution.

Uses *Sphagnum* is used widely in the floral industry for wreaths or to line hanging baskets. Because of its peculiar leaf structure, which enables the plant to absorb and store water many times its own weight, *Sphagnum* is often used in potting new plants in greenhouse propagation practices. Mixed with humus, it is a good germinating medium for seeds of many economically important plants. Less frequently *Sphagnum* is used in boxing fragile commodities for transport. At the crocodile breeding station in Palawan Island (the Philippines), it is used as a cushion or layering

material for the incubation of reptilian eggs collected from the wild. In Europe and Asia during the Second World War, *Sphagnum* was used extensively as antiseptic wound dressing pad to stop bleeding.

In South-East Asia, unlike in temperate countries, *Sphagnum* bogs have not been exploited as a fuel source owing to the relatively small biomass formed in tropical mountains. For this purpose, the dead, partially decomposed material accumulating in the lower levels in the peat bog is used. This material is also widely used by gardeners as a soil amendment.

Production and international trade The small commercial supplies of *Sphagnum* sold in local markets in South-East Asian countries have always been taken from the wild. The market price of a kilo of pure *Sphagnum* moss in Manila was about US$ 1 in 1986. No international trade of *Sphagnum* from the Malesian region exists.

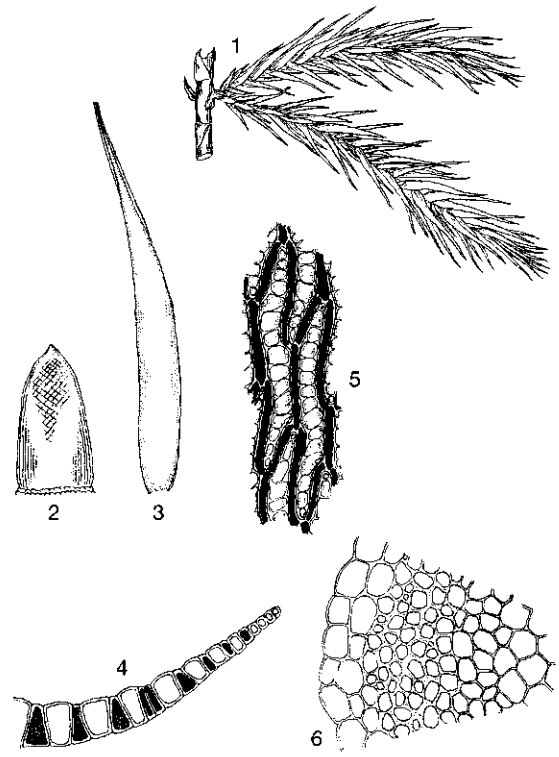
Properties Chemical analysis of *Sphagnum* moss showed the presence of glucose and disaccharide, as well as several organic acid compounds. Antibiotic activity of a peat moss extract has been reported against gram-positive bacteria.

Description Autoecious or dioecious mosses growing in variously coloured tussocks, often forming extensive carpets; stems soft, tufted, often long, differentiated into a cortex of 1–4 layers of often hyaline cells surrounding a central cylinder; branches in fascicles of (1–)2–8, usually differentiated into spreading and pendent branches. Leaves arranged spirally with a 2/5 phyllotaxy, midrib absent; stem leaves often triangular or lingulate in shape, branch leaves lanceolate, oblong to linear; leaf cells in a single layer, consisting of 3 main types: elongated border cells, narrow, living green cells and inflated dead hyaline cells, the latter often with wall fibrils and pores. Sporophytes infrequently produced. Capsule globose, borne on top of a short transparent stalk which is the extension of the branch subtending archegonia; lid convex, lacking a peristome.

Growth and development In general, *Sphagnum* grows slowly. Growth may be slightly over 5 cm/year, but it is much less at higher altitudes. Ripe capsules shrink in dry weather to build up internal pressure, blowing off the lid and ejecting the spores, but this mechanism frequently does not work, and then the lid merely falls off or the capsule disintegrates.

Ecology The *Sphagnum* bog developed in Malesian mountains belongs mostly to the blanket type and covers wet slopes or cliff faces in shaded sites. Blanket bogs develop on acid, mineral-deficient soils, where draining is poor, and peat accumulates year by year. The bogs may cover large areas of level and sloping ground, like a blanket. However, small floating bogs of *Sphagnum* exist around the margin of high mountain lakes, e.g. on Mount Apo in the Philippines. The well-known ecological role played by peat mosses in the succession of aquatic to terrestrial ecosystems, such as that seen in temperate and boreal bogs, has not been documented for South-East Asia. Blanket bogs are very important locally in the water and soil conservation of tropical mountain ecosystems. They are also the germinating and growing sites of acid-loving plants such as the insectivorous *Drosera* species and ferns such as *Matonia* species.

Management A disease called cutaneous sporotrichosis causing ulcerous skin lesions is caused by a fungus that may be present in *Sphagnum* moss. This disease is known in the United States, but may occur elsewhere. It is advised that people



Sphagnum cuspidatum Hoffm. – 1, part of stem with branch fascicle; 2, stem leaf; 3, branch leaf; 4, part of transverse section of branch leaf; 5, cells on dorsal surface of branch leaf; 6, part of transverse section of stem.

who regularly work with fresh or dried peat moss wear gloves and long sleeves to avoid direct contact with cuts or scrapes in the skin.

Genetic resources Local market consumption of *Sphagnum* mosses depends on the wild populations of these slow growing plants. Thia creates a perennial risk of overexploitation or over-depletion of this ecologically important plant resource.

Prospects Peat moss will probably remain a plant product of minor importance in South-East Asia, used particularly in gardening practices. There seems no scope for increasing production and trade due to a limited demand, combined with the limited supply from natural populations and the absence of possibilities for commercial cultivation.

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Benito C. Tan

Spiridens reinwardtii Nees

Nov. Act. Ac. Leop. Car. 11(1): 143 (1823).
SPIRIDENTACEAE
$2n$ = unknown

Synonyms *Spiridens longifolius* Lindb. (1865).

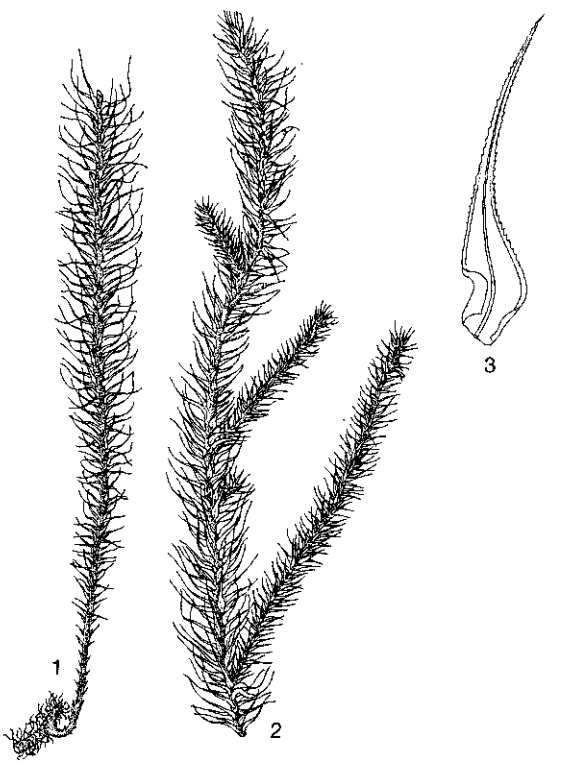
Vernacular names Philippines: lumot-kahoy (Tagalog)

Origin and geographic distribution *S. reinwardtii* is widespread in Java, Sulawesi, the Moluccas, The Philippines, New Guinea and parts of Oceania.

Uses *S. reinwardtii* is used as a binding material in some parts of the Philippines. Around Mount Wilhelm in Papua New Guinea, it is used together with another large moss, *Dawsonia* (3), by indigenous people to decorate their head gear and body wear. It is also used as filler between wood posts or shingles forming the wall and roof of local huts. As an accessory plant growing on the same substrate, *S. reinwardtii* is sold in some plant shops in the Philippines together with *Lycopodium* as ornamental plants.

Description A large dioecious moss, tufted, with short rhizomatous creeping stem, with numerous rhizoids, secondary stems and branches erect to almost pendant, up to 30 cm long, sometimes even longer, densely foliate, bright yellowish-green. Leaves stiff, widely spreading, lanceolate, up to 14 mm × 2 mm, long acuminate, with single, long protruding midrib; leaf margins markedly differentiated, strongly serrate; basal leaf cells long and linear, upper ones small, hexagonal, with thick cell walls, smooth. Sporophytes lateral, with a short seta 1–3 mm long, subtended by the leaves. Capsule narrowly ovoid, slightly curved, up to 5 mm long; peristome teeth in 2 rows, up to 3 mm long; operculum with conical lid and slender beak. Spores papillose, green at maturity.

Ecology *S. reinwardtii* commonly grows on trunks of trees, often of tree ferns, in moist mountain forests. Its presence can be taken to indicate the broad transition zone between lowland and montane rain forests where high relative humidi-



Spiridens reinwardtii Nees – 1, lower part of stem; 2, upper part of stem with capsules; 3, leaf.

ty persists. Its ability to survive severe forest fire was observed on Mount Kitanglad, Mindanao Island (the Philippines) when the burnt population started after a year to produce new shoots from the creeping rhizomes embedded in the adventitious root mats of the trunk of tree ferns.

Management Attempts to grow *S. reinwardtii* as a garden plant in the lowland or in a city environment have not been successful perhaps due to the lack of high relative humidity.

Genetic resources *S. reinwardtii* is widespread and locally common, and not much collected specifically, and it seems not threatened as long as its main habitat, i.e. the transition zone between lowland and montane rain forest with tree ferns, is not destroyed on a large scale.

Prospects It is unlikely that the use of *S. reinwardtii* will increase because it is not much in demand and difficult to bring under cultivation.

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Acronyms of organizations

- ASEAN: Association of South-East Asian Nations (Jakarta, Indonesia).
- CITES: Convention on International Trade in Endangered Species of Wild Fauna and Flora (Lausanne, Switzerland).
- DGIS: Directorate-General for International Cooperation of the Netherlands Ministry of Foreign Affairs (Den Haag, The Netherlands).
- FAO: Food and Agriculture Organization of the United Nations (Rome, Italy).
- FRIM: Forest Research Institute Malaysia (Kepong, Malaysia).
- IEBR: Institute of Ecology and Biological Resources (Hanoi, Vietnam).
- IPGRI: International Plant Genetic Resources Institute (Rome, Italy).
- IUCN: World Conservation Union (Gland, Switzerland).
- LIPI: Indonesian Institute of Sciences (Jakarta, Indonesia).
- ORSTOM: Office de la Recherche Scientifique et Technique Outre-Mer (France).
- PCARRD: Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (Los Baños, the Philippines).
- PROSEA: Plant Resources of South-East Asia (Bogor, Indonesia).
- RDCB: Research and Development Centre for Biology (Bogor, Indonesia).
- TISTR: Thailand Institute of Scientific and Technological Research (Bangkok, Thailand).
- UCL: Université Catholique de Louvain (Louvain, Belgium).
- UNDP: United Nations Development Programme (New York, United States).
- UNESCO: United Nations Educational, Scientific and Cultural Organization (Paris, France).
- UNITECH: Papua New Guinea University of Technology (Lae, Papua New Guinea).
- UPLB: University of the Philippines at Los Baños (Los Baños, The Philippines).
- WARDA: West Africa Rice Development Association (Ivory Coast).
- WHO: World Health Organization (Geneva, Switzerland).
- WU (formerly WAU): Wageningen University (Wageningen, The Netherlands).
- WWF: World Wide Fund for Nature (Gland, Switzerland).

Glossary

abaxial: on the side facing away from the axis (underside)

abortifacient: causing abortion; an agent that causes abortion

abortive: imperfectly developed; effecting an abortion (abortifacient)

abortivum: agent inducing abortion

abrupt: suddenly narrowed or cut off

abscess: a swollen, inflamed area in body tissues, in which pus gathers

accession: in germplasm collections: plant material of a particular collection, usually indicated with a number

acne: inflammatory disease affecting hair follicles and glands of the skin; frequently used to designate acne vulgaris, with lesions on the face, chest and back

acroscopic: facing or directed toward apex

acrostichoid: with sporangia densely covering the abaxial surface of the lamina

aculeate: furnished with prickles; prickly

acumen: the point of an acuminate leaf; the drip-tip

acuminate: ending in a narrowed, tapering point with concave sides

acute: in botany: sharp; ending in a point with straight or slightly convex sides; in medicine: with a short and relatively severe course

acute toxicity: toxicity characterized by a sudden onset, sharp rise and short course

adaxial: on the side facing the axis (upper side)

adenocarcinoma: carcinoma derived from glandular tissue or in which the tumour cells form recognizable glandular structures

adenovirus: a virus belonging to the *Adenoviridae*, a family of DNA viruses

adjacent: next to each other, but not touching or overlapping

adnate: united with another part; with unlike parts fused, e.g. rachis and pinna

adventitious: not in the usual place, e.g. roots on stems, or buds produced in other than terminal or axillary positions on stems

aerial: above ground

aerial root: any root that grows above the ground

agamosporous: having a life cycle in which chromosome segregation and recombination have been circumvented, spores are produced asexually

aglycones: the non-sugar part of glycosides is called the aglycone part or simply the aglycone; aglycones and their glycosides may be present in the same plant; furthermore, the combination of aglycone and sugar will alter the properties of the molecule

agonist: a drug that has affinity for and stimulates physiological activity at cell receptors normally stimulated by naturally occurring substances (see also antagonist)

AIDS: acquired immune deficiency syndrome, an epidemic, transmissible retroviral disease due to infection with HIV (human immunodeficiency virus), in severe cases manifested as a profound depression of cell-mediated immunity

alae: wings, usually long, narrow membranes laterally bordering a stipe, rachis, or costa

alate: winged

alkaloids: large group of organic bases containing nitrogen and usually oxygen that occur for the most part in the form of salts; usually optically and biologically active

allergenic: acting as an allergen; inducing allergy

allergic: pertaining to, caused by, affected with, or of the nature of allergy

allergy: a state of hypersensitivity induced by exposure to a particular antigen (allergen) resulting in harmful immunological reactions on subsequent exposures

alterative: tending to change gradually the condition of the body to a normal state; a drug having this effect

alternate: leaves, etc., inserted at different levels along the stem, as distinct from opposite or whorled

Alzheimer's disease: dementia of insidious onset and gradually progressive course, usually occurring after the age of 50

amenorrhoea: abnormal absence or suppression of the menses

amoebiasis: the state of being affected by amoebae, especially with *Entamoeba histolytica*
amoebicidal: destroying amoebae
anadromous: with the first secondary division of all the pinnae always on the acroscopic side; also so applied to venation patterns in which the first set of veins in each segment is given off on the acroscopic side
anaemia: a condition in which the blood is deficient in red blood cells, in haemoglobin, or in total volume
anaesthesia: loss of the ability to feel pain, caused by administration of a drug or by other medical interventions
anaesthetic: producing loss of sensation; producing loss of the ability to feel pain; an agent used to abolish the sensation of pain
analeptic: restorative, especially a stimulant to the central nervous system
analgesia: absence of sensibility to pain; the relief of pain without loss of consciousness
analgesic: relieving pain; not sensitive to pain; an agent alleviating pain without causing loss of consciousness
anastomosing: of veins, forming a network or reticulum
aneuploid: with other than the exact multiple of the haploid chromosome complement
angina pectoris: a paroxysmal thoracic pain, often radiating to the arms. It is most often due to deficiency of blood in the myocardium and precipitated by effort or excitement
angiotensin: any of a family of polypeptide hormones formed by the catalytic action of renin on renin substrate and stimulating contraction of the muscular tissue of the capillaries and arteries
angular: being angled
angulate: bearing corners or sharp angles
anisophyllous: having leaves unequal in size and shape at any one point along a branch; cf. isophyllous
anisotomous: dichotomies resulting in unequal branching
annual: a plant which completes its life cycle in one year
annular: used of any organs disposed in a circle
annulus: a ring or a ring-like part
anorexia: lack or loss of the appetite for food
antagonist: a substance that tends to nullify the action of another, as a drug that binds to a cell receptor without eliciting a biological response (see also agonist)
anterior: of time, previous; of place, position in front, or turned away from the axis
anthelmintic: a drug or agent that destroys or causes expulsion of intestinal worms
antheridium: the male reproductive organ in pteridophytes
antherozoid: a motile gamete produced in an antheridium; also called spermatozoid
anthocyanidins: the aglycone part of anthocyanins, compounds closely related to the flavonoids but derived from the 2-phenyl benzopyrylium cation
anthocyanins: glycosides of the anthocyanidins
anthracnose: a disease characterized by distinctive limited lesions on stem, leaf or fruit, often accompanied by dieback and usually caused by a *Gloeosporium* or a *Colletotrichum*, imperfect fungus; the perfect state of the fungus, when known, is *Gnomonia* or *Glomerella*
anthraquinones: a subgroup of the quinones, in which the dione is conjugated to the condensed polycyclic aromatic system of anthracene
anti-inflammatory: suppressing or counteracting inflammation; an agent that suppresses or counteracts the inflammatory process
anti-oestrogen: a substance capable of inhibiting the biological effects of female sex hormones
anti-ulcerogenic: preventing the production of ulcers
antiarrhythmic: preventing or alleviating arrhythmia (any variation from the normal rhythm of the heartbeat); an agent that prevents or alleviates arrhythmia
antibiotic: any of a large class of substances produced by various micro-organisms and fungi and having the power of arresting the growth of other micro-organisms or destroying them; a chemical, produced by plants, animals or synthetically, having similar properties
anticholinergic: blocking the passage of impulses through the parasympathetic nerves; an agent that blocks the parasympathetic nerves
antidiabetic: preventing or alleviating diabetes
antidiarrhoeal: counteracting diarrhoea
antidysenteric: preventing, alleviating or curing dysentery
antigastralgic: preventing or alleviating gastric colic
antihepatotoxic: counteracting injuries to the liver
antihistamine: a drug that counteracts the action of histamine; often used against allergy
antileishmanial: effective against leishmania (infection caused by a *Leishmania* protozoa)
antileukaemic: preventing or alleviating leukaemia

antimicrobial: killing micro-organisms, or suppressing their growth or multiplication; an agent acting so
antimitotic: inhibiting or preventing mitosis
antioxidant: a substance that opposes oxidation or inhibits reactions promoted by oxygen or peroxides; many of these substances are used as preservatives in various products
antiplasmodial: destroying plasmodia
antiprotozoal: destroying protozoa, or checking their growth or reproduction
antipyretic: relieving or reducing fever; an agent that relieves or reduces fever
antirheumatic: relieving or preventing rheumatism
antiseptic: pertaining to asepsis (prevention of contact with micro-organisms); preventing decay or putrefaction; a substance inhibiting the growth and development of micro-organisms without necessarily killing them
antispasmodic: relieving spasm; an agent that relieves spasm
antispermatogenic: preventing or inhibiting the production of semen or spermatozoa
antitoxic: counteracting poison
antrorse: directed upwards (opposed to retrorse)
aperient: a mild or gentle purgative; also called laxative
aperture: gap or mouth
apex (plural: apices): the tip or summit of an organ
aphrodisiac: stimulating sexual desire; a drug arousing the sexual instinct
apical: at the apex of any structure
apiculate: ending abruptly in a short point
apiculus: a small abrupt flexible point at the apex of a pinna or pinnule; adj. apiculate
apogamous: applied to pteridophytes in which a sporophyte develops from gametophyte cells, other than a fertilized egg
apogamy: reproduction without the fusion of female and male gametes, usually without meiosis; frequently found in ferns of arid regions where the water required to enable the motile male gametes to reach the female gametes is lacking
apomict: a plant that produces viable spores without fertilization
apoplexy: sudden neurologic impairment due to a cerebrovascular disorder, either an arterial occlusion or an intracranial haemorrhage; copious extravasation of blood within any organ
apospory: the formation of a gametophyte from a sporophyte by asexual means without meiosis or spore formation
appendage: a part added to another; attached secondary or subsidiary part, sometimes projecting or hanging
appressed: lying flat for the whole length of the organ
approximate: close together but not united
arachnoid: like a cobweb
arborescent: attaining the size or character of a tree
archegonium: the female reproductive organ in pteridophytes
arcuate: curved like an arch
areolate: with irregular squares or angular spaces marked out by veins on the leaf surface
areole: irregular square or angular space marked out by veins on the leaf surface
arista: a long bristle-like point
aristate: having a stiff bristle-like tip
arthritis: inflammation of a joint or joints
articulate: jointed, or with places where separation takes place naturally
ascariasis: infection by the roundworm *Ascaris lumbricoides*, which is found in the small intestine and causes colicky pains and diarrhoea, especially in children
ascending: curving or sloping upwards
asexual: sexless; not involving union of gametes
asperous: rough to the touch
asphyxia: pathological changes caused by lack of oxygen in respired air, resulting in hypoxia and hypercapnia
assurgent: abruptly ascending
asthma: a chronic disorder characterized by paroxysms of the bronchi, shortness of breath, wheezing, a suffocating feeling, and laboured coughing to remove tenacious mucus from the air passages
astringent: causing contraction; an agent or substance causing shrinkage of mucous membranes or raw or exposed tissues
asymmetrical: having a different outline on each side of a central axis
attenuate: gradually tapering
auct.: auctorum (Latin); of authors
auct. non: auctorum non (Latin); of authors not ... (author name); used after a scientific name when this name is erroneously applied by several authors to material actually belonging to a different species than the species described by the author mentioned
auricle: a small lobe or ear
auriculate: eared, having auricles
awn: a bristle-like appendage, especially occurring on the glumes of grasses

axil: the upper angle between the leaf and the stem
axillary: arising from the axil
axis: the main or central line of development of a plant or organ
Ayurvedic: traditional Hindu system of medicine based largely on homeopathy and naturopathy
bacillary dysentery: infectious disease caused by bacteria of the genus *Shigella*, and marked by intestinal pain, tenesmus, diarrhoea with mucus and blood in the stools, and variable toxaemia
bactericidal: destroying bacteria
bactericide: an agent that destroys bacteria
basal: of or pertaining to the base
base: the proximal portion of a structure, that part nearest the point of attachment
basifixed: attached or fixed by the base
basionym: the synonym of a scientific name that supplies the epithet for the correct name
basiscopic: on the side towards the base
bathyphyll: a basal lamina in some high-climbing ferns in *Lomariopsis* and related genera; cf. acrophyll
benzoquinones: quinones with the dione conjugated to an aromatic nucleus
biauriculate: having two auricles
bicolorous: a structure marked in two colours or shades
bidentate: having two teeth; doubly dentate, as when the marginal teeth are also toothed
bifid: forked, divided in two but not to the base
bifurcate: forked or cleft, sometimes twice forked
bilabiate: two-lipped
bilateral: having two, often opposite, sides
bilharzia: schistosomiasis
biliousness: a symptom complex with nausea, abdominal discomfort, headache and constipation, formerly attributed to excessive secretion of bile
bipinnate: when the primary divisions (pinnae) of a pinnate leaf are themselves pinnate
bipinnatifid: having leaflets or pinnae divided into lateral lobes down to half way to the midrib
biseriate: arranged in two rows
bivalent: a pair of chromosomes, usually one contributed from each parent
bivalvate: bearing two indusial walls on either side of the sorus, as in *Hymenophyllum*
blade: the expanded part of a leaf, i.e. the entire frond excluding the petiole; usually called lamina in ferns
branch: a division of a main stem or adventitious root; in *Equisetum*, one of few to many small stems forming whorls at intervals along the larger, main stem
branchlet: a small branch
breeding: the propagation of plants or animals to improve certain characteristics
bristle: a stiff hair or a hair-like stiff slender body
bronchitis: inflammation of one or more bronchi
bud: the nascent state of a leaf
bulbil: an aerial bulb or bud which, on separation, is capable of propagating the plant
bulbous: swollen; nearly spherical
bullate: surface much blistered or puckered
caducous: falling off early
caespitose: forming mats or spreading tufts
calcareous: consisting of or containing chalk (calcium carbonate)
calculus: an abnormal concretion within the body and usually consisting of mineral salts; also called stone
cancer: a malignant neoplasm or tumour, characterized by a morbid proliferation of epithelial cells in different parts of the body, resulting in progressive degeneration and often ending fatally
canopy: the uppermost leafy layer of a tree, forest or crop
capillary: hair-like
capitate: headed, like the head of a pin in some stigmas, or collected into compact headlike clusters as in some inflorescences
carbohydrates: compounds formed from water and carbondioxide; they can be grouped into sugars and polysaccharides
carcinogenesis: the production of carcinoma
carcinogenic: producing carcinoma
carcinoma: a malignant new growth consisting of epithelial cells, which tends to infiltrate surrounding tissues and give rise to metastasis (transfer of a disease from one part of the body to another)
cardiac: pertaining to, situated near, or affecting the heart; pertaining to the opening between the oesophagus and the stomach
cardiac glycosides: natural products characterized by a specific effect on myocardial contraction and atrioventricular conduction
cardioactive: having an effect on the heart
cardiovascular: pertaining to the heart and blood vessels
carinate: keeled
carnose: fleshy
carotenoids: a subgroup of the terpenoids, containing 8 isoprene units (C_{40}) named after β-carotene
cartilaginous: hard and tough
castaneous: chestnut-coloured, dark brown

catadromous: a fern frond in which the first secondary division of the median pinnae is on the basiscopic side; also applied to venation patterns in which the first set of veins in each segment is given off on the basiscopic side
catarrh: inflammation of the lining tissue of various organs, particularly of the nose, throat, and air passages, and characterized by an outpouring of mucus
catenate: united or linked as in a chain
caudate: with a tail-like appendage
caudex: trunk surrounded by leaf-bases and adventitious roots
cell: the basic unit of plant structure consisting, at least when young, of a protoplast surrounded by a wall
central: pertaining to or of the center
cerebrovascular: pertaining to the blood vessels of the cerebrum or brain
chlorophyll: green pigment in plants which absorbs light for photosynthesis
cholera: acute, infectious inflammation of the intestine, caused by an enterotoxin elaborated by *Vibrio cholerae*, and characterized by severe, watery diarrhoea
cholinergic: stimulated, activated or transmitted by acetylcholine; applied to the sympathetic and parasympathetic nerve fibres that liberate acetylcholine at a synapse when a nerve impulse passes (see also: anticholinergic)
cholinesterase: enzyme that catalyses the cleavage of the acyl group from various esters of choline, including acetylcholine, and several related compounds, and which occurs primarily in the serum, liver and pancreas
chronic: persisting over a long period of time
ciliate: with a fringe of hairs along the edge
circinnate (circinate): coiled in a spiral with the tip innermost
circular: having the shape of a circle
cirrhosis: liver disease characterized by diffuse, interlacing bands of fibrous tissue that divide the hepatic parenchyma into nodular areas
clathrate: of scales, with a latticed appearance due to the cells having thickened lateral walls and transparent surface walls
clavate: club-shaped or thickened towards the end
clone: a group of plants originating by vegetative propagation from a single plant and therefore of the same genotype
close-set: set very close or touching
clustered: compactly gathered together; with several stems
coalesce: come together and form one whole
coenosorus: a compound sorus, made up of several contiguous or merged sori
coma: in medicine: a state of unconsciousness from which the patient cannot be aroused; in botany: the hairs at the end of some seeds; a tuft of leafy bracts or leaves at the top of an inflorescence (e.g. pineapple)
commissure: a juncture or seam; in *Pellaea*, a more or less continuous marginal sorus formed when laterally expanded fertile vein endings coalesce
compact: pressed together or closely joined; in rhizomes, those with short internodes and closely spaced stipes
compound: in botany: of two or more similar parts in one organ, as in a compound leaf or compound fruit; in chemistry: a substance consisting of 2 or more elements combined chemically in fixed proportions
concave: hollow
conceptacle: a sac-like reproductive structure containing several sporangia, as in *Marsilea*
concoction: a combination of crude materials that are prepared (cooked) together
concolourous: similarly coloured on both sides or throughout; of the same colour as a specified structure
confluent: blended into one, passing by degrees from one into the other
conform: similar in shape and size to others; usually said of an apical pinna in comparison with the lateral pinnae of a lamina
conjunctivitis: inflammation of the conjunctiva
connate: united or joined
connective: tissue between the pollen sacs of an anther
connivent: having a gradually inward direction, as in many petals (convergent)
conspecific: belonging to the same species
constipation: a condition of the bowels in which the expulsion of waste matter is infrequent and difficult
contiguous: touching but not united, directly bordering
continuous: not interrupted
contorted: twisted or bent
contraceptive: reducing the likelihood of or preventing conception; an agent that reduces the likelihood of or prevents conception
convex: having a more or less rounded surface
convulsant: producing or causing convulsions
convulsion: a violent and involuntary contraction of the voluntary muscles
cordate: heart-shaped, as seen at the base of a leaf, etc., which is deeply notched

coriaceous: of leathery texture
corticosteroid: any of the 21-carbon steroids elaborated by the adrenal cortex (excluding sex hormones of adrenal origin) in response to the release of ACTH or angiotensin II; used clinically for hormone replacement therapy for suppression of ACTH secretion
costa: a midrib (i.e. of a leaf); in ferns applied to the vascular axis of a blade in simple fronds, or else to the axis of a primary pinna
costate: having a midrib
costule: the axis or midvein of a pinnule
coumarins: benzo-α-pyrone (α-chromone) derivatives
cover crop: a close-growing crop primarily grown for the purpose of protecting and improving soil between periods of regular crop production or between trees or vines in orchards and plantations
creeping: extending horizontally in or on the soil
crenate: the margin notched with blunt or rounded teeth
crenulate: slightly crenate, with small teeth
crispate: irregularly curled or crinkled
cristate: in ferns, having a tasselled margin to the fronds
crozier: the coiled young frond, sometimes called a fiddlehead
cultivar: an agricultural or horticultural variety that has originated and persisted under cultivation, as distinct from a botanical variety; a cultivar name should always be written with an initial capital letter and given single quotation marks (e.g. banana 'Gros Michel')
cuneate: wedge-shaped; triangular, with the narrow end at the point of attachment, as the bases of leaves or petals
cuspidate: abruptly tipped with a sharp rigid point
cylindric: elongate, with a circular cross-section
cyst: a stage in the life cycle of certain parasites, during which they have a protective wall
cytokine: generic term for nonantibody proteins released by a cell population on contact with a specific antigen and acting as intercellular mediators
cytoplasm: the protoplasm of a cell, excluding the nucleus
cytotoxic: pertaining to or exhibiting a destructive effect on certain cells
decaploid: having 10 sets of chromosomes
deciduous: shedding, applied to leaves, scales, etc.
decompound: several times divided or compounded
decongestant: an agent that reduces congestion or swelling
decumbent: reclining or lying on the ground, but with the summit ascending
decurrent: extending down and adnate to the petiole or stem, as occurs in some leaves
decurved: bent downward
deflexed: abruptly recurved; bent downwards or backwards
degrade: of timber, any effect that lowers the grade or quality
dehisce: the opening of spore-producing organs and the release of the spores
delicate: fragile; easily broken
deltate: of a frond or leaflet, having the form of an equilateral triangle
deltoid: shaped like an equilateral triangle
dentate: margin prominently toothed with the pointed teeth directed outwards
denticulate: minutely toothed
depauperate: diminutive, looking starved and underdeveloped
depressed: sunk down, as if flattened from above
depurative: tending to purify or cleanse
dermatitis: inflammation of the skin typically marked by reddening, swelling, oozing, crusting or scaling
dermatomycosis: superficial fungal infection of the skin or its appendages, with the term including dermatophytosis
dermatophyte: a fungus parasitic on the skin
dermatophytosis: any superficial fungal infection caused by a dermatophyte and involving the horny layer of skin, hair and nails
determinate: of inflorescences, when the terminal or central flower of an inflorescence opens first and the prolongation of the axis is arrested; of shoot growth, when extension growth takes the form of a flush, i.e. only the previously formed leaf primordia unfold
diabetes: a general term referring to disorders characterized by the excretion of excessive amounts of urine; when used alone, usually referring to diabetes mellitus, i.e. a chronic syndrome of impaired carbohydrate, protein and fat metabolism owing to insufficient secretion of insulin or tissue insulin resistance
diaphoretic: pertaining to, characterized by, or promoting (profuse) perspiration; an agent inducing sweating, having the power to increase perspiration
diarrhoea: a profuse, frequent, and loose discharge from the bowels
dichotomous: forked, parted by pairs
dictyostele: a cylindrical arrangement of vascular tissue consisting of a number of separate

strands; in transverse section these strands appear as a ring of separate bundles

digestibility: the percentage of a foodstuff taken into the digestive tract that is absorbed into the body

digitate: a compound leaf whose leaflets diverge from the same point like the fingers of a hand

dilated: expanded into a flat structure

dimorphic (*dimorphous*): of two forms, as may occur with branches, etc.

dioecious: with unisexual gametophytes

diploid: with two sets (genomes) of chromosomes, as occurs in somatic or body cells; usually written $2n$, having twice the basic chromosome number of the haploid germ cells

discrete: remaining separate

disjunct: separated

dispersal: the various ways by which seeds are scattered, e.g. by wind, water or animals

dissected: divided into many slender segments

distal: situated farthest from the place of attachment

distant: similar parts that are well separated and not overlapping or touching at the edges; stipes that are widely spaced; not approximate

distichous: regularly arranged in two opposite rows on either side of an axis

diterpenes: a subgroup of the isoprenoids, formed by coupling of 4 C_5 units

diuresis: increased discharge of urine

diuretic: tending to increase the flow of urine; an agent that promotes the excretion of urine

dorsal: back; referring to the back or outer surface of a part or organ (abaxial)

dorsiventral: having structurally different upper and lower surfaces

dropsy: an abnormal accumulation of serous fluid in connective tissue, causing puffy swelling; oedema

dysentery: any of various diseases characterized by inflammation of the intestines, abdominal pain and frequent bloody, mucous faeces

dysmenorrhoea: painful menstruation

dyspepsia: a condition of disturbed digestion

dyspeptic: relating to or having dyspepsia

dysphoria: malaise, disquiet, restlessness; opposite of euphoria

dyspnoea: laboured or difficult breathing

dystonia: distorted or impaired movements resulting from disordered muscle tonicity

dystonic: pertaining to or characterized by dystonia

dysuria: difficult or painful urination

EC50: median effective concentration, i.e. the concentration that produces the desired effect in 50% of a test population

echinate: bearing spines or bristles

egg: the female sex cell (gamete)

eglandular: without glands

elaters: in *Equisetum*, appendages of the spore which help in dispersal

elfin forest: a low type of montane forest with trees of about 15 m tall or less

ellipsoid: a solid which is elliptical in outline

elliptic(al) : oval in outline but widest about the middle

elongate: much longer than wide

emarginate: notched at the extremity

emargination: a V-shaped sinus at the apex of a lobe or tooth

emetic: tending to induce or cause vomiting; an agent that induces or causes vomiting

emeto-cathartic: an agent that is both emetic and cathartic

emmenagogue: a substance or measure that induces menstruation

emollient: soothening and softening; an agent that soothes or softens the skin or soothes an irritated internal surface

emphysema: pathological accumulation of air in organs or tissues, especially applied to the lungs

encephalitis: inflammation of the brain

enema: a liquid injected into the rectum

entire: with an even margin without teeth, lobes, etc.

ephemeral: a plant which completes its life-cycle in a very short time

epidermis: in plants, the true cellular skin or covering of a plant below the cuticle; in humans, the outermost and nonvascular layer of the skin

epilepsy: any of a group of syndromes characterized by recurrent, transient disturbances of the brain function, with manifestations including unconsciousness and uncontrolled motion

epileptic: pertaining to epilepsy

epipetric: growing on rocks

epiphyte: a plant that grows on another plant but without deriving nourishment from it

epiphytic: growing as an epiphyte

epithet: the second part of the scientific name of a species, the first part denoting the genus to which the species belongs

epizoochory: dispersal of plants by animals carrying them on their fur

equilateral: equal on both sides of an axis

erect: directed towards summit, not decumbent

erecto-patent: between spreading and erect

erose: of a margin, finely and irregularly eroded or incised
essential oil: a volatile product, obtained from a natural source, which agrees with that source in odour and name; in a narrow sense, only volatile products obtained by steam or water distillation are called essential oils
ex situ: in an artificial environment or unnatural habitat
excurrent: running or pointing outward or away from the point of origin
exindusiate: of a sorus, having no indusium
exine: outer layer of a spore wall (or second layer, if perine is present)
expectorant: promoting the ejection of mucus or other fluids from the respiratory tract; an agent tending to promote discharge of mucus or other fluids from the respiratory tract
extract: a concentrated preparation of a vegetal or animal drug obtained by removing the active constituents with a suitable solvent
extraction: any process for separating aroma compounds from animal or plant matter using a volatile solvent; the product is called a concrete; the composition, and hence odour quality, of an aromatic extract depends strongly on the nature of the solvent used
extrorse: directed outward, as the dehiscence of an anther
exudate: the secreted substance
F_1, F_2: symbols used to designate the first generation, second generation, etc., after a cross
falcate: sickle-shaped
farinose: coated with fine, meal-like powder
febrifuge: an agent serving to reduce fever
ferrugineous: rust-coloured, reddish-brown
fertilization: union of the gametes (egg and sperm) to form a zygote
fertilization (biology): union of the gametes (egg and sperm) to form a zygote
fibre: in plants: any long, narrow cell of wood or bark other than vessel or parenchyma elements; in humans: an elongated, threadlike structure
fibre pit: a pit in the cell wall of a fibre
fibrosis: the formation of fibrous tissue
fibrous: composed of or containing fibres
filiform: slender; threadlike
fimbriate: fringed
fissured: provided with fissures (cracks of considerable length and depth), e.g. in the bark of some trees
flabellate: fan-shaped, dilated in a wedge-shape, sometimes plaited (folded)
flatulence: the presence of excessive amounts of air or gases in the intestine
flavanoles: a subgroup of the flavonoids
flavanones: a subgroup of the flavonoids
flavones: a subgroup of the flavonoids
flavonoids: a group of natural products in which the basic structure is the 2-phenyl-chromane skeleton
flavonoles: a subgroup of the flavonoids
flexuose (flexuous): zigzag or bent alternately in opposite directions
fodder: something fed to domesticated animals, especially coarse, dried food from plants (hay, straw, leaves)
foliaceous: leaf-like
forage: grassland and fodder plants suitable as feed for herbivores, usually with lower nutrient concentration and digestibility than concentrates such as grain
free: neither adhering nor united
frond: the whole leaf of a fern or cycad, including the lamina and the stipe or petiole
fungicidal: destroying fungi
fungicide: an agent that destroys fungi or inhibits their growth
furcate: forked
furfuraceous: covered with minute flaky particles
fuscous: dusky
gametocyte: a cell capable of dividing to form gametes
gametophyte: the gamete-producing (sexual) generation of the pteridophyte life cycle; a prothallus
gastric: pertaining to, originating in, or affecting the stomach
gastritis: inflammation of the stomach
gastro-enteritis: acute inflammation of the lining of stomach and intestines, which may be caused by food poisoning, ingestion of irritating food or drinks, or psychological factors
gemmiferous: bearing asexual buds or bulbils
genetic erosion: the decline or loss of genetic variability
genus: the smallest natural group containing distinct species
germplasm: the genetic material that provides the physical basis of heredity
giardiasis: common infection of the small intestine with the flagellate protozoan *Giardia lamblia*
glabrescent: becoming glabrous or nearly so
glabrous: devoid of hairs
gland: a unicellular or multicellular, filiform, clavate, capitate, or globular epidermal appendage secreting and/or containing resinous or waxlike, often highly coloured substances

glandular: having or bearing secreting organs or glands

glaucoma: a group of eye diseases characterized by an increased intraocular pressure which causes pathological changes in the eye and impaired vision, and which may lead to blindness

glaucous: pale bluish-green, or with a whitish bloom which rubs off

globose: spherical or nearly so

globular: nearly spherical

glochidium (plural: glochidia): a minute, terminally barbed, spine-like hair present on the microspore-bearing structures of *Azolla*

glucoside: compound that is an acetal derivative of sugars and that on hydrolysis yields glucose

glycoside: compound that is an acetal derivative of sugars and that on hydrolysis yields one or more molecules of a sugar and often a noncarbohydrate

glycosides: see aglycones

gonorrhoea: a venereal disease characterized by inflammation of the mucous membrane of the genitourinary tract and a discharge of mucus and pus

gout: a group of disorders of (purine) metabolism, characterized by inflammation of a joint, paroxysmal recurrent pain and an excess of uric acid in the blood

gouty: characterized by inflammation of a joint, paroxysmal recurrent pain and an excess of uric acid in the blood

gram-negative: losing the stain or decolorized by alcohol in Gram's staining method, which is a primary characteristic for bacteria with a cell wall consisting of a thin layer of peptidoglycan with an outer membrane of lipoprotein and lipopolysaccharide

gram-positive: retaining the stain or resisting decolorization by alcohol in Gram's staining method, which is a primary characteristic for bacteria with a cell wall consisting of a thick layer of peptidologlycan with attached teichoic acids

green manure: green leafy material applied to and mostly worked into the soil to enrich the soil with nutrients and organic matter

gymnosperm: a seed plant with the ovules borne on the surface of a sporophyll

habit: external appearance or way of growth of a plant

habitat: the kind of locality in which a plant grows

haemoptysis: expectoration of blood or blood-stained sputum from some part of the respiratory tract

haemorrhage: bleeding; the escape of blood from blood vessels

haemorrhoid: a mass of dilated veins in swollen tissue situated near the anal sphincter

haemostatic: arresting the flow of blood; an agent that checks the flow of blood

haemostyptic: haemostatic

hair: an epidermal outgrowth composed of a single elongate cell or a single file of cells

haploid: refers to the basic chromosome number (n) of a plant as found in the gametes and in all cells of normal gametophytes

hastate: with more or less triangular basal lobes diverging laterally

hepatitis: inflammation of the liver

hepatotoxic: having a toxic effect on liver cells

herbaceous: with the texture, colour and properties of a herb; not woody

herbivore: a plant-eating animal

herpes: any of several inflammatory diseases of the skin caused by a herpesvirus and characterized by clusters of vesicles

herpes simplex: group of acute infections caused by herpes simplex virus type 1 or type 2, characterized by the development of one or more small fluid-filled vesicles on the skin or mucous membrane, and occurring as a primary infection or recurring because of reactivatio

heteromorphic: varying in number or form

heterosis: exceptional vigour of organisms through crossbreeding between two different types

heterosporous: producing spores of 2 sizes, the larger (the mega-spore) giving rise to a female mega-gametophyte, the smaller (the micro-spore) giving rise to a male microgametophyte

hexaploid: having six sets of chromosomes ($6n$)

hirsute: with rather coarse stiff hairs

hispid: covered with long rigid hairs or bristles

hispidulous: minutely hispid

histochemical: pertaining to the chemical components or activities of cells and tissues

HIV: a virus that is the aetiological agent of acquired immunodeficiency syndrome (AIDS); two serotypes are distinguished: HIV-1, with a worldwide distribution, and HIV-2, which is largely confined to West Africa

Hodgkin's disease: a form of malignant lymphoma characterized by painless, progressive enlargement of the lymph nodes, spleen and general lymphoid tissue

homosporous: producing only one kind of spore which develops into a gametophyte having both male and female gametes

hyaline: almost transparent

hybrid: the first generation offspring of a cross between two individuals of different species or taxa

hybridization: the crossing of individuals of different species or taxa

hydathode: the enlarged tip of a vein; an epidermal structure supposedly for the secretion or exudation of water

hygroscopic: susceptible to extending or shrinking on application or removal of water or vapour

hyperaccumulator: a plant that accumulates metals from the substrate to such an extent that it achieves metal concentrations over 1 mg/kg

hyperglycaemia: an abnormally increased glucose concentration in the blood

hypertension: high arterial blood pressure

hypoglycaemic: pertaining to, characterized by, or producing an abnormally decreased glucose concentration in the blood (hypoglycaemia)

imbricate: overlapping like tiles; in a flower bud when one sepal or petal is wholly external and one wholly internal and the others overlapping at the edges only

immersed: embedded, as of sori that are surrounded by leaf-tissue

impetigo: a contagious, purulent skin disease, caused by group A streptococci or *Staphylococcus aureus*, and mostly seen in children, usually on the face

in situ: in the natural environment

in vitro: outside the living body and in an artificial environment

inbreeding: breeding through a succession of parents belonging to the same stock

incised: cut deeply

included: contained within, as a veinlet within an areola

indefinite growth: said of a plant member that, given continuous optimum growing conditions, would continue growing indefinitely, as do nails or hair in a human being, e.g. *Adiantum incisum* and *Lygodium* spp.

indeterminate: of inflorescences, a sequence in which the terminal flowers are the last to open, so that the floral axis may be prolonged indefinitely by the terminal meristem; of shoot growth: when the shoot apex forms and unfolds leaves during extension growth, so that shoot growth can continue indefinitely

indigenous: native to a particular area or region

indigestion: lack or failure of digestion

indumentum: a covering, as of hairs, scales, etc.

indurated: becoming firmer or harder

indusiate: bearing an indusium

indusium: a thin flap of tissue covering at least the young sorus

inequilateral: unequal-sided

inflammation: a protective response of the body in response to injury, infection, irritation, etc., aimed at destroying or isolating the injurious agent and injured tissue, and characterized by redness, pain, heat, and swelling

inflexed: bent or curved inward toward the centre

influenza: an acute highly contagious virus disease characterized by sudden onset, fever, prostration, severe aches and pains, and progressive inflammation of the respiratory mucous membrane

infra- or intramarginal: slightly set back from the margin

inframedial: below the middle; son a little closer to the costa or costule than to the margin

infraspecific: referring to any taxon below the species level

infusion: a liquid extract obtained by steeping or soaking something in a liquid for the purpose of extracting its medicinal principles without boiling; the therapeutic introduction of a fluid, other than blood, into a vein

insecticidal: destroying or controlling insects

insecticide: an agent that destroys insects

insomnia: sleeplessness

internode: the portion of the stem between two nodes

intricate: finely interwoven

introrse: turned inward, towards the axis, as the dehiscence of an anther

ischias: pain in the inferior dorsal portion of the hip bone (ischium)

isoflavonoids: a subgroup of the flavonoids, in which the basic structure is the 3-phenyl chromane skeleton

isomer: a compound, radical or ion containing the same numbers of atoms of the same elements in the molecule as one or more others, and hence having the same molecular formula, but differing in the structural arrangement of the atoms and consequently in one or mo

isophyllous: leaves equal in size and shape at any point on the branch. cf. see also: anisophyllous

isotomous: having all dichotomies resulting in equally thin branches. cf. see also: anisotomous

jaundice: a syndrome marked by hyperbilirubinaemia and deposition of bile pigments in the skin, mucous membranes and eyeball, resulting in yellowish pigmentation of these body parts

joint(ed): an articulation, like a node in plants and

a place of union of two bones in the human body; articulated

juvenile: young; not adult in morphology; in ferns, juveniles may be precociously fertile

kaolin: a fine, usually white clay resulting from extreme weathering of aluminous minerals

lacerate: torn; irregularly cleft or cut

laciniate: slashed, cut into narrow lobes

lamina: see blade

laminate: consisting of plates or layers

lanceolate: lance-shaped; much longer than broad, being widest at the base and tapering to the apex

laxative: aperient, mildly purgative; an agent that promotes evacuation of the bowel

leaf gap: a point in the stele at which the vascular supply to a leaf is attached

leaflet: one part of a compound leaf

lecitins: glycerophosphoric acid derivatives, in which 2 free hydroxyl groups of the glycerol are esterified with fatty acids, while 1 of the 2 remaining groups of the phosphoric acid residue is esterified to an alcohol

lectins: proteins of glycoproteins, which are not antibodies or enzymes, but which have the ability to attach themselves to specific sugars; the binding is not covalent, and the sugar can either be free or constituent part of a larger molecule, which may be present

leprosy: a chronic, infectious, slowly progressive disease, caused by *Mycobacterium leprae*, characterized by lesions in the skin, mucous membranes, nerves, bones and viscera, and manifested by a broad range of clinical symptoms

leptosporangiate: with each sporangium originating from a single cell and the wall consisting of a single layer of cells

leucoderma: a skin abnormality that is characterized by a usually congenital lack of pigment in spots or bands and produces a patchy whiteness

leucopaenia: reduction in the number of leucocytes (white blood cells) in the blood

leucorrhoea: a whitish, viscid discharge from the female genitals

leukaemia: a malignant, progressive disease of the blood-forming organs, with distorted proliferation and development of the white corpuscles (leucocytes) and their precursors

ligand: a molecule that binds to another molecule, used especially to refer to a small molecule that binds specifically to a larger molecule, e.g. an antigen binding to an antibody, or a hormone or neurotransmitter binding to a receptor

lignans: a group of natural products (dimers) derived from condensation of 2 phenylpropane units

lignin: a colloidal polymer of varying chemical structure used as secondary wall material in xylem vessels, tracheids and sclerenchyma fibres

ligulate: possessing an elongated flattened strap-shaped structure or ligule

linear: long and narrow with parallel sides

liquorice: black substance extracted from the root of *Glycyrrhiza glabra* L. used in medicine especially against coughs and colds

lobe: any division of an organ or specially rounded division

lobed: divided, but not to the base

lobulate: having small lobes

long-creeping: growing horizontally for at least a few cm. In rhizomes, usually with the stipes distant

lumbago: pain in the lumbar region of the back (loins); lumbar rheumatism

lumen: the space enclosed by the walls of a cell

lunulate: crescent-shaped, like a new moon

lupus: name originally given to localized destruction or degeneration of the skin caused by various cutaneous diseases; formerly the term was used to designate lupus vulgaris and lupus erythematosus, nowadays it is only used with modifier

lustrous: shiny

Malesia: the biogeographical region including Malaysia, Indonesia, the Philippines, Singapore, Brunei and Papua New Guinea

malignant: tending to become progressively worse and to result in death

mangrove: a brackish-water coastal swamp of tropical and subtropical areas that is partly inundated by tidal flow

margin: the edge or boundary line of a body

marginal: attached to or on the edge

marginate: furnished with a margin of distinct character

massula: group of microspores enclosed in a hardened mucilage

medial: pertaining to the middle; in son, those positioned mid-way between the costa or costule and the margin

median: belonging to the middle

medullated protostele: protostele in which the xylem has a core of non-vascular tissue

megasporangium: sporangium within which megaspores are formed

megaspore: the larger of two kinds of spores in heterosporous pteridophytes, which after germi-

nation produces a female (archegoniate) gametophyte

megasporocarp: a sporocarp containing megasporangia

megasporophyll: a specialized leaf upon which (or in the axil of which) one or more megasporangia are borne

meiosis: nuclear divisions in which the diploid chromosome number is reduced to half that of the parent cell to give the haploid number, as in gametes

melanoma: a tumour arising from the melanocytic system of the skin and other organs; when used alone, the term refers to malignant melanoma

membranaceous: like a membrane in thickness and texture

menorrhagia: excessive uterine bleeding, occurring at regular intervals, with the period of flow being of usual duration; also called hypermenorrhoea

meristele: the portion of a stele received by each leaf

meristem: undifferentiated tissue of the growing point whose cells are capable of dividing and developing into various organs and tissues

metabolite: any substance produced by metabolism or by a particular metabolic process

microsporangium: sporangium within which microspores are formed

microspore: the smaller of two kinds of spores in heterosporous pteridophytes, which after germination produces a male (antheridial) gametophyte

microsporocarp: a sporocarp containing microsporangia

midrib: the main vein of a leaf which is a continuation of the petiole

mitosis: a method of indirect division of a cell, consisting of a complex of various processes, through which the two daughter nuclei normally receive identical complements of the chromosomes

molluscicidal: destroying molluscs such as snails

monoecious: with unisexual flowers, but male and female flowers borne on the same plant

monolete: of a spore, bilateral, having a single straight scar

monomorphic (*monomorphous*): of uniform shape and size

monophyletic: of a group of taxa, a natural one including the known or hypothesized common ancestor and all of its descendants

mordant: a compound that serves to fix a dye in or on a substance, e.g. a textile fibre, often a salt or hydroxide of chromium, aluminium or tin

morphology: the actual external shape of a plant; often referring to the study of external form

mucilage: a gelatinous substance that is similar to gum but that swells in water without dissolving and forms a slimy mass

mucilaginous: slimy

mucous: secreting or containing a viscous or slimy matter

mucronate: ending abruptly in a short stiff point

multicellular: formed of more than 2 cells

multiple sclerosis: disease caused by sclerosis occurring in patches in the brain and/or spinal cord, leading to tremors, failure of coordination and various nervous and mental symptoms

multiseptate: divided by several or many cross-walls

multiseriate: in two to many rows

mutagenic: capable of inducing genetic mutation

myalgia: pain in a muscle

mycorrhiza: a symbiotic association of roots with a fungal mycelium which may form a layer outside the root (ectotrophic) or within the outer root tissue (endotrophic)

myosis: contraction of the pupil

naturalised: of foreign origin, but established and reproducing itself as if indigenous

naturalized: introduced into a new area and established there, giving the impression of wild growth

nausea (nauseous): an uncomfortable feeling in and about the stomach associated with aversion to food and a need to vomit

necrosis: death of a portion of tissue often characterized by a brown or black discoloration

nematicide: an agent that destroys nematodes

nematode: small elongated cylindrical worm-like micro-organism, free-living in soil or water, or parasitic in animals or plants

neolignans: condensation products of phenylpropanoid units with the bond involving a single β-carbon

nest fronds: specialised shield-like basal fronds in some ferns (e.g. *Platycerium*) which accumulate leaf litter

nest leaf: the sterile frond of some genera of epiphytic ferns in which humus collects

neuralgia: pain radiating along the course of one or more nerves

neurasthenia: a syndrome of chronic mental and physical weakness and fatigue, which was thought to be caused by exhaustion of the nervous system

neuroleptic: term referring to effects of antipsychotic drugs, such as producing a state of apa-

thy, lack of initiative, limited range of emotion, and, in psychotic patients, normalization of psychomotor activity and reduced confusion and agitation

neuron: any of the conducting cells of the nervous system

neuropathy: a functional disturbance or pathological change in the peripheral nervous system

node: the point on the stem or branch at which a leaf or lateral shoot is borne

oblanceolate: reverse of lanceolate

oblique: slanting; of unequal sides

oblong: longer than broad, with the sides parallel or almost so

obovate: like ovate, but with the widest portion beyond the middle

obovoid: solid and reversely egg-shaped

obscure: hidden

obtuse: blunt or rounded at the end

octoploid: having eight times the basic number of chromosomes ($8n$)

oedema: the presence of abnormally large amounts of fluid in the intercellular tissue spaces of the body

ophthalmia: severe inflammation of the eye, or of the conjunctiva or deeper structures of the eye

opposite: of leaves and branches when two are borne at the same node on opposite sides of the stem

orbicular: flat with a more or less circular outline

ovate: egg-shaped in outline or in section; a flat surface which is scarcely twice as long as broad with the widest portion below the middle

ovate-lanceolate: between ovate and lanceolate in outline

ovoid: a solid object which is egg-shaped (ovate in section)

palmate: of leaflets, leaf-lobes or veins, with the different elements arising from the same point

pantropical: distributed throughout the tropics

papyraceous: like paper in texture and thickness

paraphyses: sterile hairs of various shapes arising among sporangia

parkinsonism: a group of neurological disorders marked by abnormally decreased motor function (hypokinesia), tremor and muscular rigidity

pedate: having 3 or more divisions arising from a single point with the 2 lateral divisions more divided than the others, especially on the basiscopic side

peduncle: the stalk of an inflorescence or partial inflorescence

peltate: of scales and indusia: with the stalk attached to the lower surface, nowhere touching the margin

pendent, pendulous: drooping; hanging down from its support

pentaploid: having 5 times the basic haploid number ($5n$)

perispore: the folded membrane of most spores, forming an ornamental external covering

persistent: remaining attached; not falling off, not deciduous; applies to organs that remain in place after they have fulfilled their natural functions

pharmacopoeia: an authorative treatise on drugs and their preparations; a book containing a list of products used in medicine, with descriptions, chemical tests for determining identity and purity, formulas for certain mixtures of these substances, and generally also statements of average dosage

phenolics: phenols are compounds which have an aromatic ring with an alcoholic group attached to it

phlegm: a viscid, stringy mucous secretion, like that produced by the mucous membranes of the respiratory tract, as during a cold

phthisis: wasting away of (a part of) the body; tuberculosis, especially of the lungs

phyllopodia: projections from a rhizome where fronds are or were attached; usually found in those species (or some of them) with articulate fronds (e.g. *Oleandra*)

phyllopodium: base of a leaf thickened into a short outgrowth where the stipe joins the rhizome; when the leaf falls, the phyllopodium remains as a raised scar

phytotherapy: treatment by use of plants

pilose: hairy with rather long soft hairs

pinna (plural: pinnae): a primary division or leaflet of a pinnate leaf

pinnate: said of any divided frond or leaf where the division is complete to the rachis or midrib, with the formation of distinct pinnae, pinnules or leaflets

pinnatifid: said of any divided leaf where the division is incomplete, not forming distinct pinnae or pinnules but incised more than halfway to the midrib or costa

pinnatisect: pinnately divided down to the midrib

pinnule: a secondary or tertiary (etc.) subdivision of a blade, attached at one point only (if attached by the whole basal edge, called a segment)

pioneer species: a species able to establish itself on bare ground, starting primary succession, often

showing rapid growth and producing large amounts of diaspores

pith: the tissue, sometimes soft, in the centre of the stem

pleuritis, pleurisy: inflammation of the pleura (the membrane between thorax and lung), which may be acute or chronic

ploidy: degree or repetition of the basic number of chromosomes

pneumatophore: used of air vessels of any description; a root often functioning as a respiratory organ in a marsh plant

pneumonia: inflammation of the lungs, with the lungs becoming firm following the filling of air spaces with exudate

pollen: spores or grains borne by the anthers containing the male element (gametophyte)

polymorphic, polymorphous: with several or various forms; variable as to habit

polyphyletic: of a group of species or taxa, a non-natural group in which the most recent common ancestor for all species (or taxa) is assigned to another group, the characterization of the group being based on convergent similarity

polyploid: with more than two sets (genomes) of chromosomes in the somatic cells, e.g. triploid (3 sets, $3n$), tetraploid ($4n$), pentaploid ($5n$), hexaploid ($6n$), heptaploid ($7n$), octoploid ($8n$), etc.

polyploidy: the state of having more than two full sets of homologous chromosomes

polyuria: the passage of a large volume of urine in a given period, a characteristic of diabetes

poultice: a soft, usually heated and sometimes medicated mass spread on cloth and applied to sores or other lesions

primary: the first or principal order of veins or axes in a branching system

proliferous: multiplying quickly; bearing progeny as offshoot

prolonged: extended

prominent: noticeable because of contrasting colon and/or raised position with respect to surrounding tissue

prominulous: slightly raised above the lamina tissue, and so readily seen upon superficial examination of the lamina

propagule: a part of a plant that becomes detached and grows into a new plant

prophylactic: tending to ward off disease

prostrate: lying flat on the ground

prothallus: the gametophyte of a fern or fern ally

protostele: a simple primitive type of stele having a solid central vascular core

proximal: in botany: the part nearest the axis (as opposed to distal); in human anatomy: relatively nearer to the central part of the body or point of origin

pruinose: having a fine waxy-powdery secretion on the surface

pseudo-: false; apparent but not genuine

pseudo-indusium: indusium formed by modification of the lamina margin

psoriasis: a common chronic, scaly dermatosis with polygenic inheritance and a fluctuating course

psychomotor: pertaining to motor effects of cerebral or psychic activity

psychosis: a mental disorder marked by gross impairment in reality testing, reflected in delusions, hallucinations, incoherent speech or disorganized and agitated behaviour; also used in a more general sense for mental disorders in which impairment of mental functioning interferes with the capacity to meet the ordinary demands of life

pteridophyte: a fern or other spore-bearing vascular plant

ptyxis: pattern of folding and rolling shown during leaf development

puberulent: covered with down or fine hairs

puberulous: minutely pubescent

pubescent: covered with soft short hairs

pungent: bearing a sharp point; causing a sharp or irritating sensation

purgative: causing evacuation of the bowels; an agent causing evacuation of the bowels, especially through stimulating peristaltic action; also called cathartic

quadrifoliolate: bearing four leaflets at the same point, as in *Marsilea*

quadripinnate: having a lamina subdivided four times consecutively into pinnately arranged leaflets (fourth order)

quadripinnatifid: having a lamina subdivided three times consecutively into pinnately arranged leaflets divided into lateral lobes

quinones: a group of oxygen-containing homologues of aromatic derivatives, characterized by a diketo pattern (dione structure)

racemic: made up of two enantiomorphic isomers (stereoisomers which have molecules which are mirror images of each other) and therefore optically inactive

rachis (rhachis): the continuation of the petiole into the decompound lamina, where it lies free and not embedded within leaf tissue; the main axis of the blade (lamina) of a fern frond (fern leaf)

rain forest: a tropical forest receiving an annual

rainfall of at least 1800 mm, characterized by lofty evergreen trees forming a continuous canopy below which terrestrial herbs and shrubs are poorly developed

rash: a temporary eruption on the skin, as in urticaria

receptacle: the flat, concave or convex part of the axis from which the parts of the flower arise

receptacle (botany): the flat, concave or convex part of the axis from which the parts of the flower arise

recurved: bent or curved downward or backward

reduced: subnormal in size; connotes also either a failure to fulfil a normal function, or a diminution the expected number of parts in a set (of stamens, for example)

reflexed: abruptly bent or turned downward or backward

renal calculi: kidney-stones

reniform: kidney-shaped

repand: with an undulating margin

resin: solid to soft semisolid amorphous fusible flammable substance obtained as exudate or as an extract of plants

resinous: exuding, made of, or similar to resin

restorative: capable of restoring health, strength, consciousness; an agent having this capability

reticulate: netted, as when the smallest veins of a leaf are connected together like the meshes of a net

retrorse: turned or directed backward or downward (opposed to antrorse)

rheophyte: organism preferring or living in flowing water

rheumatism: any of various disorders, characterized by inflammation, degeneration, or metabolic derangement of the connective tissue structures of the body, especially the joints and related structures, and accompanied by pain, stiffness or limited mobility of these parts

rhinitis: inflammation of the mucous membrane of the nose

rhizobia: bacteria of the genus *Rhizobium* capable of forming symbiotic nodules on the roots of leguminous plants and able to fix atmospheric nitrogen

rhizoid: a filamentous root-like structure on the gametophytes of ferns; also similar structures elsewhere, as on the rhizomes of some filmy ferns

rhizome: a rootstock or root-like stem prostrate on or under the ground, sending adventitious rootlets downwards and fronds upwards; always distinguished from a true root by the presence of buds, fronds or scales

rhizophore: an unbranched structure arising at points of branching in some *Selaginella* species; it produces roots on contact with the soil

ringworm: popular name for tinea, which is a term used to describe various fungal skin infections; the name refers to the ring-shaped lesions

rosette: a cluster of leaves or other organs in a circular form

rot: disintegration of tissue due to the action of invading organisms, usually bacteria or fungi; a disease so characterized

saponins: a group of glycosides which have the ability to lower the surface tension of aqueous solutions

saprophytic: living upon dead organic matter such as humus

sarcoma: any of a group of tumours usually arising from connective tissue, most of which are malignant

scabies: a contagious dermatitis caused by the itch mite (*Sarcoptes scabiei*) that burrows under the skin and deposit eggs, causing intense itching

scale: a flat epidermal appendage related to a hair but 2- to many-celled in width

scarious: thin, dry, and membranous, not green

scleroderma: chronic hardening and thickening of the skin, which may be a finding in several different diseases

sclerotic: hardened, stony in texture

scrub: vegetation whose growth is stunted because of lack of water coupled with strong transpiration

scurvy: a disease resulting from a deficiency of vitamin C in the body, characterized by weakness, anaemia, spongy gums, bleeding from mucous membrane, etc.

season: to reduce the moisture content of timber either by air drying (air season) or kiln drying (kiln season); timber is fully seasoned when the moisture content has dropped to the equilibrium moisture content of the ambient climate

secondary: the next order after primary of veins or axes in a branching system

sedative: allaying activity and excitement; an agent that allays excitement

segment: one of the divisions into which a plant organ, as a leaf or a calyx, may be cleft; the division of a palmate or costapalmate leaf

senescence: advancing in age

sepsis: the presence of pathogens or their toxins in the blood or other tissues

serrate: toothed like a saw, with regular pointed teeth pointing forwards

serrulate: serrate with minute teeth
sesquiterpene: terpenes of molecular formula $C_{15}H_{24}$, e.g. caryophyllene and farnesene
sesquiterpenes: a subgroup of the isoprenoids, formed by coupling of 3 C_5 units
sessile: without a stalk
setose: set with bristles or bristle-like elements
sheath: a tubular structure surrounding an organ or part, as the lower part of the leaf clasping the stem in grasses
short-creeping: growing horizontally a few cm at most, usually said of rhizomes, which then have the stipe bases approximate
shrub: a woody plant branching from the base, all branches being equivalent
siliceous: containing silica
silicosis: a pulmonary disease due to the inhalation of the dust of stone, sand or flint containing silicon dioxide
simple: not compound, as in leaves with a single blade
sinuate: with a deep wavy margin
sinuous: wavy
solenostelic: having a tubular stele with both internal and external phloem (phloem tissues are the portion of a vascular bundle concerned with the conduction of nutrient materials)
solitary: single stemmed, not clustering
sorus: a cluster of sporangia having a distinct shape
spasmodic: of the nature of a spasm, i.e. a sudden, violent, involuntary contraction of a muscle or of a group of muscles
spasmolytic: checking spasms; antispasmodic
spastic: of the nature of or characterized by spasms
spatulate (spathulate): spoon-shaped
spherical: globular
spike: an unbranched fertile segment or inflorescence with sessile sporangia or flowers (e.g. in *Ophioglossum*)
spinose: having spines
spinulose: bearing small or minute spines
sporangiate: bearing sporangia
sporangiophore: a specialised structure bearing sporangia
sporangium: a sac endogenously producing spores
spore: a small asexual reproductive body, consisting of one cell, which gives rise to the prothallus or gametophyte
sporiferous: spore-bearing
sporocarp: a closed stalked ovoid multicellular organ containing sporangia, produced by some aquatic ferns
sporophyll: a leaf or leaf-like structure bearing or subtending a sporangium
sporophyte: an individual of the diploid generation, usually producing spores, that is formed by the union of sexual cells produced by the gametophyte
spreading: directed outwards from the stem at a rather broad angle; as of leaves
starch: polysaccharide made up of a long chain of glucose units joined by α-1,4 linkages, either unbranched (amylose) or branched (amylopectin) at a α-1,6 linkage, and which is the storage carbohydrate in plants, occurring as starch granules in amyloplа
stele: the vascular structure of a stem or root
stellate: star-shaped, as of hairs with radiating branches
stem: the main ascending axis of a plant; in bamboos usually named culm, in other plant groups occasionally
stimulant: producing a temporary increase of the functional activity or efficiency of an organism or any of its parts; an agent acting so
stipe: the stalk supporting a carpel or gynoecium; in ferns similar to petiole
stolon: a trailing stem usually above the ground which is capable of producing roots and shoots at its nodes
stoloniferous: bearing a stolon or stolons
stout: thick and short
stramineous: straw-coloured
strobilus: a cone-like, reproductive structure formed by the aggregation of sporophylls along an axis
styptic: astringent, tending to check bleeding through astringent properties; a remedy which is astringent and arrests bleeding
subspecies: a subdivision of a species, in rank between a variety and a species
subterranean: below ground; hypogeous; cf. aerial
succulent: juicy, fleshy
sulcate: with a longitudinal groove
suprabasal: above the base, usually referring to pinnae or pinnules
supramedial: pertaining to sori located nearer to the margins than to the midvein, but not touching the margin
symbiosis: the intimate living together of two dissimilar organisms in a mutually beneficial relationship
symbiotic: of two organisms living together to their mutual advantage
symmetrical: having a similar outline on both sides of a central axis; cf. asymmetrical

sympatrically: occupying an area together with another species
synangium: structure formed by the fusion of sporangia
syphilis: a disease usually communicated by sexual contact, or via the blood or bite of an infected person, caused by a spirochete (*Treponema pallidum*) and characterized by a clinical course in 3 stages continued over many years
tachypnea: excessive rapidity of respiration
tannins: a large group of plant-derived phenolic compounds
tapered: gradually narrower or thinner
taxon: a term applied to any taxonomic unit irrespective of its classification level, e.g. variety, species, genus, etc.
taxonomy: the study of principles and practice of classifying living organisms (systematics)
terete: cylindrical; circular in transverse section
terminal: placed at the end or apex; a termination, end or extremity
terpenes: unsaturated hydrocarbons of molecular formula $(C_5H_8)n$; in monoterpenes n = 2, in sesquiterpenes n = 3; the term terpene is often used to refer to a terpenoid
terpenoids: chemical compounds derived from a terpene
terrestrial: on or in the ground
tetanus: an acute, often fatal, infectious disease characterized by muscular contractions and abnormal reflexes, and caused by a toxin produced by *Clostridium tetani*, a bacillus which is usually introduced through a wound
tetrad: a group of four
tetraploid: having four times ($4n$) the basic number of chromosomes or twice the diploid number ($2n$)
thallus: a vegetative body without differentiation into stem and leaf
thrombosis: the formation, development or presence of an aggregation of blood factors (thrombus), often causing vascular obstruction
timber: any wood other than fuelwood
tinnitus: a noise in the ears, like ringing, buzzing, roaring or clicking
tissue culture: a body of tissue growing in a culture medium outside the organism
tomentose: densely covered with short soft hairs
translucent: thin enough to pass light, but not an image
transparent: thin enough to pass an image
transverse: straight across; of tertiary veins, connecting the secondary veins, not necessarily in a perpendicular way
trapeziform: having the outline of a trapezoid, with 4 unequal sides, none of them parallel
trapezoid: like a trapezium, a figure of four unequal sides
trauma: a wound or injury, whether physical or psychic
trichome: any hair, bristle or scale-like outgrowth of the epidermis
trifoliate: three-leaved
tripinnate: having pinnules further subdivided into pinnately arranged leaflets (third order)
tripinnatifid: having pinnules divided into lateral lobes
triploid: having three times the basic number of chromosomes, usually written $3n$
triterpenes: a subgroup of the isoprenoids, formed by coupling of 6 C_5 units
trophophyll: a sterile, vegetative leaf
truncate: cut off more or less squarely at the end
trunk: the main stem of a tree apart from its limbs and roots
tuber: the swollen portion of an underground stem or root which acts as a storage organ and propagule; it is usually of one year's duration, those of successive years not arising directly from the old ones nor bearing any constant relation to them
tuberculosis: any of the diseases in man and animals caused by *Mycobacterium* spp., characterized by the formation of lesions (tubercles) and necrosis in the tissue of the lung or other organs and having a tendency to great chronicity
tuberous: producing tubers or resembling a tuber
tufted: growing in tufts (caespitose)
tumour necrosis factor: a substance (lymphokine) produced by macrophages, capable of causing in vivo haemorrhagic necrosis of certain tumour cells, but not affecting normal cells
ulcer: an open sore on an external or internal body surface, usually accompanied by disintegration of tissue and formation of pus
ultimate segments: the last leaflets in a consecutive series of subdivisions of a lamina
ultrabasic: of soil, very low in silica and rich in ferromagnesian minerals as in e.g. serpentine soils
unilateral: one-sided
variegated: irregularly coloured in patches, blotched
variety: botanical variety which is a subdivision of a species; an agricultural or horticultural variety is referred to as a cultivar
vegetative reproduction: propagation without sexual fertilization, and not derived from a spore
vein (botany): a strand of vascular tissue in a flat organ, such as a leaf

veinlet: a subdivision or branch of a vein
venation (botany): the arrangement of the veins in a leaf
vermifuge: an agent expelling worms or intestinal animal parasites; an anthelminthic
verrucose: warty
vertigo: an illusory sense that the surroundings or one's own body are revolving
vesicular stomatitis: a vesicular eruption caused by a virus and affecting pigs, cattle and horses
viability: ability to live, grow and develop
volatile oils: see essential oils
wart: a small, usually hard and non-malignant, excrescence on the skin
whipworm: an intestinal nematode parasite (*Trichuris trichiura*)
whorl: arrangement with more than two organs of the same kind arising at the same level
whorled: having a whorl
wilt: loss of turgidity, usually in leaves, typically caused by pathogens which colonize the vascular system
xerophytic: relating to a plant structurally adapted for life and growth with a limited water supply

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Figure 2b. do Amaral Franco, J., & da Luz da Rocha Alfonso, M., 1982. Distribuição de pteridófitos e gimnospérmicas em Portugal [Distribution of pteridophytes and gymnosperms in Portugal]. Serviço Nacional de Parques, Reservas e Património Paisagístico, Lisbon, Portugal. Fig. on p. 55 (Equisetum habit); Huang, T.-C. (General Editor): Flora of Taiwan. 2nd Edition. Vol. 1. Pteridophyta and Gymnospermae. Editorial Committee of the Flora of Taiwan, Taipei, Taiwan. Fig. 4, p. 34 (Lycopodium), fig. 15, p. 62 (Equisetum details stem). Redrawn and adapted by Iskak Syamsudin.

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Acrostichum aureum. Berry, P.E., Holst, B.K. &

Yatskievych, K., 1995. Flora of the Venezuelan Guayana. Vol. 2. Missouri Botanical Garden, St. Louis, Timber Press, Portland, United States. Fig. 203, p. 254 (rhizome); Burrows, J.E., 1990. Southern African ferns and fern allies. Frandsen Publishers, Sandton, South Africa. Fig. 25, p. 113 (venation); Lasser, T., 1969. Flora de Venezuela. Vol. 1 (2). Botanical Institute, Caracas, Venezuela. Fig. 159, p. 848 (habit). Redrawn and adapted by Iskak Syamsudin.

Adianthum caudatum. Beddome, R.H., 1883. Handbook to the ferns of British India, Ceylon and the Malay Peninsula. Thacker, Spink and Co., Calcutta, India. Fig. 44, p. 85 (leaflet with false indusia); Sastrapradja, S., Afriastini, J.J., Darnaedi, D. & Widjaja, E.A., 1979. Jenis paku Indonesia [Indonesian fern species]. Lembaga Biologi Nasional-LIPI, Bogor, Indonesia. LBN 17, SDE 76. Fig. on p. 112 (habit); Shieh, W.-C., 1994. Adiantaceae. In: Huang, T.-C. (General Editor): Flora of Taiwan. 2nd Edition. Vol. 1. Pteridophyta and Gymnospermae. Editorial Committee of the Flora of Taiwan, Taipei, Taiwan. Fig. 98, p. 238 (leaflet venation, scale, sporangium, spores). Redrawn and adapted by Iskak Syamsudin.

Ampelopteris prolifera. Burrows, J.E., 1990. Southern African ferns and fern allies. Frandsen Publishers, Sandton, South Africa. Fig. 62, p. 267 (schematic habit); Holttum, R.E., 1981. Thelypteridaceae. Flora Malesiana, Series 2. Pteridophyta (Ferns & fern allies). Vol. 1, part 5. M. Nijhoff / W. Junk Publishers, The Hague, The Netherlands. Fig. 7, p. 385 (young plant, venation pinna-lobes); Schelpe, E.A.C.L.E., 1970. Pteridophyta. In: Exell, A.W. & Launert, E. (Editors): Flora Zambesiaca. Crown Agents for Oversea Governments and Administrations, London, United Kingdom. Fig. 56, p. 201 (habit leaf part, pinna-lobes venation). Redrawn and adapted by Achmad Satiri Nurhaman.

Amphineuron terminans. Beddome, R.H., 1873. The ferns of southern India. Reprint 2nd edition. Bishen Sing Mahendra Pal Singh, Dehradun, India. Fig. 90 (habit leaf part, sporangium); Bostock, P.D., 1998. Thelypteridaceae. Flora of Australia 48. Fig. 118C, p. 348 (pinnae-lobes no 2); Holttum, R.E., 1982. Thelypteridaceae. Flora Malesiana, Series 2. Pteridophyta (Ferns & fern allies). Vol. 1, part 5. M. Nijhoff / W. Junk Publishers, The Hague, The Netherlands. Fig. 19, p. 546 (pinnae-lobes no 3). Redrawn and adapted by Achmad Satiri Nurhaman.

Angiopteris evecta. Bitter, G., 1900. Marattiales. In: Engler, A. & Prantl, K. (Editors): Die natürlichen Pflanzenfamilien [The natural plant families].Teil 1, Abteilung 4. Wilhelm Engelmann Verlag, Leipzig, Germany. Fig. 240, p. 437 (habit); de Winter, W.A. (original drawings venation and sori); Holttum, R.E., 1966. A revised flora of Malaya. 2nd Edition. Vol. 2. Ferns of Malaya. Government Printing Office, Singapore. Fig. 3, p. 45. (pinnae bases, petiole base with stipules). Redrawn and adapted by Iskak Syamsudin.

Asplenium nidus. Zamora, P.M. & Co, L., 1986. Guide to Philippine flora and fauna. Vol. 2. Economic ferns, endemic ferns, gymnosperms. Natural Resources Management Center, Ministry of Natural Resources and University of the Philippines, Goodwill Bookstore, Manila, the Philippines. Fig. 40, p. 48. Redrawn and adapted by Achmad Satiri Nurhaman.

Azolla pinnata. Soerjani, M., Kostermans, A.J.G.H. & Tjitrosoepomo, G. (Editors), 1987. Weeds of rice in Indonesia. Balai Pustaka, Jakarta, Indonesia. Fig. on p. 113. Redrawn and adapted by Iskak Syamsudin.

Blechnum vulcanicum. Chambers, T.C. & Farrant, P.A., 2001. Revision of Blechnum (Blechnaceae) in Malesia. Blumea 46: 283–350. Fig. 17, p. 341. Redrawn and adapted by Achmad Satiri Nurhaman.

Cephalomanes javanicum. Backer, C.A. & Posthumus, O., 1939. Varenflora voor Java [Fern flora for Java]. 's Lands Plantentuin Buitenzorg, Dutch East Indies. Fig. 4, p. 6. Redrawn and adapted by Achmad Satiri Nurhaman.

Ceratopteris thalictroides. Beddome, R.H., 1883. Handbook to the ferns of British India, Ceylon and the Malay Peninsula. Thacker, Spink and Co., Calcutta, India. Fig. on p. 124 (fertile pinnules, sporangia along lateral parallel veins); Huang, Tseng-Chieng (General Editor), 1994. Flora of Taiwan, 2nd Edition, Vol. 1. Pteridophyta and Gymnospermae. Editorial Committee of the Flora of Taiwan, Taipei, Taiwan. Fig. 208, p. 536 (sporangium); Hui-lin Li et al. (Editors), 1975. Flora of Taiwan, 1st Edition, Vol. 1. Pteridophyta and Gymnospermae. Editorial Committee of the Flora of Taiwan, Epoch Publishing Company, Taipei, Taiwan. Fig. 43, p. 130 (stipe scale, spores); Sastraparadja, S., Afriastini, J.J., Darnaedi, D. & Widjaja, E.A., 1979. Jenis paku Indonesia [Indonesian fern species]. Lembaga Biologi Nasional No 17, SDE 76, Lembaga Ilmu Pengetahuan Indonesia (LIPI), Bogor, Indone-

sia. Fig. on p. 36 (habit). Redrawn and adapted by Iskak Syamsudin.

Cheilanthes tenuifolia. Andrews, S.B., 1990. Ferns of Queensland. Queensland Department of Primary Industries, Brisbane, Australia. p. 334 (pertions of fertile blade); Jones, D.L. & Clemesha, S.C., 1980. Australian ferns and fern allies. 2nd Edition. Reed, Sydney, Australia. p. 152 (scale); Nayar, B.K., 1963. The morphology of some species of Cheilanthes. The Journal of the Linnean Society of London (Botany) 58(374): 454 (spore); Sastraparadja, S., Afriastini, J.J., Darnaedi, D. & Widjaja, E.A., 1979. Jenis paku Indonesia [Indonesian fern species]. Lembaga Biologi Nasional No 17, SDE 76, Lembaga Ilmu Pengetahuan Indonesia (LIPI), Bogor, Indonesia. p. 102 (habit). Redrawn and adapted by Iskak Syamsudin.

Cibotium barometz. Backer, C.A. & Posthumus, O., 1939. Varenflora voor Java [Fern flora for Java]. 's Lands Plantentuin, Buitenzorg, Java. Archipel Drukkerij, Dutch East Indies. Fig. 7, p. 23 (lower surface of pinnule with sori); Holttum, R.E., 1963. Cyatheaceae. In: van Steenis, C.G.G.J. & Holttum, R.E. (General editors): Flora Malesiana, Series 2. Pteridophyta (Ferns & fern allies). Vol. 1, part 2. Martinus Nijhoff / Dr W. Junk Publishers, The Hague, The Netherlands. Fig. 33, p. 165 (part of pinnule showing sori, with 2 closed and 2 open indusia); Sastraparadja, S., Afriastini, J.J., Darnaedi, D. & Widjaja, E.A., 1979. Jenis paku Indonesia [Indonesian fern species]. Lembaga Biologi Nasional No 17, SDE 76, Lembaga Ilmu Pengetahuan Indonesia (LIPI), Bogor, Indonesia. Fig. on p. 90 (pinna-rachis with pinnules, crozier). Redrawn and adapted by Iskak Syamsudin.

Cyathea. Holttum, R.E., 1963. Cyatheaceae. In: van Steenis, C.G.G.J. & Holttum, R.E. (General Editors): Flora Malesiana. Series 2. Vol. 1, part 2. Martinus Nijhoff/Dr W. Junk Publishers, The Hague, The Netherlands. Fig. 9, p. 75 (indusium types), fig. 21, p. 122 (sterile pinna), fig.28, p. 144 (petiole scale); Ochse, J.J., 1980. Vegetables of the Dutch East Indies. 3rd English Edition (translation of 'Indische groenten', 1931). A. Asher & Co., Amsterdam, The Netherlands. Fig. 128, p. 213 (habit). Redrawn and adapted by Achmad Satiri Nurhaman.

Cyclosorus heterocarpus. Ferns, gymnosperms and allied groups. In: Flora of Australia. Vol. 48. CSIRO Publishing/Australian Biological Resources Study, Australia. Fig. 120, p. 353 (basal pinna; lower surface of central lobes of a middle pinna); Piggott, A.G., 1988. Ferns of Malaysia in colour. Tropical Press Sdn. Bhd., Kuala Lumpur, Malaysia. P. 201, Fig. 603 (basal part of leaf), 604 (lower surface fertile middle pinnae). Redrawn and adapted by Achmad Satiri Nurhaman.

Davallia trichomanoides. Backer, C.A. & Posthumus, O., 1939. Varenflora voor Java [Fern flora for Java]. 's Lands Plantentuin, Buitenzorg, Java. Archipel Drukkerij, Dutch East Indies. Fig. 18, p. 100. Redrawn and adapted by Achmad Satiri Nurhaman.

Dicranopteris linearis. Schelpe, E.A.C.L.E., 1970. Pteridophyta. In: Exell, A.W. & Launert, E. (Editors): Flora Zambesiaca. Crown Agents for Oversea Governments and Administrations, London, United Kingdom. Fig. 13, p. 51. Redrawn and adapted by Achmad Satiri Nurhaman.

Diplazium. Beddome, R.H., 1983. The ferns of southern India. Reprint 2nd ed. Bishen Sing Mahendra Pal Singh, Dehradun, India. Plates 163 (1 & 2) and 164 (3 & 4). Redrawn and adapted by Iskak Syamsudin.

Dipteris conjugata. Andrews, S.B., 1990. Ferns of Queensland. Queensland Department of Primary Industries, Brisbane, Australia. Fig. on p. 138 (rhizome and base of petiole, leaf); Backer, C.A. & Posthumus, O., 1939. Varenflora voor Java [Fern flora for Java]. 's Lands Plantentuin, Buitenzorg, Java. Archipel Drukkerij, Dutch East Indies. Fig. 60, p. 245 (part of leaf from below); Piggott, A.G., 1988. Ferns of Malaysia in colour. Tropical Press Sdn. Bhd, Kuala Lumpur, Malaysia. Fig. on p. 103 (folded two halves of expanding leaf). Redrawn and adapted by Iskak Syamsudin.

Drynaria sparsisora. Andrews, S.B., 1990. Ferns of Queensland. Queensland Department of Primary Industries, Brisbane, Australia. p 276 (rhizome scale); Sastrapradja, S., Afriastini, J.J., Darnaedi, D. & Widjaja, E.A., 1979. Jenis paku Indonesia [Indonesian fern species]. LBN 17, SDE 76. Lembaga Biologi Nasional–LIPI, Bogor, Indonesia. p. 28 (habit and sori). Redrawn and adapted by Iskak Syamsudin.

Equisetum ramosissimum. Backer, C.A. & Posthumus, O., 1939. Varenflora voor Java [Fern flora for Java]. 's Lands Plantentuin Buitenzorg, Dutch East Indies. Fig. 81, p. 287 (part of stem with sheath and branches, stem apex with strobilus); Laferrière, J.E., 1998. Equisetaceae. In: Kalkman, C. & Nooteboom, H.P. (Editors): Flora Malesiana. Series 2. Pterido-

phyta. Ferns and fern allies. Vol. 3. Rijksherbarium/Hortus Botanicus (under the auspices of Foundation Flora Malesiana), Leiden, The Netherlands. Fig. 1, p. 288 (habit, transverse section internode, sheath with persisting teeth). Redrawn and adapted by Achmad Satiri Nurhaman.

Helminthostachys zeylanica. Beddome, R.H., 1983. The ferns of southern India. Reprint 2nd ed. Bishen Sing Mahendra Pal Singh, Dehradun, India. Plate 69 (habit, apex spike); Bitter, G., 1900. Ophioglossales. In: Engler, A. & Prantl, K. (Editors): Die natürlichen Pflanzenfamilien [The natural plant families].Teil 1, Abteilung 4. Wilhelm Engelmann Verlag, Leipzig, Germany. Fig. 260, p. 462 (sporangiophore); Campbell, D.H., 1911. The eusporangiatae – the comparative morphology of the Ophioglossaceae and Marattiaceae. Carnegie Institution, Washington, United States. Fig. 79, p. 106 (rhizome apex); Huang, Tseng-Chieng (General Editor), 1994. Flora of Taiwan. 2nd Edition, Vol. 1. Pteridophyta and Gymnospermae. Editorial Committee of the flora of Taiwan, Taipei, Taiwan. Fig. 19, p. 69 (venation lateral leaf). Redrawn and adapted by Iskak Syamsudin.

Hemionitis arifolia. Beddome, C.R.H., 1883. Handbook to the ferns of British India, Ceylon and the Malay Peninsula. Thacker, Spink and Co., Calcutta, India. Plate 53, p. 412 (sterile and fertile leaf); Huang, Tseng-Chieng (General Editor), 1994. Flora of Taiwan, 2nd Edition, Vol. 1. Pteridophyta and Gymnospermae. Editorial Committee of the Flora of Taiwan, Taipei, Taiwan. Fig. 105, p. 252 (habit, rhizome scale and hair, petiole scale, sori along veins, sporangium with spores). Redrawn and adapted by Achmad Satiri Nurhaman.

Huperzia carinata. Andrews, S.B., 1990. Ferns of Queensland. Queensland Department of Primary Industries, Brisbane, Australia. p. 233 (sterile leaf, fertile leaf with sporangium); Sastrapradja, S., Afriastini, J.J., Darnaedi, D. & Widjaja, E.A., 1979. Jenis paku Indonesia [Indonesian fern species]. LBN 17, SDE 76. Lembaga Biologi Nasional–LIPI, Bogor, Indonesia. Fig. p. 22 (habit, part of fertile spike). Redrawn and adapted by Achmad Satiri Nurhaman.

Huperzia phlegmaria Andrews, S.B., 1990. Ferns of Queensland. Queensland Department of Primary Industries, Brisbane, Australia. p. 231 (sterile leaf); Sastrapradja, S., Afriastini, J.J., Darnaedi, D. & Widjaja, E.A., 1979. Jenis paku Indonesia [Indonesian fern species]. Lembaga Biologi Nasional - LIPI, Bogor, Indonesia. LBN 17/SDE 76. p. 26 (branch with strobili and detail). Redrawn and adapted by Iskak Syamsudin.

Huperzia serrata. Mickel, J.T. & Beitel, J.M., 1988. Pteridophyte flora of Oaxaca, Mexico. Memoirs of the New York Botanical Garden 46. Fig. 5, p. 417. Redrawn and adapted by Achmad Satiri Nurhaman.

Hypolepis punctata. Brownsey, P.J., 1987. A review of the fern genus Hypolepis (Dennstaedtiaceae) in the Malesian and Pacific regions. Blumea 32: 227–276. Fig. 4, p. 244 (pinnule); Shieh, W.-C., 1994. Dennstaedtiaceae. In: Huang, T.-C. (General Editor): Flora of Taiwan. 2nd Edition. Vol. 1. Pteridophyta and Gymnospermae. Editorial Committee of the Flora of Taiwan, Taipei, Taiwan. Fig. 60, p. 157 (habit leaf). Redrawn and adapted by Achmad Satiri Nurhaman.

Loxogramme scolopendrina. Price, M.G., 1975. The pteridophytes of Mount Makiling and vicinity. MSc thesis (Mimeographed), University of the Philippines, Los Baños, the Philippines. Fig. 28, p. 179. Redrawn and adapted by Iskak Syamsudin.

Lycopodiella cernua. Andrews, S.B., 1990. Ferns of Queensland. Queensland Department of Primary Industries, Brisbane, Australia. p. 227 (part of a branch, fertile leaf with sporangium); Sastrapradja, S., Afriastini, J.J., Darnaedi, D. & Widjaja, E.A., 1979. Jenis paku Indonesia [Indonesian fern species]. Lembaga Biologi Nasional – LIPI, Bogor, Indonesia. LBN 17/SDE 76. p. 60 (part of a plant with strobili, apical part of a branch with strobilus). Redrawn and adapted by Achmad Satiri Nurhaman.

Lycopodium clavatum. Thomé, O.W., 1885. Flora von Deutschland, Österreich und der Schweiz – in Wort und Bild für Schule und Haus [Flora of Germany, Austria and Switzerland – in word and illustration, for school and home]. Gera-Untermhaus, Germany. Fig. 19. Redrawn and adapted by Achmad Satiri Nurhaman.

Lycopodium complanatum. Cobb, B., 1984. A field guide to the ferns and their related families. Peterson field guide series, Hoghton Mifflin Company, Boston/New York, United States. Fig. a & b, p. 233 (shoot branch views); Dorstal, J., 1984. Lycopodiaceae. In: Kramer, K.U. (Editor): Hegi, G., Illustrierte Flora van Mitteleuropa, Band 1, Teil 1. Pteridophyta. 3rd Edition. Fig. 2, p. 18 (sporophyll); Jonsell, B. (Editor), 2000. Flora Nordica, vol. 1. Bergius Foundation, Royal

Swedish Academy of Sciences, Stockholm, Sweden. Fig. 5b (habit); Wherry, E.T., 1995. The fern guide - Northeastern and midland United States and adjacent Canada. Dover Publications. New York, United States. Fig. C, p. 267 (strobilus). Redrawn and adapted by Iskak Syamsudin.

Lygodium microphyllum. Beddome, R.H., 1873. The ferns of southern India. Reprint 2nd edition. Bishen Sing Mahendra Pal Singh, Dehradun, India. Fig. 61. Redrawn and adapted by Achmad Satiri Nurhaman.

Marsilea crenata. Huang, Tseng-Chieng (General Editor), 1994. Flora of Taiwan. 2nd Edition, Vol. 1. Pteridophyta and Gymnospermae. Editorial Committee of the Flora of Taiwan, Taipei, Taiwan. Fig. 209, p. 538 (habit, leaflet); Soerjani, M., Kostermans, A.J.G.H. & Tjitrosoepomo, G. (Editors), 1987. Weeds of rice in Indonesia. Balai Pustaka, Jakarta, Indonesia. Fig. 4.162, p. 355 (sporocarp). Redrawn and adapted by Iskak Syamsudin.

Microlepia speluncae. Diels, L., 1902. Polypodiaceae. In: Engler, A. & Prantl, K. (Editors): Die natürlichen Pflanzenfamilien [The natural plant families]. Teil 1, Abteilung 4. Wilhelm Engelmann Verlag, Leipzig, Germany. Fig. 116, p. 216 (sorus); Schelpe, E.A.C.L.E. & Anthony, N.C., 1986. Pteridophyta. In: Leistner, O.A. (Editor): Flora of southern Africa. Botanical Research Institute, Department of Agriculture and Water Supply, Pretoria, South Africa. Fig. on p. 86 (part of leaf, pinnules with sori). Redrawn and adapted by Iskak Syamsudin.

Microsorum scolopendria. Bostock, P.D. & Spokes, T.M., 1998. Polypodiaceae. Flora of Australia 48. Fig. 149, p. 476 (rhizome part, rhizome scale); Holttum, R.E., 1966. A revised flora of Malaya. 2nd Ed. Vol. 2. Ferns of Malaya. Government Printing Office, Singapore. Fig. 94, p.192 (habit, venation and sori). Redrawn and adapted by Iskak Syamsudin.

Nephrolepis biserrata. Holttum, R.E., 1966. A revised flora of Malaya. Vol. 2. Ferns of Malaya. Government Printing Office, Singapore. p. 373, fig. 217 (habit rhizome part, separate sterile and fertile pinnae); Sastrapradja, S., Afriastini, J.J., Darnaedi, D. & Widjaja, E.A., 1979. Jenis paku Indonesia [Indonesian fern species]. Lembaga Biologi Nasional-LIPI, Bogor, Indonesia. LBN 17, SDE 76. Fig. on p. 52 (habit aerial part). Redrawn and adapted by Iskak Syamsudin.

Odontosoria chinensis. Kramer, K.U., 1971. Lindsaea Group. In: van Steenis, C.G.G.J. & Holttum, R.E. (General Editors): Flora Malesiana. Series 2. Vol. 1. Part 3. Martinus Nijhoff/Dr. W. Junk Publishers, The Hague, The Netherlands. Figs. 1–3, p. 181 (pinnules); Zamora, P.M. & Co, L., 1986. Guide to Philippine flora and fauna. Vol. 2. Economic ferns, endemic ferns , gymnosperms. Natural Resources Management Center, Ministry of Natural Resources and University of the Philippines. Goodwill Bookstore, Manila, the Philippines. Fig. 29, p. 38 (habit). Redrawn and adapted by Achmad Satiri Nurhaman.

Oleandra neriiformis: Diels, L., 1902. Polypodiaceae. In: Engler, A. & Prantl, K. (Editors): Die natürlichen Pflanzenfamilien [The natural plant families]. Teil 1, Abteilung 4. Wilhelm Engelmann Verlag, Leipzig, Germany. Fig. 109, p. 204. Redrawn and adapted by Iskak Syamsudin.

Onychium siliculosum. Shieh, Wang-Chueng, 1994. Pteridaceae. Onychium. In: Huang, T.-C. (General Editor): Flora of Taiwan. 2nd Edition. Vol. 1. Pteridophyta and Gymnospermae. Editorial Committee of the Flora of Taiwan, Taipei, Taiwan. Fig. 93, p. 221. Redrawn and adapted by Iskak Syamsudin.

Ophioglossum pendulum. Beddome, R.H., 1873. The ferns of southern India. Higginbottham, Madras, India. Fig. 269 (venation and spike); Sastrapradja, S., Afriastini, J.J., Darnaedi, D. & Widjaja, E.A., 1979. Jenis paku Indonesia [Indonesian fern species]. LBN 17, SDE 76. Lembaga Biologi Nasional–LIPI, Bogor, Indonesia. Fig. p. 106 (habit). Redrawn and adapted by Achmad Satiri Nurhaman.

Ophioglossum reticulatum. Backer, C.A. & van Slooten, D.F., 1924. Geïllustreerd handboek der Javaansche theeonkruiden en hunne betekenis voor de cultuur [Illustrated handbook of weeds of Javanese tea plantations and their significance for tea-growing]. Ruygrok, Batavia, Dutch East Indies. Fig. 24, p. 24 (plants connected by stolons); Sastrapradja, S., Afriastini, J.J., Darnaedi, D. & Widjaja, E.A., 1979. Jenis paku Indonesia [Indonesian fern species]. LBN 17, SDE 76. Lembaga Biologi Nasional–LIPI, Bogor, Indonesia. Fig. p. 20 (habit, spike). Redrawn and adapted by Iskak Syamsudin.

Pityrogramma calomelanos. Tardieu-Blot, M.L., 1964. Ptéridophytes. In: Flore du Cameroun. Vol. 3. Muséum National D'Histoire Naturelle, Laboratoire de Phanérogamie, Paris, France. Fig. 17, p. 133. Redrawn and adapted by Iskak Syamsudin.

Platycerium bifurcatum Sastrapradja, S., Afriastini, J.J., Darnaedi, D. & Widjaja, E.A., 1979. Jenis paku Indonesia [Indonesian fern species]. Lembaga Biologi Nasional-LIPI, Bogor, Indonesia. LBN 17, SDE 76. Fig. on p. 108. Redrawn and adapted by Achmad Satiri Nurhaman.

Pleocnemia irregularis. Bakhuizen van den Brink, R.C., 1924. Lalab. De Tropische Natuur 13: 55–61, fig. 20, p. 57 (young leaf), fig. 20a, p. 58 (pinna with sori); Holttum, R.E., 1966. A revised flora of Malaya. 2nd Edition. Vol. 2. Ferns of Malaya. Government Printing Office, Singapore. Fig. 318, p. 539 (a middle pinna, enlarged lobe). Redrawn and adapted by Achmad Satiri Nurhaman.

Pteridium aquilinum. Backer, C.A. & van Slooten, D.F., 1924. Geïllustreerd handboek der Javaansche theeonkruiden en hunne betekenis voor de cultuur [Illustrated handbook of weeds of Javanese tea plantations and their significance for tea-growing]. Ruygrok, Batavia, Dutch East Indies. Fig. 15. Pteridium aquilinum Kuhn (habit); Weeda, E.J., Westra, R., Ch. & T., 1985. Nederlandse oecologische flora [Ecological flora of The Netherlands]. IVN, VARA, VEWIN, Hilversum, The Netherlands. Vol. 1., fig. on p. 32 (fertile leaflet segment, cross section rhizome). Redrawn and adapted by Iskak Syamsudin.

Pteris. Engler, A. & Prantl, K. (Editors): Die natürlichen Pflanzenfamilien [The natural plant families].Teil 1, Abteilung 4. Wilhelm Engelmann Verlag, Leipzig, Germany. Fig. 154, p. 291 (P. cretica); Holttum, R.E., 1966. A revised flora of Malaya. 2nd Edition. Vol. 2. Ferns of Malaya. Government Printing Office, Singapore. Fig. 230 (P. vittata), 231 (P.ensiformis), 232 (P. semipinnata), p. 397. Redrawn and adapted by Achmad Satiri Nurhaman.

Pyrrosia piloselloides. Schneider, G., 1893. The book of choice ferns: for the garden, conservatory, and stove: describing and giving explicit cultural directions for the best and most striking ferns and selaginellas in cultivation. Vol. 2. Upcott Gill, London, United Kingdom. Redrawn and adapted by Achmad Satiri Nurhaman.

Rumohra adiantiformis. Jones, D.L., 1998. Dryopteridaceae. In: Jones, D.L. & Clemesha, S.C. (Editors): Flora of Australia 48: Australian ferns and fern allies. 2nd Edition. Reed, Sydney, Australia. Fig. 135, p. 404 (rhizome, pinnule segment with sori); Schelpe, E.A.C.L.E. & Anthony, N.C., 1986. Pteridophyta. In: Leistner, O.A. (Editor): Flora of southern Africa. Botanical Research Institute, Department of Agriculture and Water Supply, Pretoria, South Africa. Fig. 90-1, p. 262 (leaf). Redrawn and adapted by Iskak Syamsudin.

Schizaea dichotoma. Beddome, R.H., 1983. The ferns of southern India. Reprint of 2nd edition. Bishen Sing Mahendra Pal Singh, Dehradun, India. Fig. 65 (leaf); Chinnock, R.J., 1998. Schizaeaceae. In: Flora of Australia 48. Fig. 58, p. 180 (rhizome, fertile segments); Holttum, R.E., 1959. Schizaeaceae. Flora Malesiana, Series 2. Pteridophyta (Ferns & fern allies). Vol. 1, part 1. M. Nijhoff / W. Junk Publishers, The Hague, The Netherlands. Fig. 4, p. 43 (lower surface of leaf, sorophores). Redrawn and adapted by Achmad Satiri Nurhaman.

Selaginella doederleinii. Huang, Tseng-Chieng (General Editor), 1994. Flora of Taiwan. 2nd Edition, Vol. 1. Pteridophyta and Gymnospermae. Editorial Committee of the Flora of Taiwan, Taipei, Taiwan. Fig.10, p. 49. Redrawn and adapted by Achmad Satiri Nurhaman.

Selliguea feei. Backer, C.A. & Posthumus, O., 1939. Varenflora voor Java [Fern flora of Java]. 's Lands Plantentuin, Buitenzorg, Dutch East Indies. Fig. 42, p. 199. Redrawn and adapted by Iskak Syamsudin.

Stenochlaena palustris. Andrews, S.B., 1990. Ferns of Queensland. Queensland Department of Primary Industries, Brisbane, Australia. p. 87 (base of sterile pinna showing gland and joint between pinna stalk and main rachis, apical part of pinna); Jones, D.L., 1987. Encyclopaedia of ferns. British Museum (Natural History), London, United Kingdom. p. 5 (crozier); Ochse, J.J., 1980. Vegetables of the Dutch East Indies. 3rd English Edition (translation of 'Indische groenten', 1931). A. Asher & Co., Amsterdam, The Netherlands. Fig. 371, p. 609 (part of rhizome and sterile leaves, fertile leaf); Sastrapradja, S., Afriastini, J.J., Darnaedi, D. & Widjaja, E.A., 1979. Jenis paku Indonesia [Indonesian fern species]. LBN 17, SDE 76. Lembaga Biologi Nasional-LIPI, Bogor, Indonesia. p. 56 (segment of fertile pinna). Redrawn and adapted by Achmad Satiri Nurhaman.

Taenitis blechnoides. Backer, C.A. & Posthumus, O., 1939. Varenflora voor Java [Fern flora for Java]. 's Lands Plantentuin Buitenzorg, Dutch East Indies. Fig. 21, p. 111. Redrawn and adapted by Achmad Satiri Nurhaman.

Tectaria crenata. Sastrapradja, S., Afriastini, J.J., Darnaedi, D. & Widjaja, E.A., 1979. Jenis paku Indonesia [Indonesian fern species]. Lembaga Biologi Nasional-LIPI, Bogor, Indonesia. LBN

17, SDE 76. Fig. on p. 66. Redrawn and adapted by Achmad Satiri Nurhaman.

Mosses

Leucobryum aduncum. Fleischer, M., 1902–1904. Die Musci der Flora von Buitenzorg [Musci of the flora of Buitenzorg]. Vol. 1. E.J. Brill, Leiden, The Netherlands. Fig. 18, p. 142. Redrawn and adapted by Achmad Satiri Nurhaman.

Sphagnum cuspidatum. Eddy, A., 1977. Sphagnales of tropical Asia. Bulletin of the British Museum (Natural History), Botany 5(7). Fig. 15, p. 411. Redrawn and adapted by Iskak Syamsudin.

Spiridens reinwardtii. Fleischer, M., 1902–1904. Die Musci der Flora von Buitenzorg [Musci of the flora of Buitenzorg]. Vol. 2. E. J. Brill, Leiden, The Netherlands. Fig. 121, p. 635. Redrawn and adapted by Achmad Satiri Nurhaman.

Index of scientific plant names

Page numbers printed in bold refer to main treatment.

Index of vernacular plant names

Page numbers printed in bold refer to main treatment.

Transcriptions of Vietnamese characters

[aa]	= â	[ar]	= ả	[ax]	= ã	[ej]	= ẹ	[oo]	= ô	[ow]	= ơ	[uj]	= ụ	[uwx]	= ữ
[aaf]	= ầ	[as]	= á	[ee]	= ê	[er]	= ẻ	[oof]	= ồ	[owf]	= ờ	[ur]	= ủ	[ux]	= ũ
[aaj]	= ậ	[aw]	= ă	[eef]	= ề	[es]	= é	[ooj]	= ộ	[owj]	= ợ	[us]	= ú		
[aar]	= ẩ	[awf]	= ằ	[eej]	= ệ	[ex]	= ẽ	[oor]	= ổ	[owr]	= ở	[uw]	= ư		
[aas]	= ấ	[awj]	= ặ	[eer]	= ể	[if]	= ì	[oos]	= ố	[ows]	= ớ	[uwf]	= ừ		
[aax]	= ẫ	[awr]	= ẳ	[ees]	= ế	[is]	= í	[oox]	= ỗ	[owx]	= ỡ	[uwj]	= ự		
[af]	= à	[aws]	= ắ	[eex]	= ễ	[of]	= ò	[or]	= ỏ	[ox]	= õ	[uwr]	= ử		
[aj]	= ạ	[awx]	= ẵ	[ef]	= è	[oj]	= ọ	[os]	= ó	[uf]	= ù	[uws]	= ứ		

The Prosea Foundation
(Plant Resources of South-East Asia)

Name, location, legal status and structure

- Prosea is a Foundation under Indonesian law, with an international charter, domiciled in Bogor. It is an autonomous, non-profit, international agency, governed by a Board of Trustees. It seeks linkage with existing regional and international organizations;
- Prosea is an international programme focusing on the documentation of information on plant resources of South-East Asia;
- Prosea consists of a Network Office in Bogor (Indonesia) coordinating 6 Country Offices in South-East Asia, and a Publication Office in Wageningen (The Netherlands).

Participating institutions

- Forest Research Institute of Malaysia (FRIM), Karung Berkunci 201, Jalan FRIM, Kepong, 52109 Kuala Lumpur, Malaysia;
- Indonesian Institute of Sciences (LIPI), Sasana Widya Sarwono, Jalan Gatot Subroto 10, Jakarta 12710, Indonesia;
- Institute of Ecology and Biological Resources (IEBR), Nghia Do, Cau Giay, Hanoi, Vietnam;
- Papua New Guinea University of Technology (UNITECH), Private Mail Bag, Lae 411, Papua New Guinea;
- Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD), Los Baños, Laguna, the Philippines;
- Thailand Institute of Scientific and Technological Research (TISTR), 196 Phahonyothin Road, Chatuchak, Bangkok 10900, Thailand;
- Wageningen University (WU), Costerweg 50, 6701 BH Wageningen, The Netherlands.

Objectives

- to document and make available the existing wealth of information on the plant resources of South-East Asia for education, extension work, research and industry;
- to make operational a computerized data bank on the plant resources of South-East Asia;
- to publish the results in the form of an illustrated, multi-volume handbook in English;
- to promote the dissemination of the information gathered.

Target groups

- those professionally concerned with plant resources in South-East Asia and working in education, extension work, research and commercial production (direct users);
- those in South-East Asia depending directly on plant resources, obtaining relevant information through extension (indirect users).

Activities

- the establishment and operation of data bases;
- the publication of books;
- the sponsorship, support and organization of training courses;
- research into topics relevant to Prosea's purpose;
- the publication and dissemination of reports and the research results.

Implementation

The programme period has been tentatively divided into 4 phases:
- preliminary phase (1985–1986): publication of 'Plant Resources of South-East Asia, Proposal for a Handbook' (1986);
- preparatory phase (1987–1990): establishing cooperation with South-East Asia through internationalization, documentation, consultation and publication; reaching agreement on the scientific, organizational and financial structure of Prosea;
- implementation phase (1991–2000): compiling, editing and publishing of the handbook; making operational the computerized data bank with the texts and additional information; promoting the dissemination of the information obtained.
- Prosea beyond 2000 (Phase 2001–2005): handbook finalization; emphasis on lesser-known useful plants, and making the information services demand-driven.

Documentation

A documentation system has been developed for information storage and retrieval called Prosea Data Bank. It consists of 7 data bases:
- BASELIST: primarily a checklist of more than 6200 plant species;
- CATALOG: references to secondary literature;
- PREPHASE: references to literature from South-East Asia;
- ORGANYM: references to institutions and their research activities;
- PERSONYM: references to specialists;
- TEXTFILE: all Prosea publications and additional information;
- PHOTFILE: photographs of useful plants of South-East Asia.

Publication

The handbook in blue cover (hardbound) is distributed by Backhuys Publishers, Leiden, The Netherlands (formerly by Pudoc, Wageningen, The Nether-

lands). The handbook in green cover (paperback) is distributed in two price-classes: a low-price paperback, distributed by Prosea South-East Asia for all developing countries; a medium-price paperback, distributed by Backhuys Publishers, Leiden, The Netherlands, and by Prosea South-East Asia for developed countries (becoming available two years after publication of the hard-bound edition). The bibliographies are distributed by Prosea South-East Asia.

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In brief, Prosea is

- an international programme, focused on plant resources of South-East Asia;
- interdisciplinary, covering the fields of agriculture, forestry, horticulture and botany;
- a research programme, making knowledge available for education and extension;
- ecologically focused on promoting plant resources for sustainable tropical land-use systems;
- committed to conservation of biodiversity;
- committed to rural development through diversification of resources and application of farmers' knowledge.

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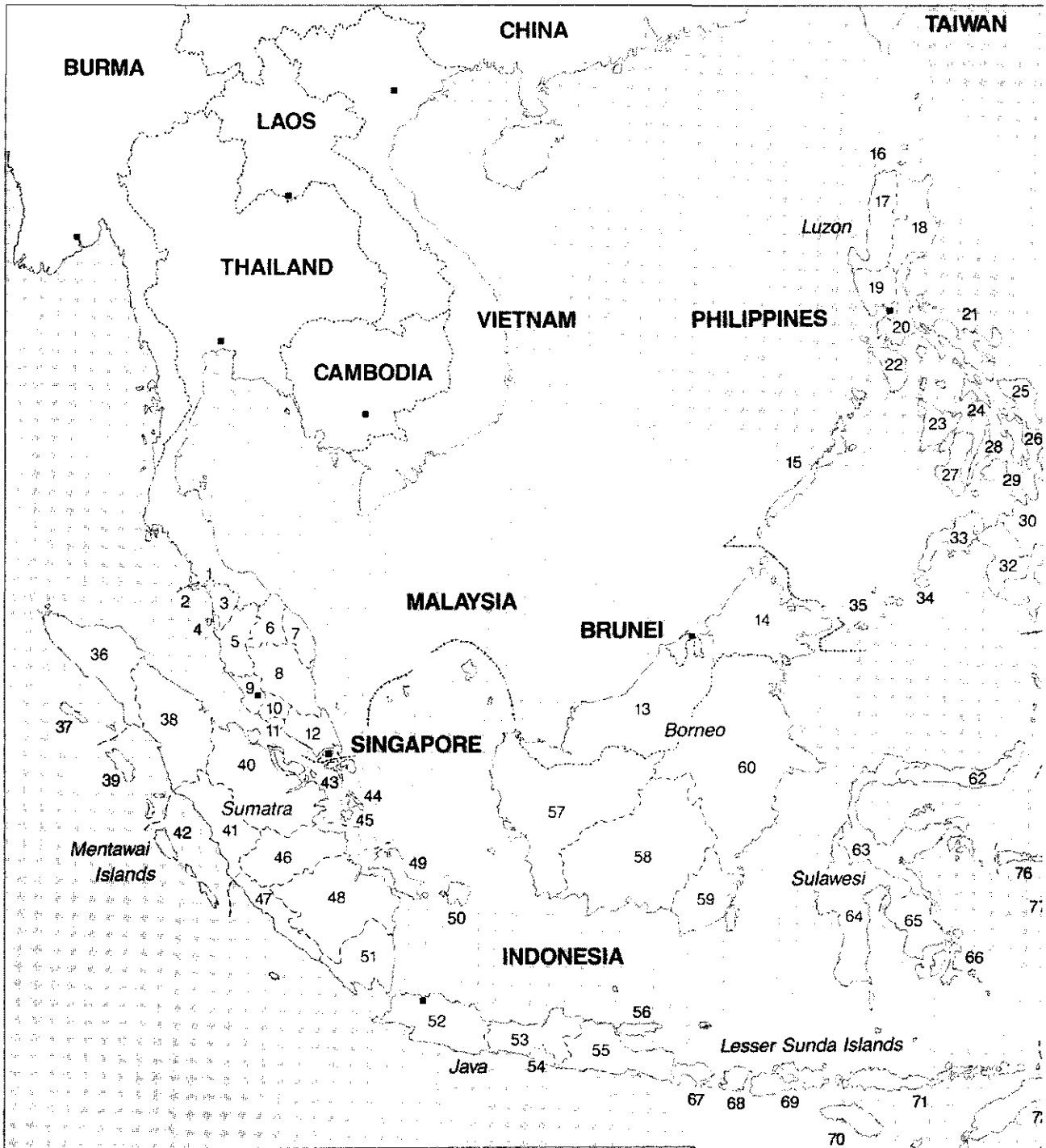
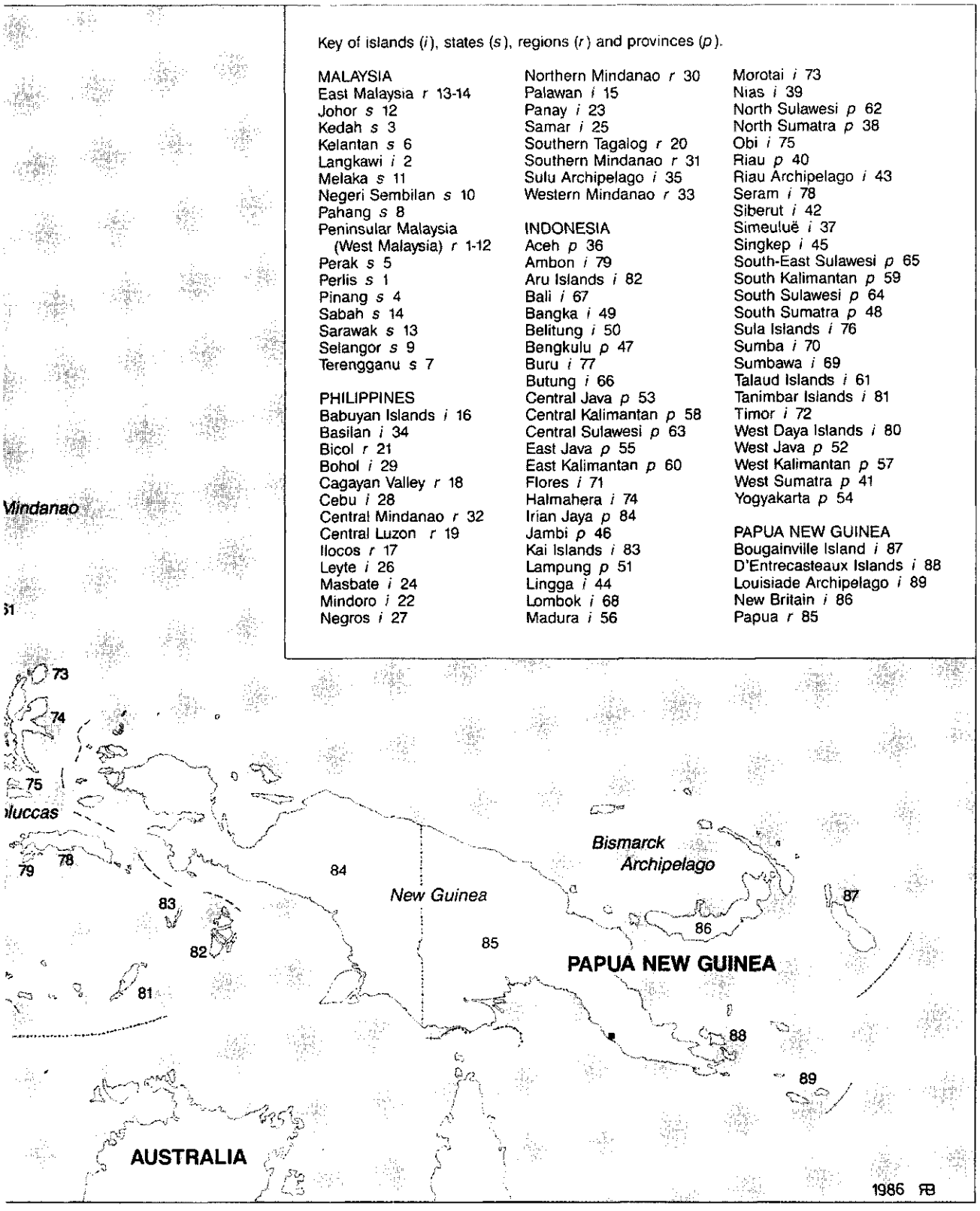


MAP OF SOUTH-EAST ASIA FOR PROSEA

Names of countries in capital letters and islands in lower case; numbers refer to the key.


Key of islands (i), states (s), regions (r) and provinces (p).
MALAYSIA
East Malaysia r 13-14
Johor s 12
Kedah s 3
Kelantan s 6
Langkawi i 2
Melaka s 11
Negeri Sembilan s 10
Pahang s 8
Peninsular Malaysia (West Malaysia) r 1-12
Perak s 5
Perlis s 1
Pinang s 4
Sabah s 14
Sarawak s 13
Selangor s 9
Terengganu s 7
PHILIPPINES
Babuyan Islands i 16
Basilan i 34
Bicol r 21
Bohol i 29
Cagayan Valley r 18
Cebu i 28
Central Mindanao r 32
Central Luzon r 19
Ilocos r 17
Leyte i 26
Masbate i 24
Mindoro i 22
Negros i 27
Northern Mindanao r 30
Palawan i 15
Panay i 23
Samar i 25
Southern Tagalog r 20
Southern Mindanao r 31
Sulu Archipelago i 35
Western Mindanao r 33
INDONESIA
Aceh p 36
Ambon i 79
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Bangka i 49
Belitung i 50
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Jambi p 46
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South Sulawesi p 64
South Sumatra p 48
Sula Islands i 76
Sumba i 70
Sumbawa i 69
Talaud Islands i 61
Tanimbar Islands i 81
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West Kalimantan p 57
West Sumatra p 41
Yogyakarta p 54
PAPUA NEW GUINEA
Bougainville Island i 87
D'Entrecasteaux Islands i 88
Louisiade Archipelago i 89
New Britain i 86
Papua r 85
Mindanao
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Moluccas
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New Guinea
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Bismarck Archipelago
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PAPUA NEW GUINEA
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AUSTRALIA
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