# Flora *of* Pan-Himalaya

Volume

30

Brassicaceae

Ihsan Ali AL-SHEHBAZ

CAMBRIDGE

SCIENCE PRESS
Beijing

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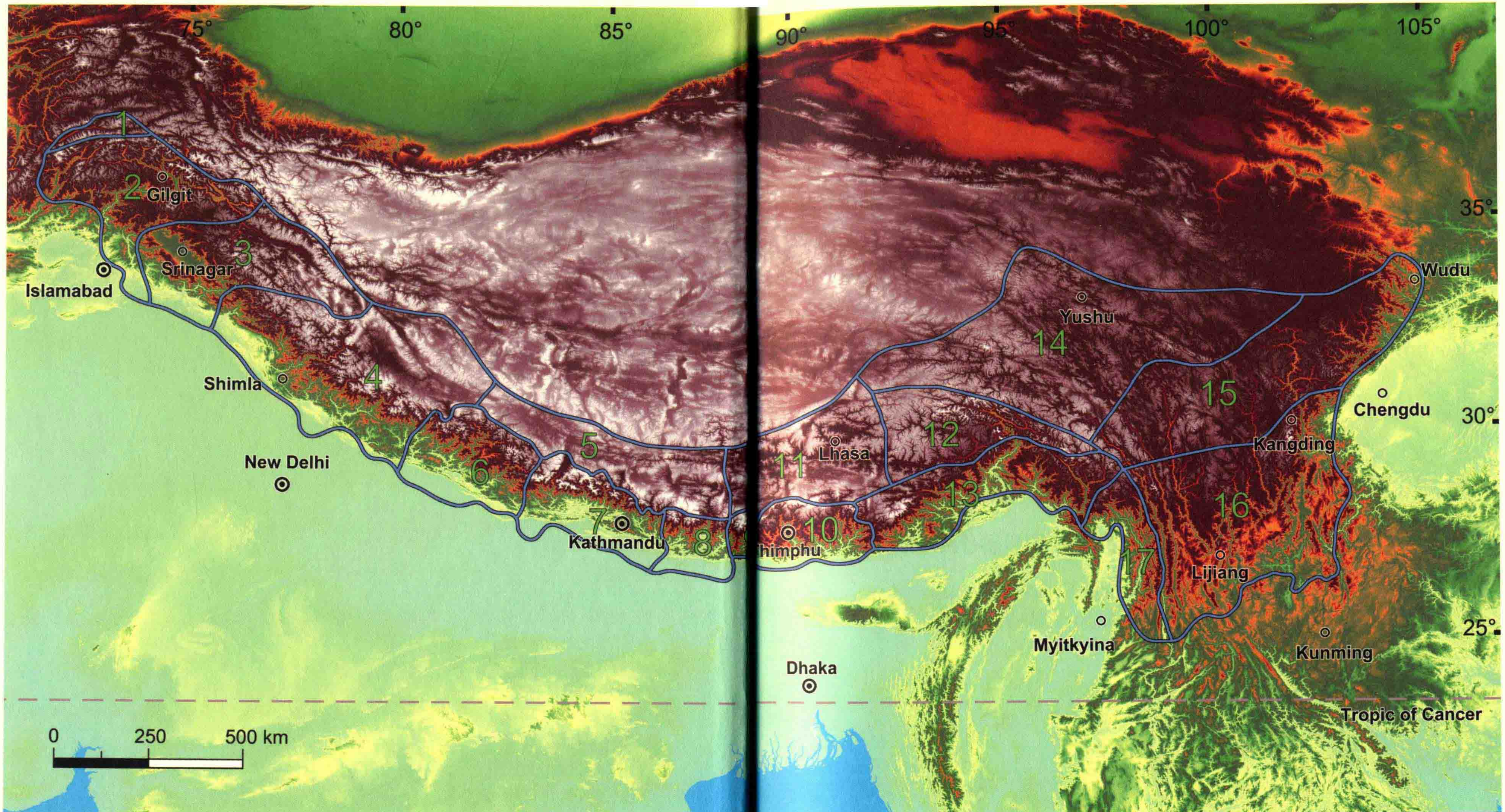
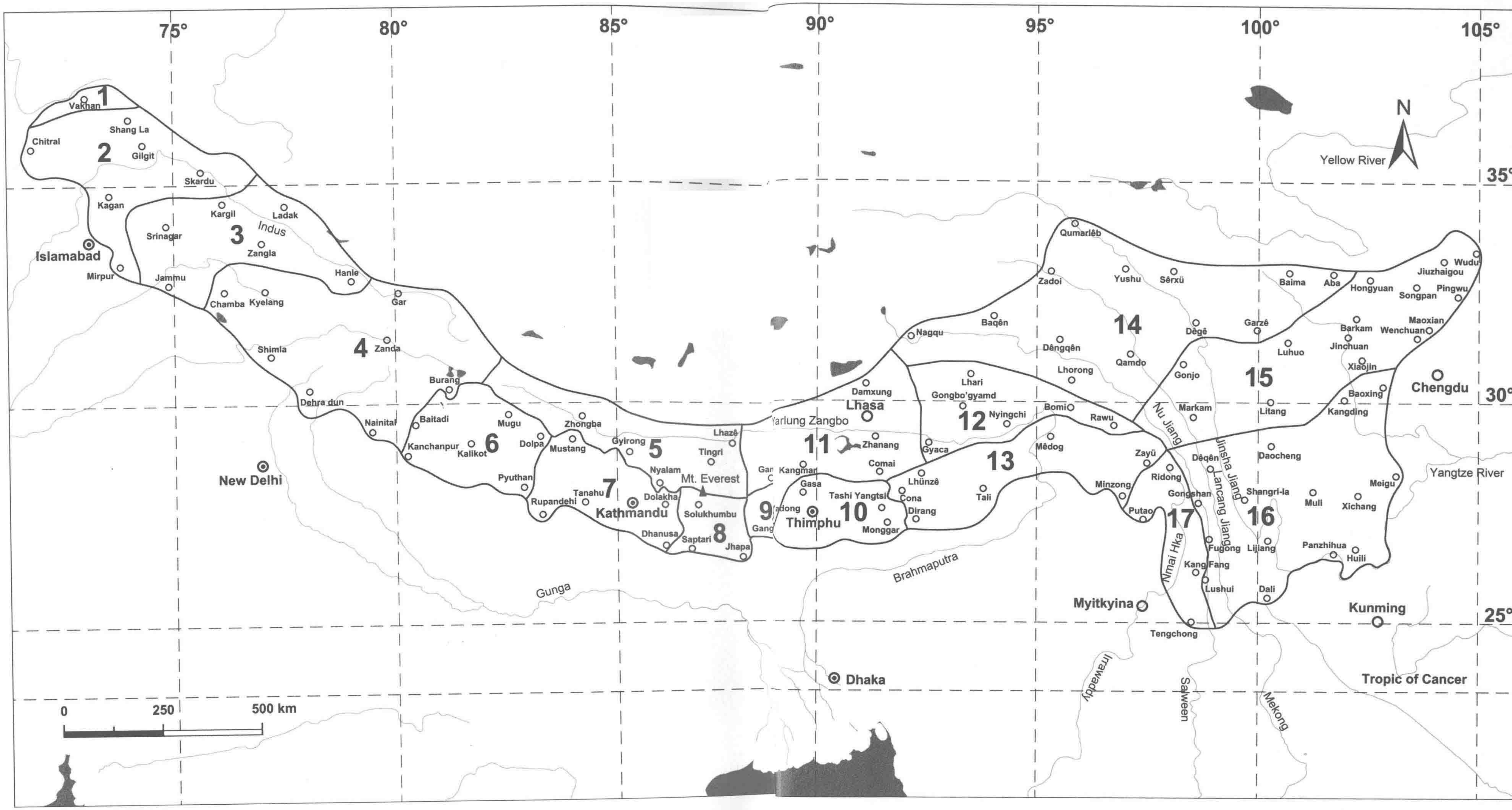



## Subdivisions of e Pan-Himalaya

1.Vakhan; 2.N Pakistan; 3. Jammu & Kashmir; 4. U Ganga & Indus; 5. U rlung Zangbo; 6. W Nepal; 7. C Nepal; 8. E Nepal; 9. Sikkim & Darjiling; 10. Bhutan; 11. M Yarlung Zangbo; 12. L Yarlung Zangbo; 13. Yarlung Zang Brahmaputra; 14. Tangut; 15. N Hengduan; 16. S Hengduan; 17. U Irrawaddy.

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# Flora *of* Pan-Himalaya



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# Foreword

We are delighted to welcome the appearance of this highly significant regional flora, and congratulate De-Yuan HONG and all of the others that worked together to make it possible. The Himalaya is one of the most beautiful, extensive, and revered ranges on earth, containing nine of our ten highest peaks, and its plants deserve the kind of inclusive and collaborative treatment that we have been presented in these fine volumes.

The mighty Himalaya were formed as the basaltic Indian plate plowed into the underbelly of Asia. Carrying the lighter rocks that would become the mountain ranges we see now, it broke out of the gigantic southern continent of Gondwanaland approximately 90 million years ago and started its journey northward to its current position. In the south, any part of India that rose above the ocean would have been covered with an archaic southern vegetation similar to that which survives today in southern Australia and South America, New Zealand, and New Caledonia. As the fragment that includes India journeyed northward, it passed from the south across the equator and started crowding into the Asian plate perhaps 55-50 million years ago, continuing to thrust up the Himalaya from that time onward. The same movement folded what is now China into a series of accordion-like pleats that became the current mountain ranges of southern and southwestern China and its neighboring countries.

Crossing so many latitudes seems to have led to the extinction of virtually all of the plants and animals that occupied India when its position lay south of the equator, but when it came within reach of Asia and under the influence of a tropical and subtropical climate from the early Eocene Period onward. The plants and animals of southern Asia colonized the new lands, and more migrated from the north as the mountains of the region were thrust ever upward. Importantly, there was a great opportunity for the evolution of endemic plants and animals in the new mountains, and the mixture of all of these rich biological strands have combined to form the incredible biological richness of the area as we see it today.

Both because of the political subdivisions of the region and its complex floristic composition, it took very courageous and forward-looking leadership for De-Yuan HONG and his colleagues to undertake this monumental flora. Except for China, there are relatively few endemics in most of the countries of the Himalayan ranges and their bordering lowlands, but many in the region. This lack of national endemics, however, stems mainly from the artificial presence of countries in the area, which taken as a whole is an extremely rich one for endemics in virtually all groups of plants, animals, and fungi that occur there. The plants of some of the countries are reasonably well known, those of others poorly known, and our historical efforts to bring the available information together and improve its quality by trans-national comparisons have been inadequate.

That situation is all the more unfortunate because of the severe threats that the ecosystems of the regions face from rapid human population growth and the even more rapidly rising expectations for increased consumption and especially from the climate change that threatens all of the ecosystems of the area, including the possible destruction of its glaciers and the disruptions of the monsoons on which so many depend for the food and livelihood. A sound knowledge of the plants and ecosystems of the region is the only way to win sustainability, even if population, consumption levels, and the runaway use of malign technologies like burning coal are brought under control.

For all of these reasons, we declare once more our delight in the appearance of this flora and congratulate those who have worked together to make it a reality. It is a critically important first step in improving our knowledge of the plants of the area on a regional basis, and one of great and general importance.

Peter H. Raven

Peter H. Raven,
President Emeritus,
Missouri Botanical Garden

# Introduction

## —General Guideline of the *Flora of Pan-Himalaya*

The Himalaya and adjacent regions (Pan-Himalaya) form a natural phytogeographical unit, from the Vakhan Corridor eastwards to the Hengduan Mountains via the Karakorum and the Himalaya. This region covers the northeastern corner of Afghanistan, northern Pakistan, northern India, Nepal, Bhutan, northern Myanmar, and southwestern China (S Tibet, SE Qinghai, SE Gansu, W Sichuan and NW Yunnan). This region is divided into 17 subregions: Vakhan, N Pakistan, Jammu & Kashmir, U Ganga & Indus, U Yarlung Zangbo, W Nepal, C Nepal, E Nepal, Sikkim & Darjiling, Bhutan, M Yarlung Zangbo, L Yarlung Zangbo, Yarlung Zangbo-Brahmaputra, Tangut, N Hengduan, S Hengduan, and U Irrawaddy (see the maps).

The *Flora of Pan-Himalaya* (FLPH) will be published in English in two editions: printed and online. It treats all the native and naturalized vascular plants of this region.

The Flora will be published in 50 volumes with ca. 80 books, with the larger families divided into two to seven parts. The classification systems used in this Flora will reflect our current understanding of phylogenetic or phylogenomic relationships of the relevant groups. The third edition of the Angiosperm Phylogeny Group system (APG III) will be adopted for the angiosperms, and up-to-date phylogenetic or phylogenomic systems for the gymnosperms, ferns, and lycophytes will be followed for the treatments of those groups.

The natural and rational delimitation of species is the critical task of taxonomy, and is the most important criterion for judging the scientific value and standard of a Flora. Population concepts should be employed in determining the taxonomy; character analysis should be considered as the basis for a rational taxonomic treatment. Therefore, field observations at the population level, and statistic analysis based on broad population sampling and collections are greatly encouraged to investigate the variation of characters and evaluate their taxonomic significance for the delimitation of taxa. Herbarium specimens kept at the following herbaria must be examined and identified: PE, KUN, K, BM, E, CDBI, and SZ. The authors are also encouraged to visit the herbaria of A, B, CAL, CAS, G, KATH, LE, P, TI, W, and HNWP.

Delimitation of closely related species should be based on correlated discontinuous (including statistically discontinuous) variation of at least two characters. As to apomicts (such as *Taraxacum* spp., *Sorbus* spp.) and vegetatively reproducing plants, "macrospecies" should be adopted instead of "microspecies".

The use of subspecies is encouraged in infraspecific classifications, but varieties only in special cases. Subspecies are geographical races and horizontally or vertically vicarious, whilst varieties are prominent ecotypes. Genotype variants within populations should not be recognized as different taxa. The description of a species should cover all its elements. Variants which do not merit formal taxonomic recognition may be noted below the description of the species.

Larger families and genera may be concisely subdivided. These systems should reflect the current understanding of phylogenetic or phylogenomic relationships, especially those generated from solid molecular and genomic data.

The concept of the genus should reflect the current understanding of phylogenies. Generic concepts strongly supported by both molecular/genomic and morphological evidence should be adopted, but those with weak support in molecular/genomic analysis and have no sound morphological evidence should not be accepted. The treatment of more poorly known groups should be conservative and any perceived problems indicated.

Identification keys are one of the most important products of classification, and the best reflection of its usefulness. Authors should construct a key based on examination of all relevant specimens.Where possible, keys should not be based on a single character, and must avoid vague words, such as "relatively large" vs. "relatively small", "longer" vs. "shorter". It is important to use easily visible characters in keys. Dichotomous indented keys such as those in the *Flora of China* are to be used in this Flora.

Description of species should be concise with emphasis on diagnostic characters, and should include habitat information and the geographical distribution, plus chromosome numbers, phenology, and other biological features, as well as reliable economic uses and conservation information where available.

Literature citation for accepted names and their basionyms must be provided. Important references, such as monographs and Floras, should be cited, but not more than three titles (at most five if absolutely necessary). All synonyms based on types from within the Flora area should be listed along with other synonyms that have been widely used in relevant publications.

Detailed type information should be indicated after the nomenclatural citation of taxa. Designation of types is highly encouraged in this Flora.

A distribution map is given for each species. This will be a dot map based on the specimens seen for the Flora. The vouchers are to be cited to record geographical distribution for each species, subspecies (or variety). At least one representative specimen is needed for each distribution unit (county in China, district in the other countries). For the more widely distributed taxa (across nine or more subdivisions), a larger distribution unit can be used, no citation of vouchers is needed, and the distribution outlines are also acceptable.

The nomenclatural novelties (new taxa, new combinations, and *nomina nova*) may be published in the Flora or elsewhere.

Sterile hybrids, and those hybrids not forming populations, are to be briefly discussed after the descriptions of their parents. Plants only konwn from cultivation may be indicated at the end of the treatment of the genus, but should not be included in the identification keys.

All genera, and at least one third of species, should be illustrated with good quality line drawings with scale bars to indicate magnifications. The illustrations can be drawn from herbarium materials, living materials or images available, selected by the authors, or taken from publications with permission. Wherever possible the material used should be indicated. Diagnostic characters of the species should be clearly illustrated. One plate may hold illustrations of one, two, or three species. For larger genera composite plates of diagnostic characters are encouraged.

The web edition of the Flora will follow the corresponding printed edition. Colour photographs, detailed citation of vouchers, and other sources of information are to be included only in the web edition.

The physical geography, history of studies of vascular plants from this region, biogeography, biodiversity conservation, general references, and key to families are to be included in the first (introductory) volume. A comprehensive index to taxa and other subjects are to be published in the last volume.

More detailed guidelines and a model treatment for preparation of Flora accounts will be provided by the Editorial Committee.

The Editorial Committee of *Flora of Pan-Himalaya*

# Preface

Volume 30 of the *Flora of Pan-Himalaya* is one in the series of 50 volumes that are divided into ca. 80 parts. It is devoted to mustard family (Brassicaceae or Cruciferae).

The Brassicaceae is one of the most natural plant families, and it is distributed on all continents except Antarctica, though mainly in the temperate, alpine, and subarctic areas. The highest diversity of the family is in the Irano-Turanian region, followed by western North America, the Mediterranean region, the Andes of South America, and the Himalayan region. However, for its relatively medium size and over 570 species, Turkey has highest diversity of any country in the world.

The nomenclatural novelties in this volume include the new species *Lepidium densipuberulum* and *Sisymbrium nepalense* and the new name *L. cuneiforme*. Furthermore, the lectotypes of *Aphragmus tibeticus*, *A. stewartii*, *Braya rubicundula*, *Cardamine calcicola*, *C. impatiens* var. *elongata*, *C. weixiensis*, *Draba lichiangensis*, *Eutrema deltoideum* var. *grandiflorum*, *E. przewalskii*, *E. sherriffii*, *Hemilophia serpens*, *Noccaea cochlearioides*, *Parrya chitralensis*, *Pyconplinthus uniflora*, *Solms-laubachia minor*, and *S.-L. xerophyta* are newly designated.

The literature on Himalayan Brassicaceae is too voluminous to cite in the present account, though every reference was checked by the present author. However, for species delimitation and distribution, some key references were constantly consulted for Afghanistan (Breckle et al., 2013; Kitamura, 1960, 1966; Hedge & Rechinger, 1968), Bhutan (Grierson, 1984), China (Zhou et al., 1987, 2001), India (Chowdhery & Wadhwa, 1984; Hajra & Chowdhery, 1993; Hajra et al., 1993a, b, c, d; Hajra et al., 1996; Srivastava, 1998; Rajeshwari et al., 2002), Nepal (Hara & Williams, 1979; Al-Shehbaz & Watson, 2011), and Pakistan (Hedge & Rechinger, 1968; Jafri, 1973).

Despite its usefulness, checklist of the Indian subcontinent (Kundu, 2007) includes many distributional, geographic, and nomenclatural inaccuracies, most of which are discussed under individual species or genera. Some species records from countries covered by the Pan-Himalaya are almost certainly based on misidentified plants of related taxa. Therefore, that checklist was consulted herein but with a great deal of caution.

Many, Brassicaceae-wide molecular phylogenetic studies during the past decade (e.g., Bailey et al., 2006; Beilstein et al., 2006, 2008; Couvreur et al., 2010; Franzke et al., 2009, 2011, German et al., 2009; Khosravi et al., 2009; Koch & Al-Shehbaz, 2009; Warwick et al., 2010) paved the way to establish the first phylogenetic tribal classification of the family (Al-Shehbaz et al., 2006) and its more recent updating (Al-Shehbaz, 2012).

Unless otherwise indicated, chromosome numbers cited in this work were taken from Warwick & Al-Shehbaz (2006) and the family-wide Brassicaceae database, or BrassiBase (see Koch et al., 2012a; Kiefer et al., 2014). For those interested in these counts, the above databases should be consulted for reference(s) on which a given chromosome count was based.

# Acknowledgements

The author is profoundly grateful to a number of colleagues too many to enlist. Most notably, I thank Academician Professor De-Yuan HONG for his friendship, continuous support, patience, and advice throughout the preparation of this account, and without that, this account would have never been completed. I am thankful to Karol Marhold and Dmitry A. German for advice on typification matters, Mark F. Watson and Colin A. Pendry for a copy of the Nepal Brassicaceae database, Michael G. Gilbert and Sa Ren for their substantial help during the editing and processing of this manuscript, and David E. Boufford for allowing me study the exceptionally rich Brassicaceae collections that he and colleagues made in Himalayan China.

I thank the following editors-in-chief of several journals for granting permission to re-publish in this book several illustrations that were previously published in their journals. These include Dr. Victoria C. Hollowell (Novon), Dr. Gustavo A. Romero (Harvard Papers in Botany), Dr. Zhang Zhi-Qiang (Phytotaxa), and Dr. Nishanta Rajakaruna (Rhodora).

Portion of this research was done during travel supported by the OPUS grant DEB-1252905 from the United States National Science Foundation to study Brassicaceae of the world, and for that support I am profoundly thankful. I am also grateful to the directors, curators, and collections managers of the following herbaria for making their collections available for the present study: A, B, BM, CAS, CDBI, E, F, FI, G, GH, GOET, HNWP, K, KATH, KUN, L, LE, M, MO, MSB, NA, NAS, NY, P, PE, PH, S, SZ, TI, UC, UPS, US, TI, W, XJU, and WU.

Last, but certainly not least, I thank Mona Al-Shehbaz, my wife and companion for the past 50 years, for her continuous support, encouragement, and endless care and love throughout my career.

# Contents

# BRASSICACEAE

Herbs annual, biennial, or perennial with rhizomes, tubers, or woody base (called caudex hereafter), sometimes subshrubs, [rarely shrubs or lianas, very rarely small trees], always with a pungent watery juice. Trichomes unicellular, simple, 2–many forked, stellate, dendritic, or malpighiaceous (medifixed, bifid, sessile, appressed). Multicellular glands with multiseriate [or rarely uniseriate] stalk sometimes present. Leaves exstipulate, alternate, rarely opposite or whorled, petiolate or sessile, simple, entire or variously divided, rarely trifoliolate or pinnately, [palmately, or bipinnately] compound, basal ones usually form a rosette, cauline leaves sometimes absent and plants scapose. Racemes ebracteate or bracteate, sometimes forming corymbs or panicles, or flowers solitary on long pedicels originating from axils of rosette leaves. Flowers hypogynous, mostly actinomorphic, bisexual [or very rarely unisexual and plant monoecious or dioecious]; sepals 4, in 2 decussate pairs, free or sometimes united, not saccate or lateral (inner) pair saccate; petals 4, alternate with sepals, arranged in the form of a cross (cruciform; hence the earlier family name Cruciferae), sometimes rudimentary or absent, clawed or not; stamens 6, in 2 whorls, tetradynamous (lateral (outer) pair shorter than median (inner) 2 pairs), rarely equal or in 3 pairs of unequal length, sometimes stamens 2 or 4, very rarely to 24 (*Megacarpaea*); filaments slender, rarely winged or appendaged, median pairs free or rarely united; anthers usually dithecal, dehiscing by longitudinal slits; pollen grains 3-colpate [or rarely 4–10-colpate], trinucleate; nectar glands receptacular, confluent and subtending bases of all filaments, or distinct, lateral and opposite bases or 1 on each side of lateral filament, median glands present or absent; pistil 2-carpelled; ovary superior, mostly 2-locular and with a false septum connecting 2 placentas; placentation parietal, rarely apical. Fruit dehiscent or indehiscent, typically a 2-valved capsule, generally termed silique (siliqua) when length more than 3 times width, or silicle (silicula) when length less than 3 times width, sometimes schizocarpic, nutletlike, lomentaceous, or samaroid, segmented or not, terete, angled, or flattened parallel to septum (latiseptate) or at a right angle to septum (angustiseptate); gynophore absent or rarely distinct; replum (persistent placenta or frame to which ovules, seeds, and valves attached) rounded, rarely flattened or winged; septum complete, perforate, or lacking; style 1, sometimes obsolete, persistent or rarely deciduous; stigma entire or 2-lobed, sometimes lobes decurrent and free or united, opposite valves or replum. Seeds without endosperm, winged or wingless, uniseriately or biseriately arranged in each locule, sometimes aseriate; seed coat variously ornamented, mucilaginous or not when wet; cotyledons incumbent (embryo notorrhizal: radicle lying along back of 1 cotyledon), accumbent (embryo pleurorrhizal: radicle applied to margins of both cotyledons), or conduplicate (embryo orthoplocal: cotyledons folded longitudinally around radicle), [rarely other types]. Germination epigeal.

Limits of the Brassicaceae have not changed over the centuries, and the family has long been well recognized as a natural and, more recently, monophyletic group based on many molecular studies, especially that of Hall et al. (2002) and the latest and continuously updated version of the Angiosperm Phylogeny Website (http: //www.mobot.org/MOBOT/research/APweb/). Therefore, expansion of the family limits to include the Capparaceae and Clemoaceae, as proposed by Judd et al. (1994) and followed by Kundu (2007), is no longer acceptable.

The ovule number per ovary is a character extremely important taxonomically, but it is quite laborious and time consuming to determine from pistils and young fruit. However, it can easily be obtained by counting the number of seeds plus the number of aborted ovules in the mature fruit. Counting seed number alone is unreliable because some ovules fail to develop into seeds due to the lack of sufficient pollen. Another taxonomically important feature is the types of cotyledonary position (accumbent, incumbent, conduplicate, etc.; see the family description above). It represents the position of the radicle in relation to the cotyledons and can easily be determined by a cross section of the seed.

Although fruit characters are subject to considerable convergence and of a limited value if used alone in assessing phylogenetic relationships at various taxonomic ranks, they are essential for the identification of genera and species. However, a key emphasizing fruiting material and another emphasizing flowering material are given. The most reliable determination of genera can be achieved when the material has fruit and flowers and when both keys are successfully used to reach the same genus. The keys were intentionally divided into smaller groups to facilitate easier and faster identification of genera.

The tribes and genera are arranged alphabetically following the family synopsis of Al-Shehbaz (2012). The species and infraspecific taxa are also arranged alphabetically within their genera. For type collections, the numbers following the herbarium acronym represent bar-code numbers, and the only exceptions are those for types at WU, most ones at HNWP, KUN, and PE, and only a handful at MO.

Fifty-one tribes, 333 genera, and about 3712 species distributed worldwide. In the Pan-Himalaya Flora, the family is represented by 30 tribes, 79 genera (11 endemic) and 373 species (176 endemic, or 47%). The Chinese part of the Pan-Himalaya area has 254 species (80 endemic), that of India has 173 species (seven endemic), that of Pakistan has 167 species (six endemic), that of Nepal has 108 species (eight endemic), all Bhutan has 76 species (three endemic), and the Afghanistan and Myanmar Himalaya parts have 64 and 15 species, respectively.

Because some of the 17 subdivisions of Pan-Himalaya fall within the boundaries of more than one country, it is more appropriate to compare the richness of Brassicaceae within and among these subdivisions rather than individual countries. N Pakistan subdivision of Pan-Himalaya has the highest number of species (148, three endemic), followed by S Hengduan (144 spp., 37 endemic), Jammu & Kashmir (121, eight endemic), U Ganga & Indus (103, two endemic), Tangut (98, four endemic), N Hengduan (88), W Nepal (72, five endemic), Sikkim & Darjiling (77, one endemic), Bhutan (77, three endemic), E Nepal (64, two endemic), M Yarlung Zangbo (61, two endemic), Vakhan (60), Yarlung Zangbo-Brahmaputra (55, two endemic), L Yarlung Zangbo (48, one endemic), U Yarlung Zangbo (44, six endemic), C Nepal (37), and U Irrawaddy (14).

The genera endemic to the Pan-Himalaya are *Arcyosperma* Thomson (one sp.), *Baimashania* Al-Shehbaz (two spp.), *Dipoma* Franch. (one sp.), *Hemilophia* Franch. (five spp.), *Ladakiella* D. A. German & Al-Shehbaz (one sp.), *Lepidostemon* Hook.f. & Thomson (six spp.), *Parryodes* Jafri (one sp.), *Pegaeophyton* Hayek & Hand.-Mazz. (seven spp.), *Pycnoplinthopsis* Jafri (one sp.), *Shangrilaia* Al-Shehbaz , J. P. Yue & H. Sun (one sp.), and *Sinoarabis* R. Karl, D. A. German, M. Koch & Al-Shehbaz (one sp.). Fifty percent of the species in our flora belong to the six largest genera. These are: *Draba* L. (68 spp., 44 endemic), *Cardamine* L. (43 spp., 28 endemic), *Solms-laubachia* Muschl. (30 spp., 23 endemic), *Erysimum* L. (19 spp., 11 endemic), *Eutrema* R.Br. (17 spp., eight endemic), and *Lepidium* L. (16 spp., two endemic).

The Brassicaceae include many crop plants of considerable importance such as those grown as vegetables (e.g., species of *Brassica* L., *Eruca* Mill., *Nasturtium* W. T. Aiton, *Raphanus* L.) and as sources of vegetable oils (*Brassica*) or condiments (*Armoracia* G. Gaertn., B. Mey. & Scherb., *Brassica*, *Eutrema*, *Sinapis* L.). Oils of *Brassica* probably rank first in terms of the worldwide tonnage production. The family includes many ornamentals in genera such as *Arabis* L., *Erysimum*, *Hesperis* L., *Iberis* L., *Lobularia* Desv., *Lunaria* L., *Malcolmia* W. T. Aiton, and *Matthiola* W. T. Aiton. It also includes more than 130 species of weeds, including *Arabidopsis thaliana* (L.) Heynh., a species universally used as the model organism in various fields of experimental biology.