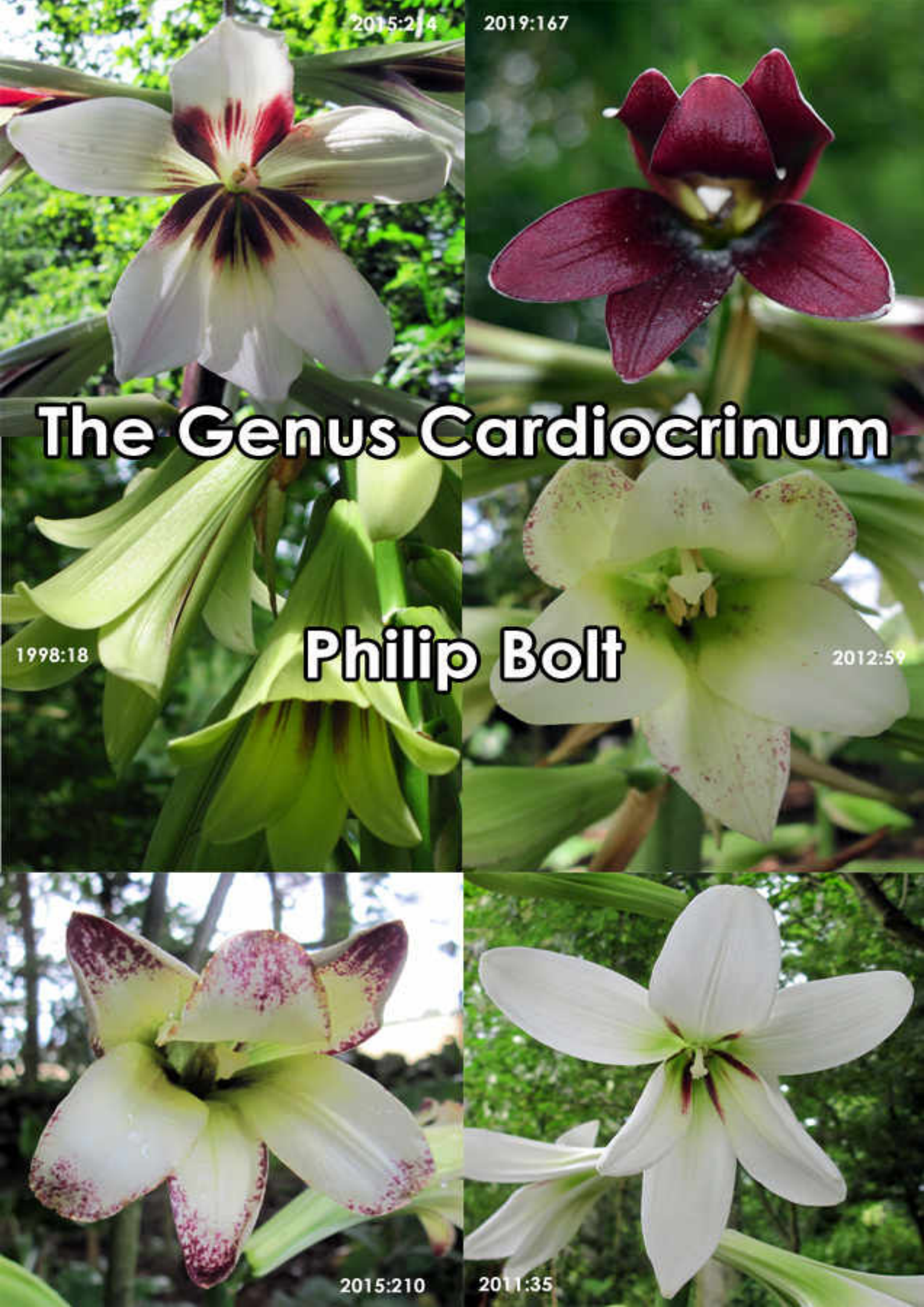

2015:214
2019:167
The Genus Cardiocrinum
Philip Bolt
1998:18
2012:59
2015:210
2011:35

The Genus Cardiocrinum:
its identification and cultivation

Philip Bolt

First edition: November, 2016

Second edition: January 2018

The revisions take into account the results published in the paper by Li-Qin Yang, Hao-Yu Hu, Chuan Xie, Shan-Pan Lai, Mei Yang, Xing-Jin He and Song-Dong Zhou in the *Annals of Botany* , [LHCSMXS], [1] and *C. cathayanum (hort.)* is designated as *C. giganteum yunnanense*.

Third edition: September, 2018

trnL barcode comparisons have been removed and an analysis made of variations in the matK sequences for *C. giganteum yunnanense*

Fourth edition: November, 2018

A chapter has been added on the problems and pitfalls associated with the purchase of *Cardiocrinum* bulbs and seeds. The identification key has also been been modified to comply with my current knowledge of *C. cathayanum*.

Fifth edition August, 2020

Information has been added on *C. giganteum yunnanense* f. *rosea* and *C. cordatum cordatum* 'Red flowered form'.

[1] Li-Qin Yang, Hao-Yu Hu, Chuan Xie, Shan-Pan Lai, Mei Yang, Xing-Jin He and Song-Dong Zhou, Molecular phylogeny, biogeography and ecological niche modelling of Cardiocrinum (Liliaceae): insights into the evolutionary history of endemic genera distributed across the Sino-Japanese floristic region, *Annals of Botany* 119: 59–72, 2017

ACKNOWLEDGEMENTS

I'm grateful to my wife, Moira Bolt, for her help in maintaining the collection, to Julia Llewellyn-Hughes, DNA Sequencing Facility Manager, and her staff at The Natural History Museum, London for the sequencing of the DNA and to Sven Landrein, (Horticultural Botanist), & László Csiba, (DNA Bank Manager), formerly of the Royal Botanic Garden, Kew for their help and information about *C. cathayanum,* Kew 2007 297.

Thanks are also due to the committee of the Grampian and Tayside branch of the National Council for the Conservation of Plants and Gardens, (Plant Heritage ®), for grants made to maintain and enlarge the collection.

I'm also grateful to all those individuals who've taught me what I know about gardening over the years.

 The photos of plants in the collection are usually labelled with the accession code of the plant which can be identified in the collection's online database.[1]

References to documents are included as footnotes using arabic numerals. Internal references are footnotes which use the symbols ∗, †, ‡, §, etc.

[1] http://www.redhall.org.uk/GardenOpening/cardio_db.htm

CONTENTS

INTRODUCTION

The genus *Cardiocrinum* consists of two or three species and several varieties and forms.

There are a number of uncertainties about it's taxonomy. Some doubt that *C. giganteum yunnanense* is a separate variety, there is uncertainty as to the existence of *C. cordatum glehnii* and the status of *C. cathayanum* is unclear.

Until 2012, *C. giganteum yunnanense* was listed as a synonym of *C. giganteum giganteum* [1], being considered as just part of a continuum of forms of the latter. '*The Plant List*' now shows it as an accepted name, albeit of low confidence [2]

C. cordatum glehnii is considered to be a synonym for *C. cordatum cordatum* but is also listed as an accepted name of low confidence [3].

This work seeks to clarify the taxonomy of the genus and to give information on the propagation and cultivation of these impressive plants.

The data concerning growing plants is taken from observations of the UK National Collection® of the genus *Cardiocrinum* which I hold and which is located at Redhall at the mouth of the Angus Glens at an altitude of 150m and a latitude of 56°N. [4]

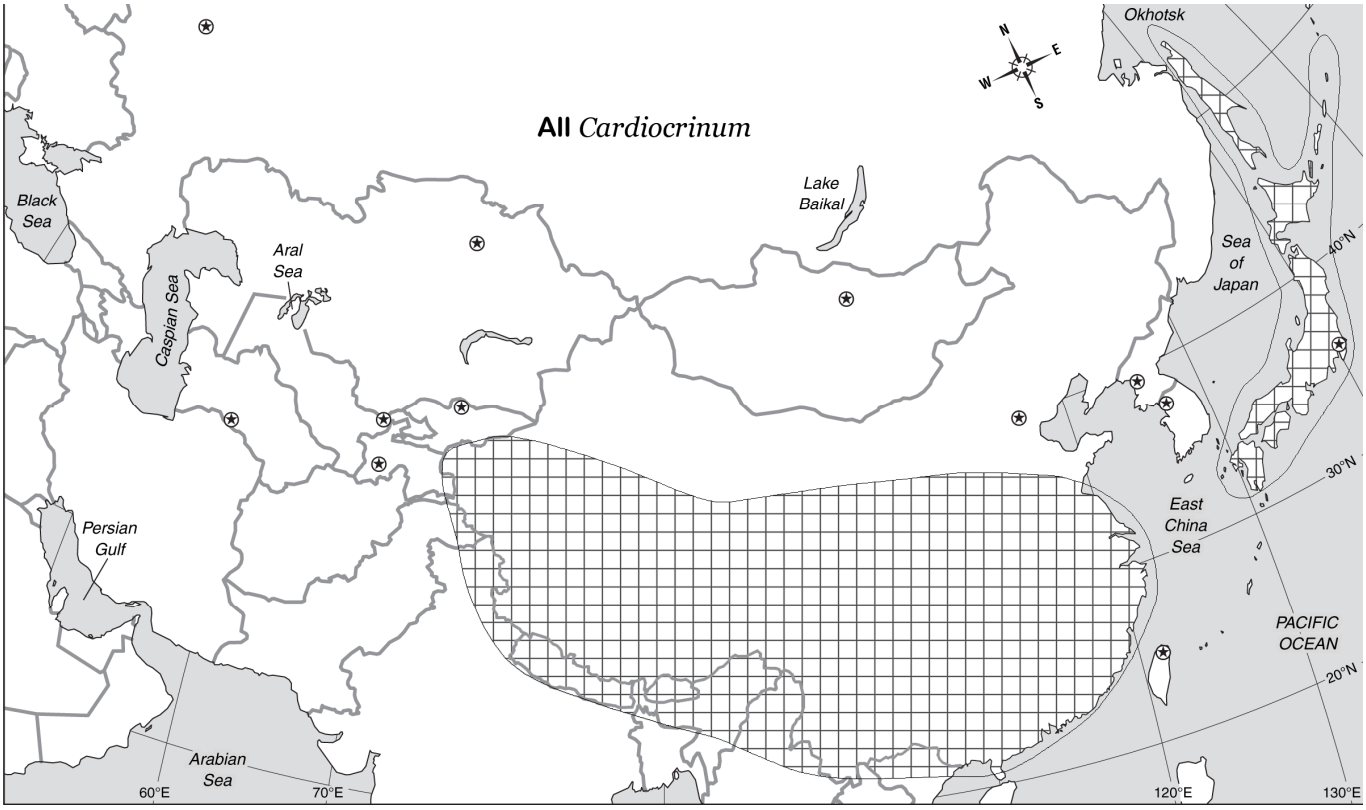
This is area is considered particularly fitting for the cultivation of plants from the Himalayas as Ascreavie House, four miles from Redhall, was chosen by Major and Mrs Sherriff [5] as the location in Scotland most suitable for their collection of Himalayan flora .

[1] *Flora Reipublicae Popularis Sinicae* Vol. 14 (1980), quoted by Matthews, *The Plantsman*, December 2002, p. 200
[2] *The Plant List* (2013). Version 1.1. Published on the Internet; http://www.theplantlist.org/ (accessed 21/2/15).
[3] *The Plant List* (2013). Version 1.1. Published on the Internet; http://www.theplantlist.org/ (accessed 21/2/15).
[4] See page 20 for more details of the collection.
[5] Major George Sherriff,1898 - 1967 http://www.geos.ed.ac.uk/~scotgaz//people/famousfirst1916.html

THE TAXA

Cardiocrinum (Endlicher)

Givnish et al consider that *Cardiocrinum* evolved on the Tibetan Plateau about 28 – 24 Mya[1] and then spread to Kashmir in the West, Northern Myanmar, (Burma), in the South, to most of mainland China in the East and, eventually, into Japan. However, LHCSMXS [2] suggest a much later appearance for the archetypal Cardiocrinum and a much different development. *



Generic description , a [3]

Cardiocrinum (Endlicher) Lindley *Veg. Kingdom* 205 (1846).
Syn: *Lilium* subgenus *Cardiocrinum* (Endlicher, Baker in *Journal of the Linnean Society* (Botany)14 (1874);
Lilium section *Cardiocrinum* Endlicher, Gen. Pl. 141 (1836).

Hairless, bulbous herbs. Bulbs composed of numerous fleshy, overlapping scales. Stems erect, unbranched. Leaves long-stalked, the blade broadly ovate-cordate, net-veined. Flowers with short stalks, funnel-shaped, in a terminal raceme. Perianth-segments 6, free from one another, the inner 3 with a nectar-bearing furrow at the base. Stamens 6, each attached at the base of the perianth-segments, free from one another. Anthers versatile i.e. attached to the filament at their mid-point, so that they are able to move. Ovary superior. Style 1, longer than stamens. Stigma 3-lobed. Fruit a 3-celled capsule, which when mature splits into 3 valves that are fringed with membranous teeth. Seeds many, triangular, flat with a marginal membranous wing.

---

[1] Givnish et al, *Cladistics* (2016) 1–25 Phylogenomics and historical biogeography of the monocot order Liliales: out of Australia and through Antarctica.
[2] LHCSMXS, p. 69 - 70
* See p. 24 for details of their ideas.
[3] Matthews, *The Plantsman*, December 2002, p. 196

The plants produce their flowers, depending on conditions, in summer, generally between June and August. Each flower usually lasts for two to three weeks.

Generic description, b (Endlicher)

Lindley, Veg. Kingd. 205. 1846. [1]
大百合属 da bai he shu
Liang Songyun (梁松筠 Liang Song-jun); Minoru N. Tamura
Lilium [unranked] *Cardiocrinum* Endlicher, Gen. Pl. 141. 1836.

Herbs perennial, bulbiferous. Bulb formed by swollen base of usually deciduous basal leaves; bulbils several, ovoid, covered with tunics. Stem very tall, stout, glabrous. Leaves basal and cauline, petiolate, usually ovate-cordate, reticulate veined. Inflorescence a terminal raceme, several to many flowered; bracts persistent or caducous. Flowers bisexual, tubular-funnelform, large; pedicel rather short. Tepals 6, free, ± connivent. Stamens 6, inserted at base of tepals; filaments flat; anthers dorsifixed, versatile, narrowly ellipsoid. Ovary cylindric, 3-loculed; ovules many per locule. Style elongate; stigma slightly 3-lobed. Fruit a loculicidal capsule. Seeds reddish brown, flat, narrowly winged all round.
Three species: Bhutan, China, India, Japan, Myanmar, Nepal, Sikkim; two species (one endemic) in China.

It is considered that the the movement into Japan occurred during one of the periods when it was connected to China by a land bridge, (e.g. Plate 1, A, p. 8), which could have happened as recently as 130,000–114,000 yr BP [2]. The problem with this conjecture is that the genus should also have populated Korea but *Cardiocrinum* are not found as part of the Korean Flora [3]. It is possible that, if the land bridge arose due to falling sea levels in a period of glaciation, the transfer occurred in what is now southern Kyushu and Korea was just a little too far North for *Cardiocrinum* taxa to survive at that time. LHCSMXS place the transfer from China to Japan at about 4.97 Mya [4]

One point not made in the above description is that all taxa have an extremely attractive scent which is most notable after rain or in the early evening. One plant is capable of perfuming an acre of garden.

1.a *Cardiocrinum giganteum* (Wallich)

C. giganteum (Wallich) Makino in Bot. Mag. Tokyo 27: 125 (1913).
Syn: *Lilium giganteum* Wallich, Tent. Fl. Napal. 21: t. 12, 13 (1824)
excl. syn.; *L. cordfolium* subsp. *giganteum* (Wallich) Baker in Gard. Chron. 1871: 479.

Bulb dark green, becoming brownish or maroon on exposure to light, ovoid, reaching 12 - 18 cm high and 10 - 15 cm wide;scales relatively few, loose, widely separated, broadly ovate, with an apical scar and fibres left by the former leaf-stalk. Stem 1.5 – 4m. tall, green or deep purple, stout, smooth. Leaves dark shiny green above, paler beneath; basal leaves in a rosette, stalks 30-35 cm long, blades up to 50 cm long and 40 cm wide, broadly ovate with a cordate base; stem-leaves alternate, long-stalked, scattered, decreasing in size up the stem. Raceme usually 30 - 60 cm long, with (6-)10 - 25(32) flowers that are borne horizontally or inclined slightly downwards. Bracts absent. Flowers regularly funnel-shaped, fragrant, outside pure white or tinged green, inside striped reddish purple and sometimes blotched with yellow perianth segments oblanceolate, more or less blunt, 15 -20(-25) cm long, narrowed gradually to

[1] *Flora of China*, Vol. 24 Page 134 , published on the internet http://www.efloras.org/florataxon.aspx?flora_id=2&taxon_id=105621
[2] A strong 'filter' effect of the East China Sea land bridge for East Asia's temperate plant species: inferences from molecular phylogeography and ecological niche modelling of *Platycrater arguta* (Hydrangeaceae), "*BMC Evol Biol. 2014; 14: 41*" Xin-Shuai Qi, Na Yuan, Hans Peter Comes,Shota Sakaguchi, and Ying-Xiong Qiu.
[3] Prof. C-S Chang, editor, "*Provisonal Checklist of Vascular Plants for the Korea Peninsula Flora*", personal correspondence
[4] LHCSMXS, p. 68.

the base, outer segments 2 - 2.7 cm wide, inner segments 2.7 - 3.4 cm wide. Filaments 7.5 - 8.8 cm long, half to two-thirds the length of the perianth segments; anthers linear with yellow pollen. Ovary club-shaped, 2.7 - 3.4 cm long. Style, 3.8 - 6 cm long. Capsule obovoid, erect, 3 - 6.3 cm long, bluntly angled, the coriaceous valves 2.7 - 3.4 cm wide. Seeds triangular, flat, with a broad membranous wing.
DISTRIBUTION. Extends along the Himalaya from Simla eastward through Nepal, Sikkim, Bhutan, the Khasi Hills and upper Assam to the extreme north of Myanmar, and China (SE Tibet (Xizang). It usually occurs at altitudes between 1500 and 3700m., in moist but well-drained soil in shady forest. The hill-people of the central Himalaya use the hollow stems as musical pipes.[1]

The important point in this description is,"… basal leaves in a rosette …" I'm aware of no case where a *Cardiocrinum* flowering stem has 'basal' leaves. Examination of situations where these have been described to me have shown that the description has confused the leaves of offsets with those of the actual plant although in their growing years all the leaves form a rosette.

Claims are also made that plants will re-flower in future years: i.e. they are polycarpic. In all cases which I've examined, there is no bulb left when the plant has flowered and, again, I believe that offsets are being confused with the original plant.

Paterson and Givnish place the genus in a monocarpic clade which later gave rise to the polycarpic *Lilium*, *Nomocharis* and *Fritillaria*. [2]

1.b *Cardiocrinum giganteum* (Wallich)

Makino, Bot. Mag. (Tokyo). 27: 125. 1913. [3]
大百合 da bai he

Bulbels 3.5 - 4 × 1.2 - 2 cm. Stem erect, green or dark green, 1 - 3 m × 3 - 5 cm, hollow. Leaves on proximal 1/2 of stem larger, those on distal 1/2 much smaller, sometimes bractlike; petiole 15-20 cm; leaf blade ovate-cordate, 15 - 20 × 12 - 15 cm. Raceme 10 - 16-flowered; bracts caducous. Tepals white or tinged with green, streaked with purple or purple-red adaxially, linear-oblanceolate, 12 - 15 × 1.5-2 cm, apex obtuse. Stamens 6.5 - 7.5 cm; filaments slightly widened toward base; anthers ca. 8 × 2 mm. Ovary 2.5 - 3 cm × 4 - 5 mm. Style 5 - 6 cm. Capsule subglobose, 3.5-4 cm in diam.; apex beaked. Seeds ovate-deltoid, 4 - 5 × 2 - 3 mm. Fl. Jun - Jul, fr. Sep - Oct.

Forests, hillsides; 1200 - 3600 m. Gansu, Guangdong, Guangxi, Guizhou, Henan, Hubei, Hunan, Shaanxi, Sichuan, S Xizang, Yunnan [Bhutan, NE India, Myanmar, Nepal, Sikkim].

These description seems covers both the species and *C. giganteum yunnanense*. c.f. stem height & colour and flower colour.

[1] Matthews, *The Plantsman*, December 2002, p. 198
[2] T P Patterson & T J Givnish, Phylogeny, concerted convergence and phylogenetic niche conservatism in the core Liliales: insights from *rbc*L and *ndh*F sequence data, *Evolution,* 56(2), 2002, p. 242
[8] *Flora of China*, Vol. 24 Page 134 , published on the internet http://www.efloras.org/florataxon.aspx?flora_id=2&taxon_id=200027592

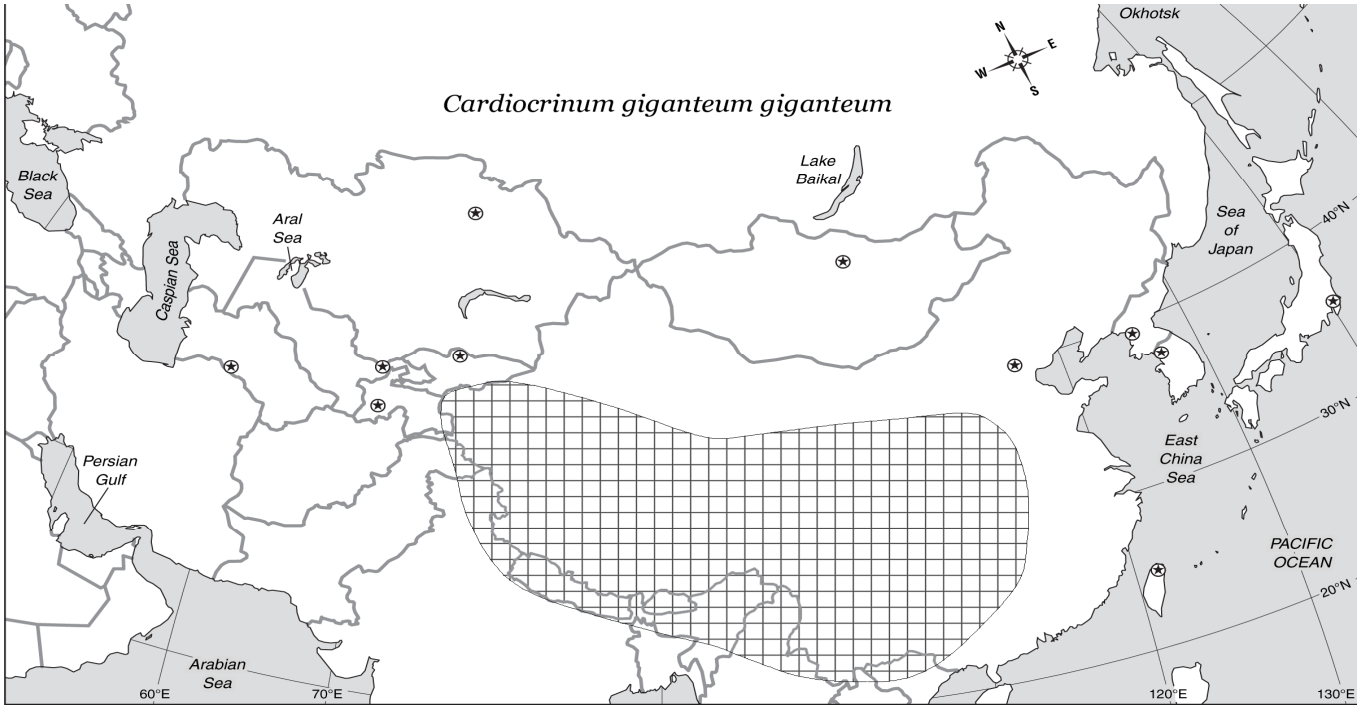
1.1 ***Cardiocrinum giganteum* v. *giganteum*** (Wallich) [1]

大百合 (原变种) da bai he (yuan bian zhong)

Lilium giganteum Wallich, Tent. Fl. Napal. 21. 1824.

Stem green, 1.5 - 3 m. Tepals adaxially streaked with purple, abaxially greenish. 2 *n* = 24*.

Forests, hillsides; 2300 - 2900 m. S Xizang [Bhutan, NE India, Myanmar, Nepal, Sikkim].



1.2.a ***C. giganteum* v. *yunnanense*** (Leichtlin ex Elwes)

Var. *yunnanense,* (Leichtlin ex Elwes) Stearn in Gard. Chron. 124: 4 (1948).

Syn; *Lilium mirabile* Franchet in Morot, Bot. 6: 310 (1892);

Cardiocrinum mirabile (Franchet) Makino in Bot. Mag. Tokyo 27: 126 (1913);

Lilium giganteum var. *yunnanense* Leichtlin ex Elwes in Gard. Chron. 60: 49, fig. 18 (1916).

Stem deep purple, generally shorter, 1.5 - 2 (- 3) m. Young leaves are often bronze. Mature flowers tinged green outside, those at the top of the raceme opening first and held horizontally.
W & C China (Yunnan, Sichuan, Shaanxi, Hubei, Hunan, Guangxi), NW Myanmar.

In general, it begins to flower two to four weeks earlier than var. giganteum. In the early stages the flowers are always very green, but although the colour fades as they mature, they never attain the white purity of var. giganteum.

1.2.b ***C. giganteum* v. *yunnanense*** (Leichtlin ex Elwes) [2]

(Leichtlin ex Elwes) Stearn, Gard. Chron., ser. 3. 124: 4. 1948.

云南大百合 yun nan da bai he

Lilium giganteum Wallich var. *yunnanense* Leichtlin ex Elwes, Gard. Chron., ser. 3, 60: 49. 1916; *L. mirabile* Franchet.

Stem dark green, 1 - 2 m. Tepals adaxially streaked with purple-red, abaxially white. 2 *n* = 24*.

Forests; 1200 - 3600 m. Gansu, Guangdong, Guangxi; Guizhou, Henan, Hubei, Hunan, Shaanxi, Sichuan, Yunnan [Myanmar].

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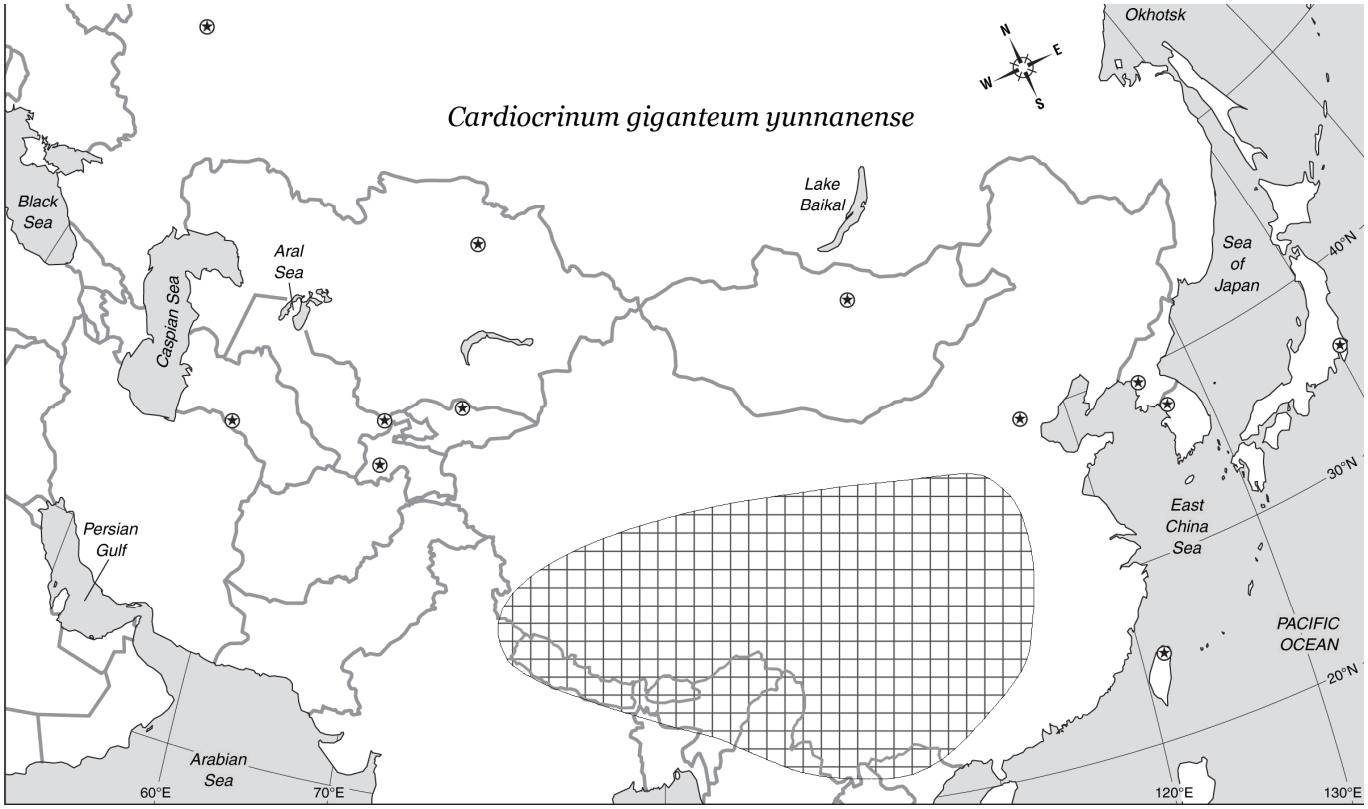
[1] *Flora of China*, Vol. 24 Page 134 , published on the internet http://www.efloras.org/florataxon.aspx?flora_id=2&taxon_id=240001169

[2] *Flora of China*, vol. 24, p. 134, , published on the internet http://www.efloras.org/florataxon.aspx?flora_id=2&taxon_id=240001170



Whilst stems can be purple and young leaves are sometimes bronze neither of these traits is general and, within the collection, both types flower at the same time.

The most recent descriptions, (FOC 1.1 & 1.2.b), indicate that the white flowered form is now considered to be *yunnanense* whilst the green/yellow form is *giganteum,* as shown on Plate 1, B. p. 8

The main points to be taken from the above is that FOC does recognise *yunnanense* as a variety of *giganteum* and sees the main distinguishing features as being,

- stem colour,
- height,
- flower colour,

The question still remains as to whether *yunnanense* is a 'variety' or a 'form'?

There is no clear-cut definition of which I'm aware that distinguishes between 'varieties' and 'forms' but it's been suggested that there must be a stable population for a plant to be considered as a 'variety' but not necessarily so for a' form' [1] so the question becomes that of whether *yunnanense* plants are variable or not.

The National Collection now contains fifth generation *yunnanense* as shown in the tree diagram on the fold-out Plate 1, page, 8 which includes images of the flowers of the descendents of 2002:1, our original *yunnanense.*

Even allowing for colour variation in the photography, it can be seen that there are significant variations in the flower colour. This is particularly true for 2011:35, 2009: 87 and, most markedly, 2009:70 and 2013:88. If I'd not known that the latter were descendants

[1] Oak Leaf Gardening, published on the internet http://www.oakleafgardening.com/glossary-terms/botanical-name/

of 2002:1, I would have identified them as *C. giganteum giganteum*! It should be stressed that 2013:88 is **not** a descendent of 2009:70 but an offset of 2009:42 as is 2012:57!
2011:35 is the nearest to pure white that we have had but its offset, 2013:81, looks like any other *yunnanense*.

These are variations in flower colour from a series of offsets which should be genetically identical, so the differences must be due to other factors, possible epigenic.

Whilst there are variations in *yunnanense* flower colours, this does not mean that there isn't a stable population. Therefore, it was decided to see if DNA barcoding code provide any useful information, (see appendix 1, p. 39).

DNA barcoding isn't generally considered to be useful beyond the species stage[1] but reports have been made of the use of the trnL chloroplast gene in identifying *C. giganteum yunnanense,* (LCBS). [2]

Therefore, in 2014 it was decided to obtain sequences of the matK and trnL chloroplast genes for a number of *C. giganteum giganteum* and *C. giganteum yunnanense* taxa, both from the collection and from any other source. There is just one example of a matK sequence for each of the above taxa in the BOLD pubic database and no trnL data [3]. This was later extended to samples of all extant strains in the collection in 2015.

The comparisons indicate that there is no significant differences between the DNA of these taxa for the sequenced barcode genes, (Table 8, p. 59). There are some variations but they appear in both the *giganteum* and *yunnanense* taxa.

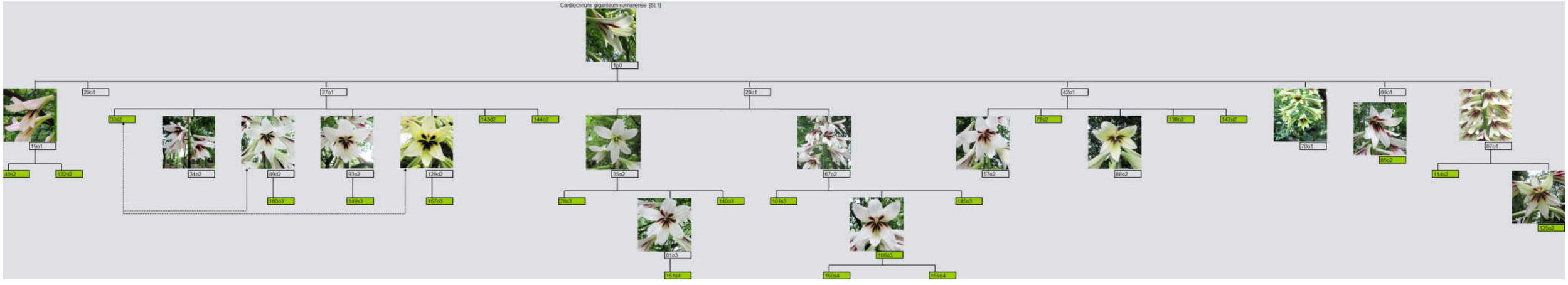
Whilst LCBS reported the development of a number of micro-satellite markers to distinguish *C. gig. giganteum* from *C. gig. yunnanense*, these do not seem to have been included in the section of the trnL gene sequenced from the collection samples. If it was not for the above report on the existence of such markers, I would believe that *C. gig. yunnanense* was just a form of *C. gig. giganteum* with variable flower colouring.

However, whilst there are variations in flower colour as shown in Plate 1, p. 7, the *yunnanense* taxon seems to come true from seed as shown in Plate 2, C, p. 8.

Some variations in flower colour have been seen in offsets of *C. giganteum giganteum*, but these are not as wide ranging as those found in *C. giganteum yunnanense* and I've never seen flowers of an offset of *C. giganteum giganteum* which could be mistaken for those of a *yunnanense*.

[1] Choosing and Using a Plant DNA Barcode, Hollingsworth, Graham, and Little, PLOS one, Published online 2011 May 26.https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3102656/
[2] Identification of herbal medicinal materials using DNA barcodes, Li, Cao, But & Shaw *Journal of Systematics and Evolution* 49 (3): 271–283 (2011)
[3] BOLD systems, Public database, published on the internet http://www.boldsystems.org/index.php /Public_SearchTerms

Plate 1


Cardiocrinum giganteum yunnanense [St.1]
1p0
20o1
27o1
28s1
42o1
99o1
19o1
38o2
35o2
67o2
57o2
78s2
70o1
87o1
49o2
132d3
34o2
89d2
93o2
129d2
143d2
144o2
160o3
169e3
157o3
79e3
146o3
81o3
151t4
161t3
145o3
106t3
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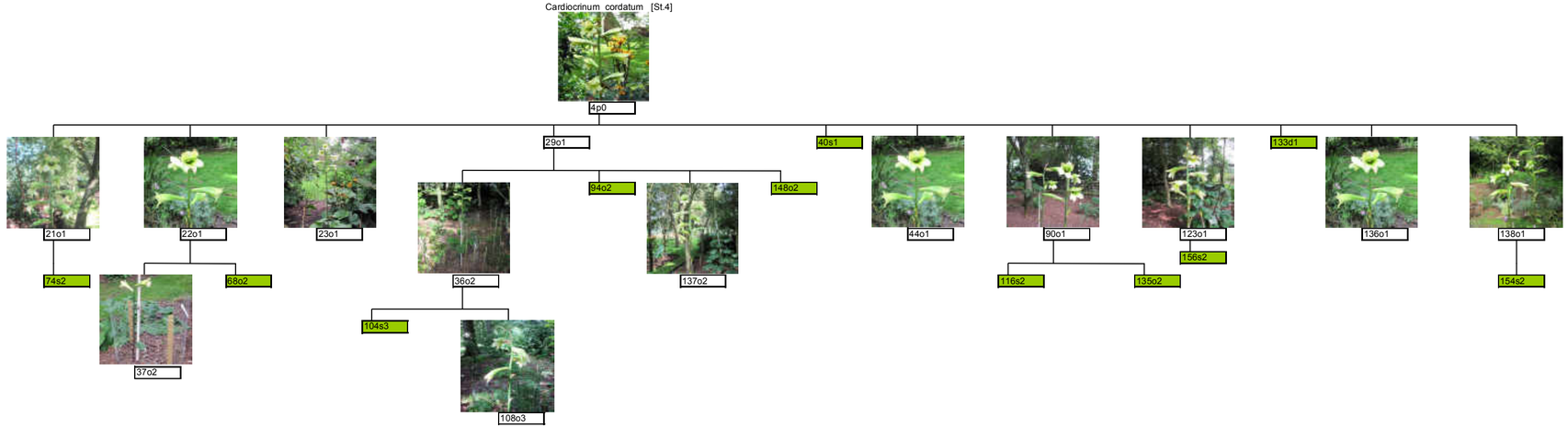

Cardiocrinum cordatum [St.4]
4p0
21o1
22o1
23o1
29o1
40s1
44o1
90o1
123o1
133d1
136o1
138o1
74s2
68o2
37o2
36o2
94o2
148o2
137o2
104s3
108o3
116s2
135o2
156s2
154s2

Plate 2

A

China – Japan land bridge

B

C. giganteum giganteum in front of *C. giganteum yunnanense*

C

C. giganteum yunnanense seedling 2012: 81

cordatum glehnii tree

Cardiocrinum cordatum glehnii [St.6]

6p0

24o1

25o1

33s1

62o1

63d1

97s2

98o2

LHCSMXS [1] state that *C. giganteum yunnanense* is a separate taxa from *C. giganteum giganteum* and their data distinguishes between various strains of *C. giganteum yunnanense*.

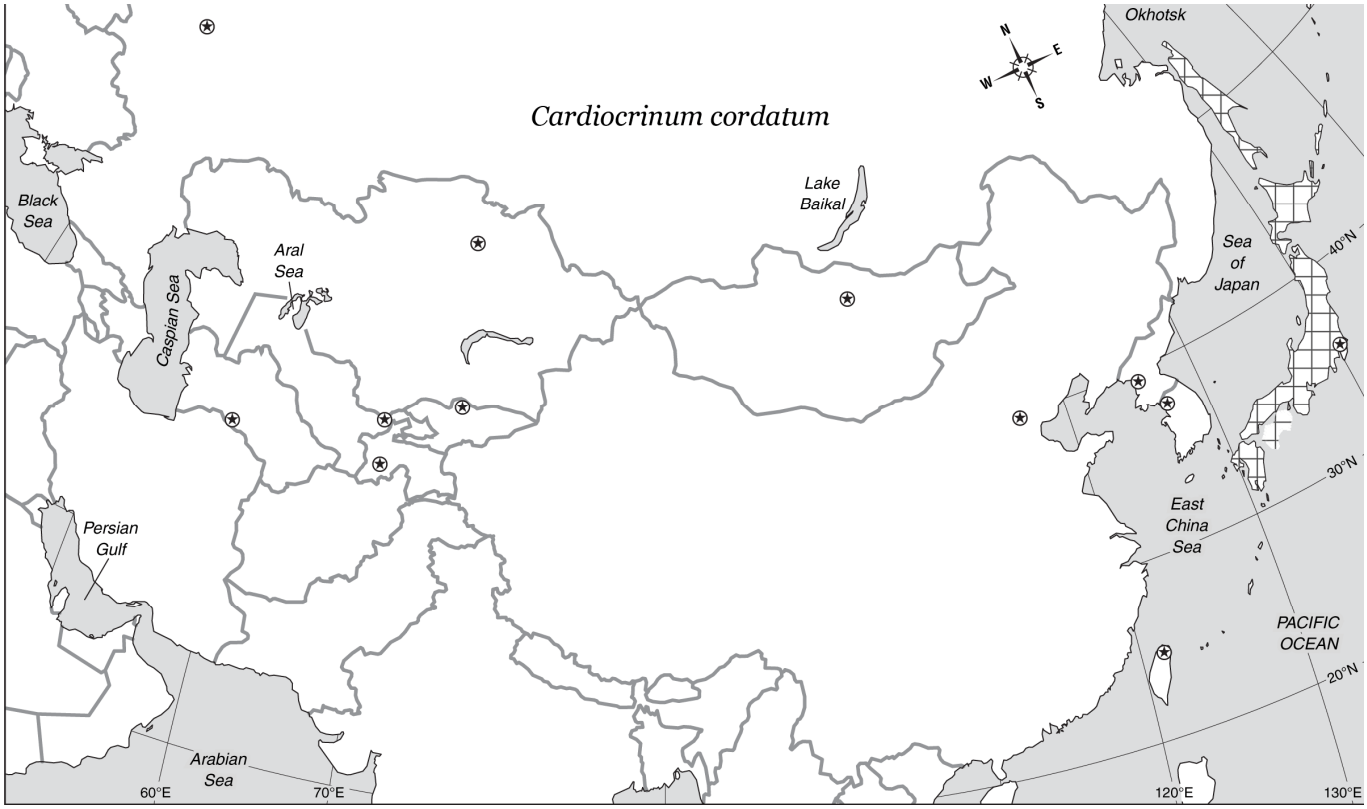
With the existing data, I suggest that *yunnanense* should be recognised as a variety of *C. giganteum,* albeit of variable flower colour; ***C. giganteum* v. *yunnanense***

[1] LHCSMXS, p. 67 - 68

2 *C. cordatum*

C. cordatum (Thunberg) Makino in Bot. MagTokyo 27: 124 (1913).
Syn: *Hemerocallis cordata* Thunberg, F1.]ap. 143 (1784);
Lilium cordifolium Thunberg inTrans. Linn. Soc. 2: 332 (1794);
Lilium cordatum (Thunberg) Koidzumi in Bot. Mag. Tokyo 40: 331 (1926).

DESCRIPTION. Bulb whitish, turning greenish brown if exposed to light, to 7.5 cm high and wide; scales ovate, acute at tip, the outer scales bearing the scar of the former leaf-stalk at the tip.~Ste1n 1.2-2 m tall, stout, green. Basal leaves in a rosette, crimson or blotched crimson or red-brown when young, becoming dark green with a coppery sheen, stalks to 30 cm, stout, flattened, base sheathing; blade broadly ovate, deeply cordate at base, up to 30 x 30 cm; leaves absent in the lower third to half of the stem, usually clustered into a pseudo-whorl of 5 or 6 about halfway up the stem, upper leaves above whorl few and smaller, scattered up stem to inflorescence. Raceme usually with 4-15 flowers, occasionally up to 24, borne horizontally or erect. Bracts narrowly lanceolate, deciduous. Flowers irregularly funnel-shaped, slightly fragrant, the lower ones opening first. Perianth segments oblong-lanceolate to oblong-spathulate, 7-15 cm long and up to 2.5 cm broad, creamy white, the 3 lower segments with a yellow blotch towards the base inside and reddish marks and spots; outer segments slightly downy; inner segments narrowed at base. Stamens about two-thirds the length of the perianth-segments, unequal; filaments flattened. Pollen yellow, Style slightly longer than stamens. Ovary cylindric, 2.5 cm long. Capsule obovoid, about 5.5 cm long and 3 cm wide. Seeds with flat membranous wing. N Japan (Kyushu to Hokkaido), former USSR (Sakhalin Islands, Kurile Islands). [1]



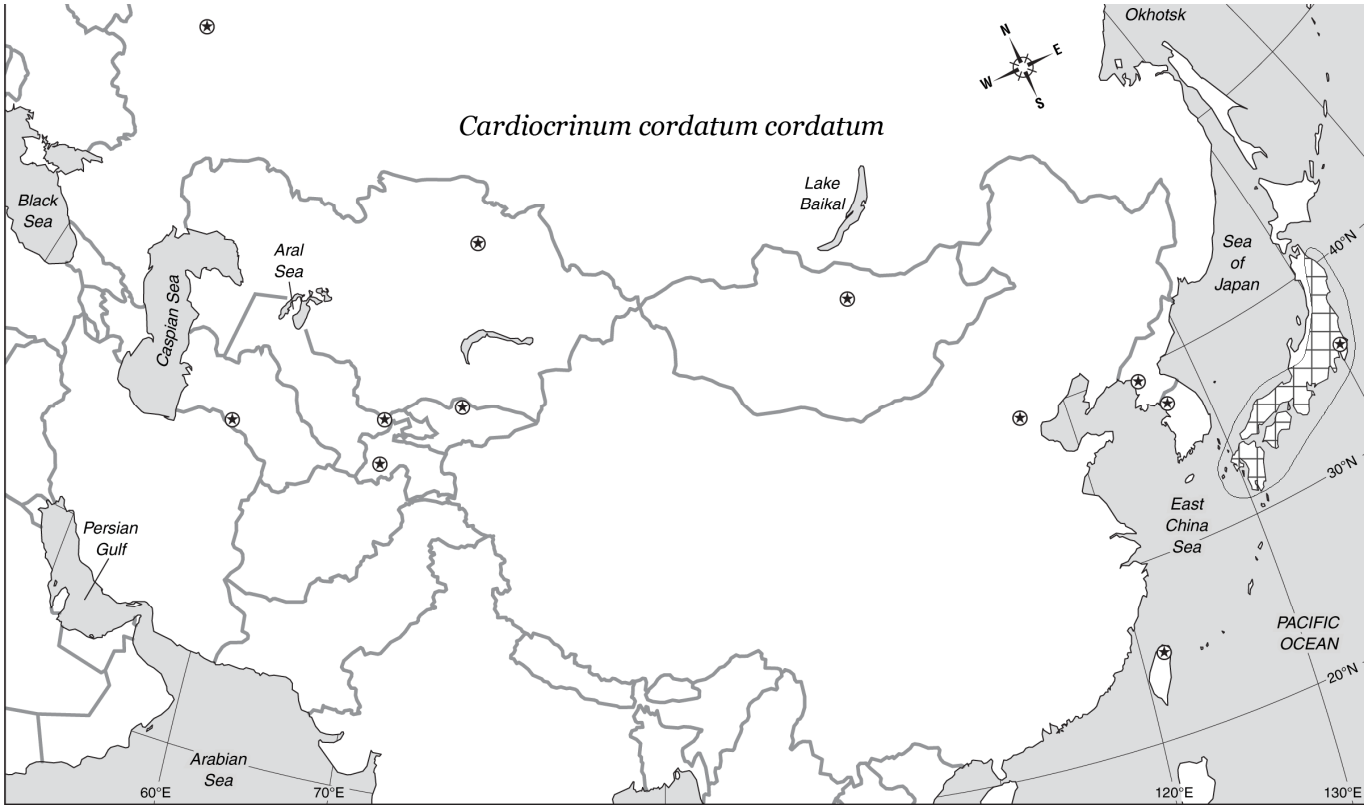
As with the description of *C. giganteum* on p. 3 & 4, this appears to covers both *C. cordatum cordatum* and *C. cordatum glehnii*. I've never seen or heard of a *C. cordatum cordatum* having anything near 15, never mind 24, flowers on a raceme. It is also the case that the lower flower bract is retained for some time after the upper. The quoted distribution also covers both taxa. Again, we don't see a basal rosette of leaves on flowering plants.

[1] Matthews, *The Plantsman*, December 2002, p. 203

2.1 *C. cordatum cordatum* (Thunberg)

Lilium cordatum (Thunb.) Koidz.
Hemerocallis cordata Thunb.; L. cordifolium Thunb.;
Cardiocrinum cordatum (Thunb.) Makino Uba-yuri.

Stout glabrous perennial; stems 50-100 cm. long, pale green, hollow; leaves loosely whorled on lower half of the stem, long-petioled, oblong-ovate to broadly ovate, cordate, 7-10 cm. long, 7-15 cm. wide, abruptly acuminate, the upper surface lustrous, pale to vivid green, the veins often variegated, the upper leaves bract like; racemes simple, 3-7 cm. long, few-flowered, the bracts narrowly lanceolate, deciduous; flowers horizontal, greenish white, tubular-infundibuliform, 7-10 cm. long, the pedicels very short, the tepals narrowly oblanceolate.- July-Aug. Moist woods in lowlands to foothills; Honshu (Kanto Distr. and wesrvv.), Shikoku, Kyushu. [1]



2.2 *C. cordatum glehnii* (F. Schmidt)

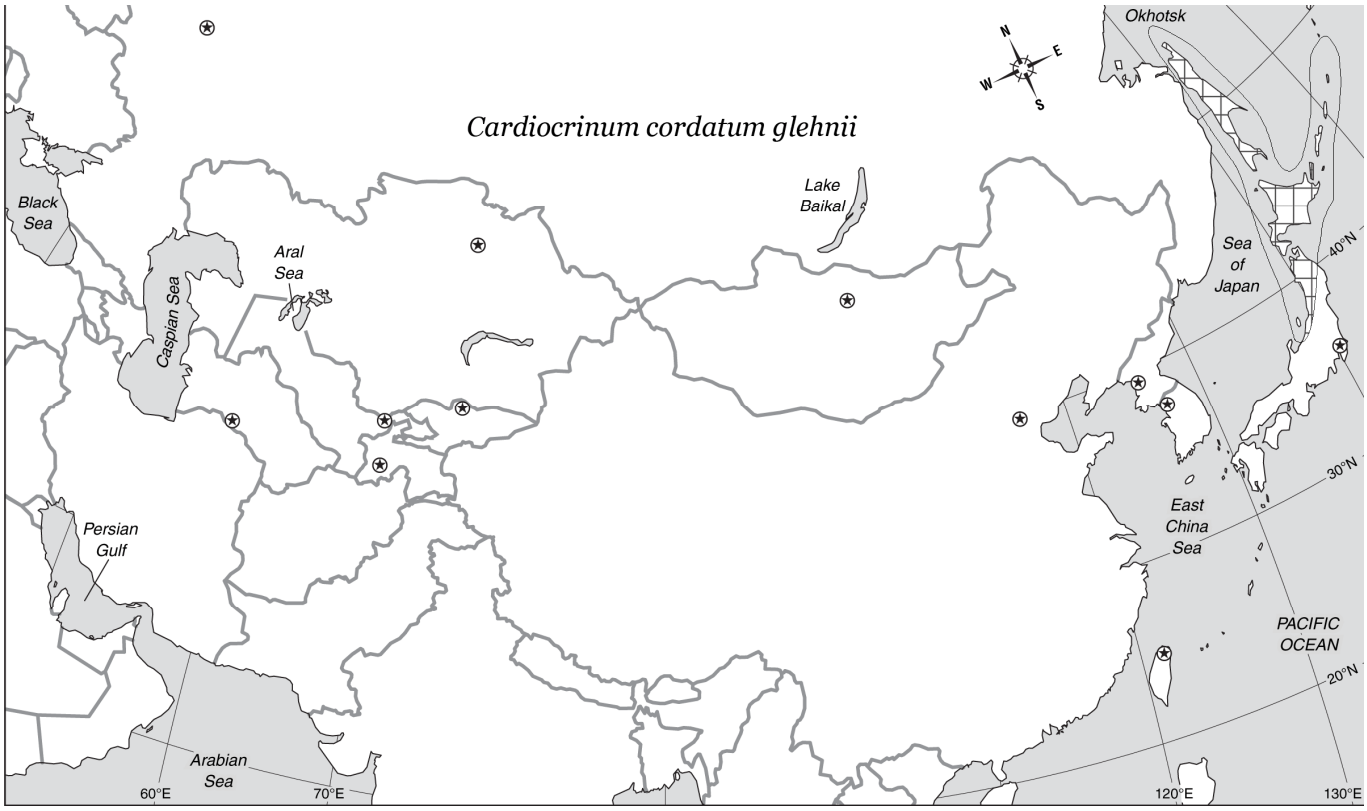
Var. *glehnii* (F. Schmidt) Hara
Syn: *Lilium cordatum* var. *glehnii* (F. Schmidt)
Woodcock & Coutts, *Lilies: their culture and management* 112 (1935);
L. glehnii E Schmidt in Mém. Acad. Sci. St. Pétersbourg ser. 7, 12(2): 187 (1868);
Cardiocrinum glehnii (E Schmidt) Makino in Tokyo Bot. Mag. 27: 125 (1913).

Woodcock & Coutts in *Lilies: their culture and management* (1935) included var. *glehnii* in *Lilium* and considered it to be merely a poor form of *L. cordatum* from northern Japan with smaller, more numerous flowers. It was not recognised by Woodcock & Stearn in their *Lilies of the world* (1950). Ohwi (1965) included it in *Lilium* and distinguished it as a variety of *L. cordatum*, stating it had stouter stems, broadly ovate leaves, and a rather long raceme with up to 20 flowers, each 10-15 cm long. [2]

[1] Matthews, *The Plantsman*, December 2002, p. 203
[2] Matthews, *The Plantsman*, December 2002, p. 204

Var. *glehnii* (F. Schmidt) Woodc.
Cardiocrinum glehnii (F. Schmidt) Makino;
L. *glehnii* F. Schmidt;
C. cordatum var. *glehnii* (F. Schmidt) Hara O-uba-yuri.

Plants stouter; leaves broadly ovate; flowers often up to 20, on a rather long rachis, 10-15 cm. long. Honshu (n. and centr. distr.), Hokkaido. Sakhalin and s. Kuriles.[1]



The clearest statement of which I'm aware on the existence of *C. cordatum glehnii* is that, "The northern populations of *C. cordatum*, especially in Sakhalin, Kuriles, Hokkaido, and particularly on the Japan sea side of Honshu, Japan are characterized by taller and more robust morphologies of the flowering individuals, with more numerous and larger flowers than other populations, and thus are referred to as a local variety, var. *glehnii*."[2]

One factor omitted from the above descriptions is the horizontal zygomorphism exhibited by *cordatum* flowers of both taxa. The upper petal and, to a lesser extent, the two upper sepals are recurved which gives the flowers a 'humpbacked' look, (the *cordatum* hump), (see plate 3, A & B, p. 15).

There are also two different flower colour patterns. The most common, applying to both *C. cordatum cordatum* and *C. cordatum glehnii,* has the tips of the petals speckled with spots of magenta and little or no magenta in the throat of the flower, as shown in Plate 3, C. The other is the reverse of this with prominent streaks of magenta in the throat and little or no speckling on the tips; essentially a smaller version of the *yunnanense* flower, as shown in Plate 3, D

[1] *Flora of Japan*, (in English), Ohwi, 1953, p. 297
[2] "*Cardiocrinum cordatum* (Thunb.) Makino (*Liliaceae*)", S Kawano, M. Ohara, and J. Masuda., In S. Kawano [ed.], *Life history monographs of Japanese plants*, vol. I, Spring plants no. 1, 49–56. Hokkaido University Press, Sapporo, Japan, 2004. (in Japanese with English summary)

I have the same question as I had for *giganteum* and *yunnanense*; is *glehnii* a sub-species, a variety or a form?

Four generations of the oldest strain of *C. cordatum cordatum* in the collection have flowered to date.

The tree diagram on the fold-out Plate 1, page 7, show the relatively low height of the plants, (the white ruler is 3' long), and the relatively small number of flowers, (2 – 10).

Only three generations of one strain, (strain 6), of *C. cordatum glehnii* in the collection have flowered.

These are shown in the tree diagram on Plate 2, Table 1, p. 8. These examples are extremely similar and significantly different from *C. cordatum cordatum* in height of stem and number of flowers, (20+/plant). It also shows that that the flowers of *C. cordatum glehnii* are very attractive to small flies unlike those of any of the other taxa!

The DNA barcode comparisons indicate that there is no significant differences between the DNA of these taxa for the sequenced barcode genes, (Table 8, p. 59). There is a report that a series of micro-satellite markers exist that distinguish *C. cordatum cordatum* from *C. cordatum glehnii,* [1] but these do not show up in the areas sequenced.

However, I suggest that the morphology of these plants does suggest that there are significant and stable differences between these taxa and that Kawano's statement shoulld be accepted and the taller plant should be recognised as a geographic sub species of *C. cordatum cordatum,* ***C. cordatum* s. sp. *glehnii,*** on the basis of the different areas colonised by each taxa, with the distinguishing features being.

- height of stem and
- number of flowers.

[1] M. Nishizawa, S. Kubota and M.Ohara Development of 13 microsatellite markers in Cadiocrinum cordatum var. glehnii, *Molecular Ecology Resources*. Published online, http://kubota.tyonmage.com/publications/MER2010B.pdf

Plate 3 *cordatum*

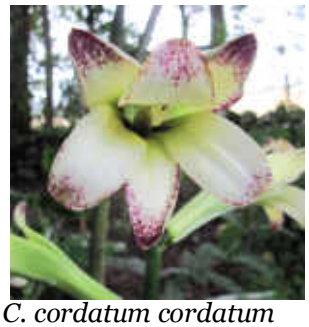
A

C. cordatum cordatum, 2010:16

B

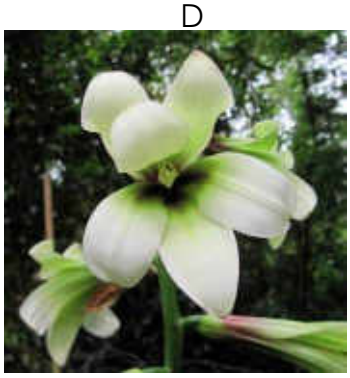
C. cordatum glehnii, 2013:69

C



C. cordatum cordatum

D



C. cordatam cordatum 2010:16

E

C. cordatum, 2011:47

F

C. giganteum yunnanense, 2012:129

G

C. cordatum, 2013:123

H

I

J

H, I & J *C. cathayanum* Kew 2007 297, photos © Sven Landrein, 2011

K

C. cordatum, 2011:40

3.a *C. cathayanum*

C. cathayanum (E.H.Wilson) Stearn in Gard. Chron. 124: 4 (1948).
Syn: *Lilium cathayanum* E.H.Wilson, *The lilies of eastern Asia* 99 (1925).

DESCRIPTION. Bulb whitish, becoming yellowish on exposure to light, to 7.5 cm high and 5.5 cm wide, with rather few scales, outer scales blunt with a scar left by the leaf-stalk. Stem 0.5-1.5 m, dark green, often dark purple in the lower half. Leaves absent in the lower third to half of the stern; lower stem leaves about 6, long-stalked, crowded into a pseudo-whorl about halfway up the stem; upper leaves few much smaller, blade oblong-ovate with shallow rounded lobes at the base, the tip shortly acuminate, up to 20 cm long and 13 cm wide, dark shiny green above, paler beneath. Raceme to about 30 cm long with (1-) 2 - 5 flowers borne more or less horizontally. Bracts 4-5.5 cm long, oblong, pointed, light green, persistent. Flowers irregularly funnel-shaped. Perianth-segments oblong-oblanceolate, 10 - 13(-15) cm long and 1.5 - 2.5 cm wide; inner segments broader but narrowed into a long claw towards the base; all segments white or greenish white outside, creamy white inside, the lower 3 segments marked with reddish brown inside and often with reddish or purplish spots at the tips. Filarnents 8-10 cm long, about two-thirds the length of the perianth-segments. Style 6-6.5 cm long, longer than stamens, thickened below. Stigma club-shaped. Ovary cylindric, about 3 cm long. Capsule obovoid, 4-5.5 cm long and 3-3.5 cm wide, shallowly furrowed with 3 rather acute ridges. Seeds with the marginal wing infolded. E & C China Qiangxi, I-lubei, Hunan, Anhui, Zhejianghliangsu). It is usually found growing in dense woods, often along the banks of mountain streams at around 1500 m.[1]

3.b *C. cathayanum* (E. H. Wilson) Stearn, Gard. Chron. ser. , 124: 4. 1948.

荞麦叶大百合 qiao mai ye da bai he
Lilium cathayanum E. H. Wilson, Lilies East. Asia, 99. 1925.

Bulbels ca. 2.5 × 1.2-1.5 cm. Stem erect, 0.5-1.5 m × 2-3 cm, hollow. Leaves absent in proximal part of stem except basal ones, crowded in middle part, laxly spirally alternate in distal part; petiole 6-20 cm; leaf blade ovate to ovate-cordate, 10-22 × 6-12 cm. Raceme 3 - 5-flowered; bracts oblong, 4-5.5 × ca. 1.6 cm, persistent. Tepals white or greenish, purple streaked adaxially, linear-oblanceolate, 13-15 × 1.5-2 cm. Stamens 8-10 cm, ca. 2/3 as long as tepals; anthers 8-9 mm. Ovary 3-3.5 cm × 5-7 mm. Style 6-6.5 cm. Capsule subglobose, 4-5 × 3-3.5 cm. Seeds 4.5-2.5 mm, reddish brownish winged all round. Fl. Jul-Aug, fr. Aug-Sep. 2 *n* = 24. Moist and shady places on forested slopes; 600 - 2200 m. Anhui, Fujian, Henan, Hubei, Hunan, Jiangsu, Jiangxi, Zhejiang.[2]

Both of these descriptions largely agree except for the former's statement that only the lower three segments of the flowers are marked with magenta streaks. I'm unaware of any *Cardiocrinum* flower which has such asymetric colouring. They also disagree concerning basal leaves. The first description states that "Leaves absent in the lower third to half of the stern", whilst the second refers to ". Leaves absent in proximal part of stem except basal ones". The Kew Herberium specimens[3] deposited by Wilson show no basal leaves, in fact, very few leaves at all, (see Plate 8, p. 50). Both state that bracts, (plural), are persistent, but the illustration which accompanies the FOC entry for *C. cathayanum* shows only the lower bract being retained.[4] However, the accuracy of this illustration must be questioned as it also shows no sign of the floral zygomorphism.

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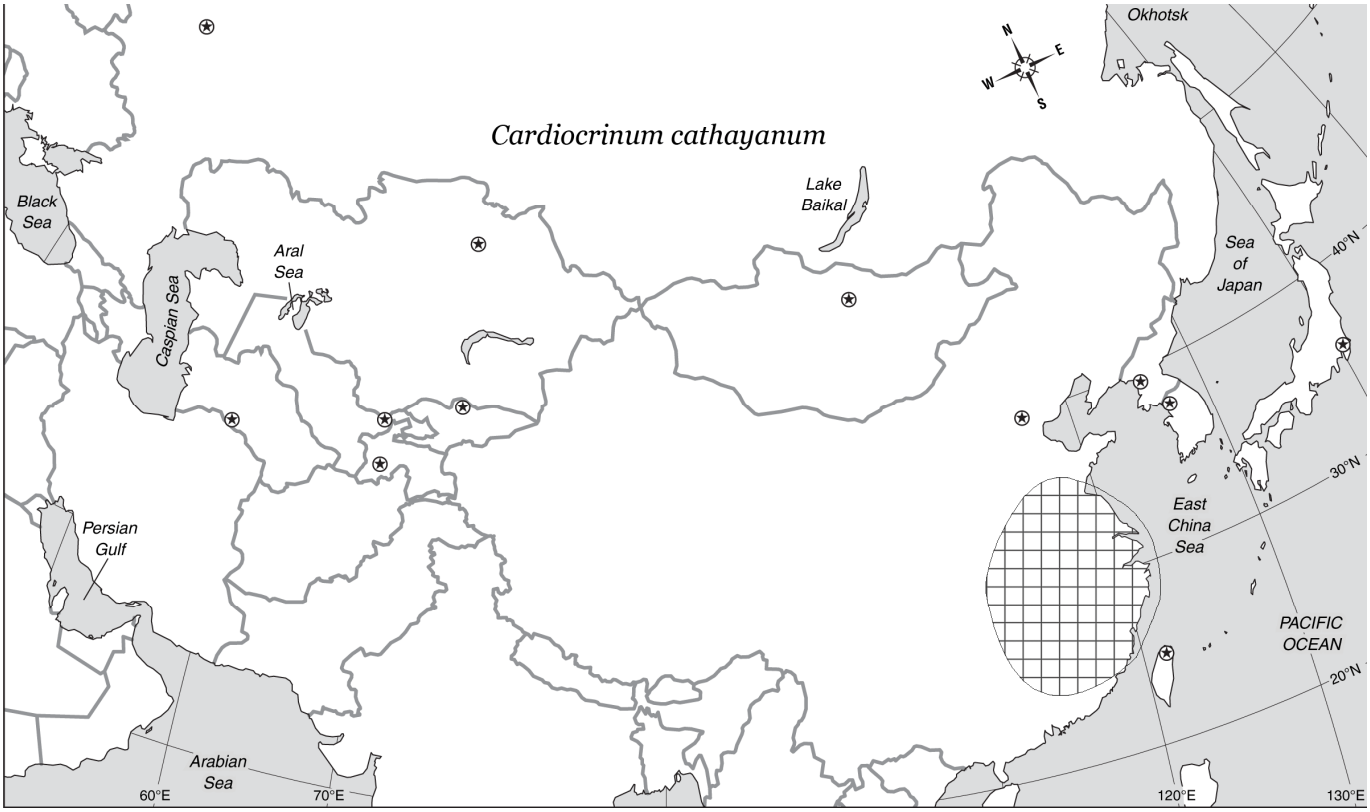
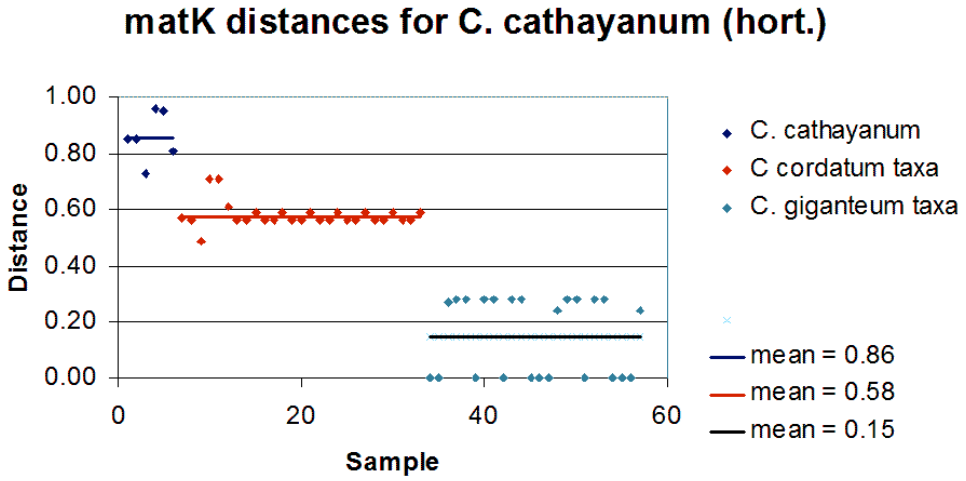
[1] Matthews, *The Plantsman*, December 2002, p. 201 - 203
[2] *Flora of China*, Vol. 24 Page 134 , published on the internet http://www.efloras.org/florataxon.aspx?flora_id=2&taxon_id=200027591
[3] Royal Botanic Gardens, Kew. Herberium catalaogue. Published on the Internet, 2016 http://apps.kew.org/herbcat/getHomePageResults.do;jsessionid=076F7D70ACC49F6E5491EEF960F283B9?homePageSearchText=Cardiocrinum+cathayanum&x=8&y=9&homePageSearchOption=scientific_name&nameOfSearchPage=home_page
[4] *Flora of China*, Illustration Taxon: *Cardiocrinum cathayanum*, published on the internet http://www.efloras.org/object_page.aspx?object_id=60399&flora_id=2



My problem with *cathayanum* is that I don't think I've ever seen one!

Two taxa, (2006:7 & 2009:13), sold to me as *C. cathayanum,* had been added to the collection before I came across Wilson's type description. When these taxa flowered, it was clear that they didn't match the holotype description in stem size, number of flowers and, particularly, the asymetric leaf distribution. In 2014 I purchased bulbs imported from China. These came as dried bulbs with no roots but they grew and flowered in that year; at ~18" tall!

Leaf samples from all three taxa were sent for barcoding and the chart below, based on the data in Tables 11, 12 & 13, p. 60, shows the relationship of these plants to *C. cathayanum, C. cordatum* and *C. giganteum.* The plot consists of the differences in matK gene sequences between the three putative *cathayanum* and the groups of authenticated *cathayanum, cordatum* and *giganteum* taxa. The line shows the mean value for each taxa.



The chart shows that these three examples are *C. giganteum* and, from the colour of the flowers, *C. giganteum* v. *yunnanense.*

I've contacted a number of nurseries in the UK who advertise *C. cathayanum* to ask if their stock matches Wilson's type description but have had no replies. This leads me to believe that this incorrect identification extends to more than the three samples I've bought.

If one looks at Chinese websites offering or referring to *C. cathayanum*, the photos shown can be divided into plants that look like *C. giganteum v. yunnanense* and those that match the type description for *C. cathayanum*.

The only examples of genuine *C. cathayanum* in the UK of which I'm aware are the descendents of Kew 2007 297, (Plate 3, H, I & J), which was authenticated by FOC.

Comparing the above descriptions of *cathayanum* with those of *C. cordatum cordatum* on p. 11 shows that both taxa are very similar as do the photos on Plate 2, Table 1, p. 9 They both have,

- relatively short stems,
- few flowers,
- similar flower colour
- an asymetric leaf distribution and
- retained bract/s.

The flowers of Kew 2007297 also show the zygomorphism exhibited by *C. cordatum,* as shown in Plate 3, I & J, p. 15.

This leads to a consideration of how closely the two taxa are related, which was examined by comparing their DNA barcodes. The results, (Table 10, p. 59), suggest that they are very closely related. The average variation of 0.28 is of the same order of magnitude as the maximum variations found between samples of *C. gig. giganteum* and *C. gig.* v. *yunnanense*, (Table 14, p. 60), of 0.24.

The morphologies of the plants, as far as can be judged from the photos of *C. cathayanum* I have available, show no significant differences and so consideration must be given to the possibility that they should be considered as one species, (see p. 21).

Makino[1] states that *C. cordatum* is found in China and it may be that I'm not alone in failing to distinguish *cathayanum* from *cordatum*.

Li-Qin Yang, Hao-Yu Hu, Chuan Xie, Shan-Pan Lai, Mei Yang, Xing-Jin He and Song-Dong Zhou, [LHCSMXS] [2] have *C. cathayanum* and *C. cordatum* as distinct species but the photos they publish [3] show plants which look the same; allbeit these are only of the inflorescence.

[1] Makino, *Bot. Mag. Tokyo* 27: 125 (1913).
[2] LHCSMXS, p. 67 - 68
[3] LHCSMXS, p. 67

More work is needed on this matter with more barcode sequences for *C. cathayanum* being generated and I'll continue my quest to add an authenticated *C. cathaynum* to the collection so that it can be observed during its whole growth cycle.

However, at this time, I know of no way to distinguish visually *C. cathayanum* from *C. cordatum cordatum.*

THE COLLECTION

At the moment, (August, 2020), the collection comprises plants from the strains listed in the table below.

Taxa	Strain	Database code	Origin
C. giganteum giganteum	12	12p0	
"	18	18p0	
C. giganteum yunnanense	1	1p0	
"	7*	7p0	
"	13*	13p0	
"	25	61p0	Baoxing, China
"	27	82d0	
	29	92p0	Kalimpong, West Bengal
"	30	109p0	
"	31*	110p0	China
"	32	115p0	
"	33	119p0	
C. cordatum cordatum	4	4p0	
"	10	10p0	
"	14	14p0	Chiba, Japan
"	15	15p0	Japan
"	16	16p0	Shikoku, Japan
" (Red flowered form)	36	167p0	Japan?
C. cordatum glehnii	6	6p0	
"	9	9p0	Northern Honshu, Japan
"	19	41p0	
"	20	50s0	
"	23	59p0	Northern Honshu, Japan
"	26	69o0	
"	37	168p0	

Recording

The plant data is stored on an Excel spreadsheet which is processed by a custom VB6 front-end application. An edited version of the current database is available online at http://www.redhall.org.uk/GardenOpening/cardio_db.htm. If the ID of a plant is selected and the 'SELECT' button clicked, a page of data for that plant will be displayed which has space of up to six images of the taxon. Not all entries have all six images, (some have none!).

As well as the plants listed in the database, there are a number of taxa, mainly *C. giganteum giganteum* and *C. giganteum yunnanense*, which are planted in the garden for ornamental effect. This results in us having about 50 to 70 plants flowering each year so, all in all, we've observed the growth and flowering of more than 400 *Cardiocrinum* in the last nine years.

* Strains thus marked were sold to us as C. cathayanum, see p. 17

FORMS

There are reports of a number of forms of *Cardiocrinum*.

Red-veined plants

Plants do occur which have red veining on young leaves. The two seedlings, shown on Plate 3, F, p. 15, are from the same pod of seeds but the red veining on the upper plant cannot be guaranteed to re-appear in subsequent years and I've never seen a example which maintains its red veining as a mature, flowering plant.

This veining can appear on the young leaves of several types of *Cardiocrinum,* as is shown on Plate 3, G, but is more common on *cordatum* taxa which can sometimes have completely red leaves at the start of the growing season as shown on Plate 3, H.

I don't consider that it can be claimed that there is 'Red veined form' of any species.

Bronze leaved plants

A number of taxa can have a bronze/olive tinge to the young foliage as shown in Plate 4, A & B, p. 35, but this usually doesn't persist as the plant grows nor can it be relied on to appear each year.

However, descendents of *C. giganteum yunnanense,* 2009:13 do tend to have bronze foliage, (Plate 8, C, p. 50), which can sometimes persist in the flowering plant but which doesn't occur with all offsets. Seedlings of this strain have yet to flower in the collection. This may also prove to be the case with the progeny of *C. giganteum yunnanense,* 2014:110 which exhibit this colour on the leaves of young plants but none has yet flowered.

In light of the above, I don't think it is possible to speak of a 'Bronze leaved form' of *C. giganteum yunnanense* but this statement may be revised in the future as more evidence becomes available. There is some evidence from the DNA barcoding for two forms of *C. giganteum yunnanense* . See table 14, p. 58

***C. giganteum* 'Queen Fabiola'**

In 2010, I came across a reference and a photo of a plant with this name on the Mount Tomah Botanic Garden website, (now the Blue Mountains Botanic Garden, Mount Tomah).

The picture showed a *giganteum* with definite yellow flowers, (Plate 8, A). I mailed the garden to ask about this but no-one there could they tell me if its descendents were still growing there, nor if it had been as yellow as the picture suggested. It's no longer shown on the Garden's new website and, as this is the only reference to this cultivar I've been able to find, I think it was a misnomer; picking up the 'Queen Fabiola' cultivar name from one of the other plants bearing the Belgian Queen's name such as *Brodiaea* or *Triteleia*. The yellow flowers could possibly have been due to exposure to a lot of sun or an artifact of the photograph. However, I'm happy to be corrected on this.

C. giganteum v. *yunnanense*

White flowered form

There are several reports of white flowered forms of *C. giganteum v. yunnanense*.[1] [2] and Plate 4 C, p. 35, shows such a plant at Far Reaches Farm. [3]

I think it is acceptable to speak of a 'White flowered form' of *C. giganteum v. yunnanense*, (***C. giganteum* v. *yunnanense* f. *alba***). However, this is not stable .

Pink flowered form

The only report of a pink flowered form of *C. giganteum yunnanense* of which I'm aware are the plants grown by Kelly Dodson and Sue Milliken at Far Reaches Farm, (Plate 4, D [3]). These have been hand pollinated.

It seems reasonable to speak of a ''Pink' form of *C. giganteum* v. *yunnanense*, (***C. giganteum* v. *yunnanense* f. *rosea***). However, it seems unlikely that this will be stable.

Far Reaches Farm refers to this taxon as a cultivar, *C. giganteum* v. *yunnanense,* 'Big and Pink', (B&P).

A seedling of this plant flowered with us in 2020. Whilst the flowers were not pink, there were a number of differences between this plant and other strains of ***C. giganteum* v. *yunnanense*** in the collection.

Size

The flower stem grew to 2.09m, which was comparable with other strains of this taxa for that year, but the flowers were smaller than the average, (average for most taxa: ~140mm, B&P seedling: 125mm). The leaves were also proportionaly smaller than those of similar sized plants from other strains, (Plate 4 H, p. 35). [4]

Colouration

Whilst the flowers were not pink, the distribution of colour was different from that of most stains of *yunnanense*, (Plate 4 E, F & G), with the differential between the abaxial and adaxial colouring being less pronounced than usual. [5] This suggests that, if an example with deeper, more typical, flower colour did appear, the flowers would be probably pink on the abaxial surfaces as was the case with the parent plant, (Plate 4, D, p. 35).

The leaves also showed a difference in colour from most other strains; being darker green and more glossy than the norm, (Plate 4 H).

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[1] Personal correspondence,
[2] There is a report of a hillside in China covered with white *Cardiocrinum*.
[3] Pictures © by and courtesy of Sue Milliken & Kelly Dodson, Far Reaches Farm, Port Townsend, WA 98368, http://www.farreachesfarm.com/
[4] Twelth leaf down from the raceme.
[5] See more typical flower colouring on Plate 1, p. 8 & Plate 2 C, p. 9

C. cordatum cordatum

At the start of the 20th.C. a red flowered form of *C. cordatum cordatum* appeared. One of these was added to the collection in 2019 which flowered in 2020. See Plate 5, A, B & C, p. 36.

It has the typical structure of *C. cordatum* with a retained lower bract, a small number of flowers and flower zygomorphism.

It seems possible that this is a stable form: it certainly comes true from offsets which suggests that the colouration is mainly genetic rather than there being a large epigenic contribution as seems to be the case with the coloured versions of *yunnanense*. We shall see in a few years time if it comes true from seed.

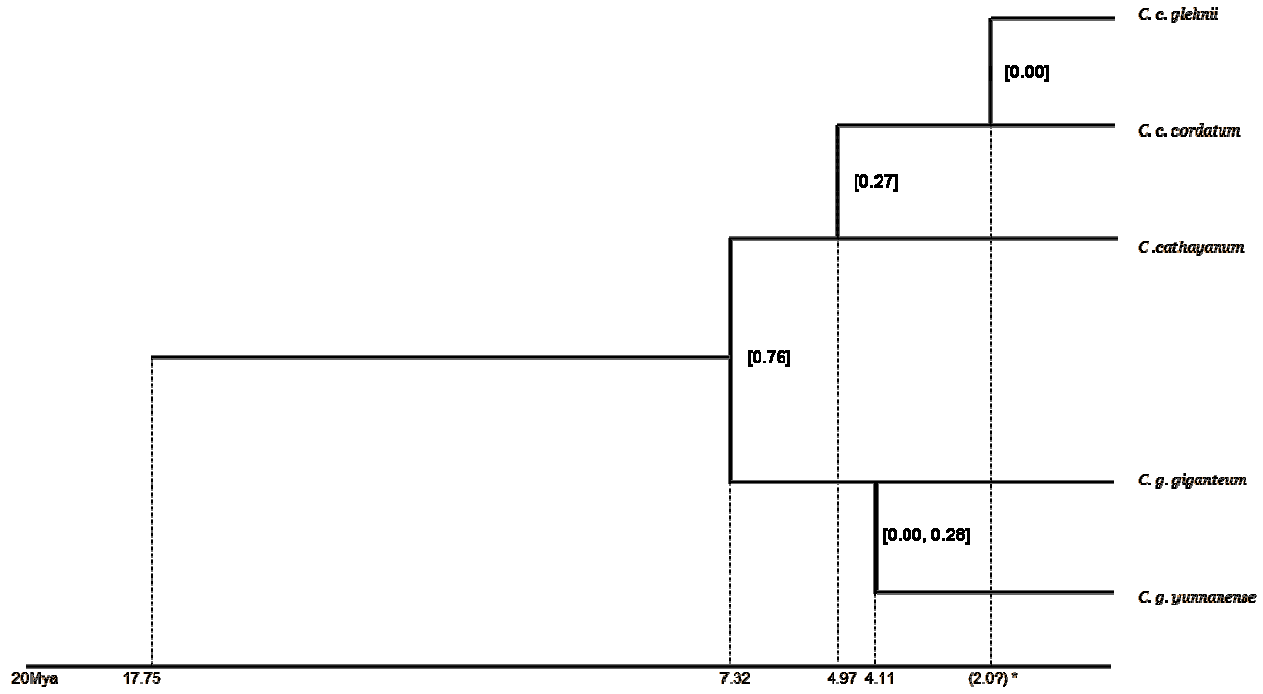
I consider that it's acceptable to speak of it as a red flowered form of *C. cordatum*, ***C. coratum cordatum* f. *rubra***

RELATIONSHIPS

The morphological and DNA data suggests that the genus exists in two clades which can be viewed as the '*Giganteum*' and the '*Cathayanum*' clades with the various taxa grouped as shown below.

Giganteum clade	**Cathayanum clade**
C. giganteum v. *giganteum*	*C. cathayanum*
C. giganteum v. *yunnanense*	*C. cordatum* v. *cordatum*
	C. cordatum s. sp. *glehnii*

The paper published in 2017 by LHCSMXS,[1] used DNA other than just that of the 'Barcode' genes to elucidate the relationships between the various species in their investigation of 54 populations of *Cardiocrinum* [2] and produced phylogenetic trees showing these relationships [3] and it is this data which I now use to define the relationships within the genus.



The above tree is a condensation of the one on p. 68 of their paper..

The date value for *C. cordatum glehnii* is in parenthesis because there's no mention of this taxon in the paper. Five samples were collected in Japan; four of them in a relatively small region of Hokkaido and the fifth in Fukushima on Honshu. Both of these regions are wihin the reported range of *glehnii*. The picture of *C. cordatum* on p. 67 of their paper looks more like *C. cordatum cordatum* than *C. cordatum glehnii* but there is no indication of which population this came from.

The DNA results show a variation between these two populations with a date of divergence of 2.0 Mya and it is <u>possible</u> that this represents the separation of the two forms of *C. cordatum*.

[1] LHCSMXS p.62, 67, 68
[2] LHCSMXS p.62, 63
[3] LHCSMXS p.67, 68

The samples of *C. cordatum* were not collected by the authors but by associates in Japan and no information is available as to why *C. cordatum glehnii* was not included nor whether the image of *C. cordatum* on p. 67 of the paper is of the group co1 – co4 or co5. [1]

LHCSMXS consider that *Cardiocrium* originated in Central China and then dispersed north, south, west and east and, finally, into Japan about 5 Mya. [2] This suggests that the separation of *C. c. cordatum* from *C. cathayanum* occurred around the same time as the genus spread into Japan.

The figures in parentheses show the mean difference for the matK gene sequences between the various taxa found in the sequencing carried out for me by The Natural History Museum [*]. The two values for *C. g. giganteum* and *C. g. yunnanense* reflect the results of the sequencing carried out on taxa from the collection. [†]

[1] Xing-Jin He, by email.
[2] LHCSMXS p. 68
[*] See Appendix 4. page 54
[†] See table 14, page 60

TAXONOMY AND DNA

What DNA can tell us

A false dichotomy can arise when considering DNA and plant identification. On one hand we're told that we share 99.9% of our DNA with all humans; 98.5% with Chimanzees and even 50% with a Banana. On the other, DNA profiling can supposedly identify an individual with a chance of a mismatch of 1 in a billion, (10^9).

However, the above statements are over-simplifications. 'Sharing' our DNA with other people or species doesn't mean that there is necessarily a one-to-one correspondence of bp throughout the genome: it means that the same mechanisms exist for protein synthesis in both organisms.

The other factor is that there is an awful lot of DNA. The human genome is thought to contain about three billion bp: 'thought to' because, no matter what you've read, we haven't actually analysed it all as yet. "*The draft sequence, (*year 2000), *covered 90 percent of the genome at an error rate of one in 1,000 base pairs, but there were more than 150,000 gaps and only 28 percent of the genome had reached the finished standard. In the April 2003 version, there are less than 400 gaps and 99 percent of the genome is finished with an accuracy rate of less than one error every 10,000 base pairs.*" [1] That corresponds to 300,000 errors and the missing 1% is 30 million bp!

Therefore, the 0.1% of difference between non-related humans equates to about 3 x 10^6, (three million), bp, which gives lots of room for analysis.

It all depends on the section of the genome you use: some sections will give a match for all primates, some for all mammals and a few for all organisms. Choose a different section and you can have human DNA profiling or animal species DNA barcoding with mitochondrial genes or plant species barcoding with chloroplast genes.

The point to be stressed is that, depending on the section of DNA you analyse, it's possible to show the unique identity of an individual organism or the broad interconnectivity of all living things.

Species and their DNA

The DNA barcoding project was developed in order to allow rapid identification of particular species of animals or plants. Genes were chosen on the basis of variation within their DNA which would be constant for a genus but which would present variations for a particular species. For plants, these are the chloroplast genes of rbsL and matK. [2]

There is nothing special about these genes. There is nothing in their structure or function that states that they will be able to make this differentiation. They were chosen on the basis of investigations that showed that they **could** be used in this way by comparing

[1] The Human Genome Project Completion: Frequently Asked Questions
https://www.genome.gov/11006943/human-genome-project-completion-frequently-asked-questions/
[2] Choosing and using a Plant DNA Barcode. Published online,
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3102656/

the sequences in **known** genera and species. i.e. there is no way in which any gene can, a priori, be guaranteed to indicate a separate species.

When it comes to varieties or sub species, there are no known genes which can provide this distinction across a number of genera: each genus has to be investigated to find genes with areas of variation which will provide this information which presupposes that the division into 'species' and 'varieties' has been made on the basis of **other** evidence.

The DNA used by LHCSMXS[1] were carefully chosen not only to distinguish the various species of *Cardiocrinum* but also to highlight the 18 haplotypes across the four taxa concerned.

Where does this leave the question of speciation and DNA? Well, the first point to make is that there is **no** general defintion of what a plant species is! * Animals are a little easier in the "*a population constitutes a species if its members can interbreed to produce fertile offspring*", but even this has become suspect due to the fact that different 'species' of *Homo* such as *sapiens, neanderthal* and *denisovan* are now thought to have interbred.

Plants are not so simple: not only can inter-species hybrids be fertile but inter-genetic hybrids also exist!

Taxonomy

At the moment, agreement between taxonomists on whether a taxon is a species depends on a general discussion over a period of time until a consensus is reached. At the best, this means that a number of views are presented and the evidence analysed to reach this consensus; at the worst it means that botany is still a descriptive rather than an experimental science. This might seem to be a similar process to that which occurred recently with the discussions of whether Pluto was a major or minor planet. However, there is one important difference: the discussions concerning Pluto were designed to provide a **definition** of the various types of orbital objects and, once a consensus on this was achieved, this definition could be applied to Pluto and **all other** such objects in the future without having to consider each one on its own merits.

It could be suggested that, if botanists are unable to arrive at an inclusive definition of what constitutes a plant species, then, at the very least, the concept itself should be re-examined or a paradigm change is needed in the concept of plant nomenclature.

Since first writing the above, I've found that I'm not alone in being unhappy with the current concept of 'species'. Frank Zarchos identifies no fewer than 32 competing definitions of a species in his book *Species Concepts in Biology*, 2016. [2] Another article states that "*There is no universal taxonomic authority. Of course, if no one is in charge of taxonomy, that also means that anyone can claim to be. Any taxonomist can publish a paper defining a new species. You don't have to say how or why you made the decision to do so. You*

[1] Li-Qin Yang, Hao-Yu Hu, Chuan Xie, Shan-Pan Lai, Mei Yang, Xing-Jin He and Song-Dong Zhou, Molecular phylogeny, biogeography and ecological niche modelling of Cardiocrinum (Liliaceae): insights into the evolutionary history of endemic genera distributed across the Sino-Japanese floristic region, Annals of Botany 119: 2017, p.60

* See footnote 2 below.

[2] 'The End of Species', *New Scientist*, 26/1/2019, p. 37

don't have to test whether your species exceeds some pre-determined threshold of "speciesness". You simply say that it does." [1]

Traditionally, taxonomy has depended on a description of the morphology of organisms as, until the advent of DNA analysis, this was just about all there was to go on. Even then, factors such as rate of growth, resistance to pests, pathogens, drought and high or low mean temperatures were not considered as anything but indicators of forms; if they were considered at all, even 'though the genetic variations giving rise to these traits might well be greater than those affecting say flower size and leaf structure.

I would suggest that DNA analysis has a limited role in the **identification** of species but a great deal to do with the **inter-relationships** with species, genera and varieties, to the extent that it should be allowed to over-ride the principal of priority. *

Taxonomy is used to define genus, species, variety, etc. and to indicate the relationships between these classifications.

Holotypes

The basic element of the process of identifying a new plant is the **Type description**. This must be published and a specimen, usually a herbarium specimen for plants, lodged in the collection of a recognised institution; a University or Botanic Garden herbarium. Until 2012 the description had to be published in Latin but since that date it can be in Latin or English.

The principle of priority means that, once used for a particular plant, a name cannot be used again. This can lead to some peculiar situation. The commonly grown Rowan, *Sorbus hupehensis*, should, in fact, be known as *S. pseudohupehensis*.[2] The type specimen of *hupehensis* was collected by Wilson in 1901 but does not seem to be in cultivation.

In view of the fact that it is believed that only about half of the plants on Earth have been described, this seems a sensible method of ensuring that names are kept unique. However, it's when you look at the details that the cracks appear.

The system is administered according to the rules of the *International Code of Nomenclature for algae, fungi, and plants*, (ICN). Whilst there are good reasons for the various rules and their exceptions, they lead to some peculiar results in that, for type specimens, there is no requirement for a "typical" individual to be used! Now this can occur for unavoidable reasons but also some others. Peter Cox states, with reference to *Cardiocrinum*, that "poorly developed plants have often been selected so that they will fit on to one or two herbarium sheets".[3]

However, what would constitute a 'typical' specimen? For there to be a mathematically meaningful definition, a statistically significant number of specimens would need to be collected and measured and some form of mean taken for each required parameter which is not a practical consideration for collection from the wild and it is possible that such a process can lead to there being **no** 'typical' example.

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[1] A defining Problem, *New Scientist*, 23/2/2019, p. 26

[*] See p. 30

[2] *The Genus Sorbus*, Hugh McAlister,Royal Botanic Gardens, Kew, 2005, ISBN 1 84246 088 9, p. 109-112

[3] Cox, Variation in Cardiocrinum giganteum, *The Plantsman*, 2009, p.91

The various requirements for the specification of a type specimen are sensible in the light of collections being made in the field. Where the system falters is in the fact that, once recorded, a type specimen is sometimes treated as holy writ.

Whilst there are mechanisms which allow other material to replace or complement the holotype, these seems to apply only in exceptional circumstances and would seem not to apply to atypical 'type' specimens or those which have been wrongly or incompletely described. *

Herbarium specimens.

Images, D, E, F and G on plate 8, p. 50 are the holotype material for *C. cathayanum* deposited in the Kew herbarium by EH Wilson on May 14th, 1920.[1]

In fact, these specimens would not be acceptable as a holotype today because they include material from at least three plants and the current requirement is that it must be a **single** specimen.

It's also interesting that, although these were lodged in 1920, the type description of *C. cathayanum* wasn't published by Wilson until 1925.†† Whilst three of the samples, (E, F & G), have labels added which state "Type *L. cathayanum*", the actual herbarium sheets have *Lilium mirabile* written on them in three of the cases, (D, E & G).

Now, these are 100 years old and are showing their age.

What they show is,

- the size of a flowering stem,
- the leaf size and structure,
- that there are flowers,
- that no bulb remains at the base of a flowering stem,
- that a flowering stem has no basal leaves,
- The rough form of the seed pods.

What they **don't** show is,

- any details of flower structure,
- any flower colour,
- the arrangement of leaves along the flowering stem,
- stem colour,
- leaf colour.

Even when freshly mounted, much of the second group of information would have been unavailable.

Whilst the production of herbarium specimens was propably the best, if not the only, means of recording plant morphological data in the 19th.C and 20th.C, I do feel it's time that the Botanic community got to grips with the use of digital imagery as its primary medium of data storage. (See appendix 3, p. 63)

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* See p. 28

[1] *The Herbarium Catalogue*, Royal Botanic Gardens, Kew. Published on the Internet http://www.kew.org/herbcat [accessed on 21/3/2018].

† See p. 16

As it seems likely that plant genome analysis will become cheaper, consideration should also be given to the lodging of a DNA sample and a print-out of the genome as part of the Type description.

Application to *Cardiocrinum*

The descriptions given on p. 4 and p. 5 are incorrect: There are no basal leaves on the flowering stem of a *Cardiocrinum* and the white flowered form of *C. giganteum* is *C. giganteum yunnanense*. Also the descriptions of *C. cordatum*, both taxa, and *C. cathayanum* are incomplete as there is no mention of the zygomorphism of the flowers. These are not all type descriptions but they illustrate that mistakes can be made which will be difficult to rectify.

The barcode DNA cannot identify varieties or sub-species so, in the absence of a definition of a plant 'variety', decisions on the status of *C. giganteum yunnanense* and *C. cordatum glehnii* become a matter of opinion rather than of science.

The insistance on herbarium specimens as a record of morpholgy rather than a sytematised, digital photographic record leads to a loss of information on the variations that exist, particularly in flower colour and structure, across the various taxa.

The major question concerns the purpose of taxonomy: is it to assemble a set of relationships showing the genetic links between various taxa or is it to describe the morphology of a genus to allow the identification of taxa in the field?

For *Cardiocrinum* we have the situation where there is a slight but distinct difference in the barcode matK sequences for *C. cordatum cordatum* and *C. cathayanum* but little, if any, difference in their morphology and *C. cordatum cordatum* and *C. cordatum glehnii* where there are no differences in the barcode sequences but distinct differences in morphology.

If it were ever decided that the differences in morphology between *C. cathayanum* and *C. c. cordatum* are too small to warrant assigning them to separate species, the species presently know as *C. cathayanum* would become *C. cordatum cordatum* by the principle of prior naming when it is obvious from the work of LHCSMXS that the Japanese species evolved from *C. cathayanum*! This is where DNA's role should be paramount: as *C. coratum cordatum* clearly evolved from *C. cathayanum*, the latter should be the recognised species name.

IDENTIFICATION

IDENTIFICATION CHARACTERISTICS

In order to develop a taxonomy key, it is necessary to identify characteristics which are,

- common across the taxa concerned and
- able to be used to group similar types or to identify a taxon.

These characteristics are then used to identify taxa according to their published descriptions.

One of the problems with *Cardiocrinum* is that a number of traits have been suggested which do not meet the above criteria: they occur in some plants but are not ubiquitous.

Unreliable characteristics

Stem colour

This can vary within a taxon. *C. giganteum v. yunnanense* has been quoted as having dark, nearly black stems. My observation is that, in general, they do have darker stems than *C. giganteum* but not in every case and I've seen none which could be described as 'black'.

Direction of flower opening [1]

C. giganteum has been described as opening from the bottom of the raceme up and *C. giganteum yunnanense* as from the top down. My observation is that most of our taxa open from the bottom up, occasionally from the top down and sometimes from the middle then up and down as is shown in the photo on Plate 8, B, p. 50.

Ratio of leaf length to width [1]

It's been suggested that a leaf blade which is longer than it is broad is an indicator for *C. cathayanum*. With some exceptions, most of our taxa show this feature, as does the description of *C. giganteum* on p. 6. although, according to images, this trait does seem to be most devloped in *C. cathayanum.*

Height to width ratio of stem

It's been stated that *C. giganteum v. yunnanense* has more slender stems than *C. giganteum*. Again, I find that this is a common but not ubiquitous trait, more suitable for differentiating plants within a mixed group rather than one that could be used to identify an isolated plant.

[1] Matthews, *The Plantsman*, December 2002, p. 196

Valid characteristics

Examination of the type descriptions in section 1 and the appearance of a variety plants in the collection, lead to the selection of a number of morphological characteristics which can be used for the identification of the various taxa.

Character	**Definitions**
1 Flower stem height	>=1.5m, (0), <1.5m, (1)
2 Leaf distribution	Generally symmetrical along the stem, (0), asymetric, bunched in middle,* (1).
3 Flower structure	Symmetric, corolla usually un-divided, l >= 2 x b, (0), Symmetric, corolla usually divided, l >= 2 x b, (1), zygomorphic about a horizontal plane, corolla usually undivided, l >= 2 x b, (2), zygomorphic about a horizontal plane, corolla usually undivided, stubby, l < 2 x b, (3)
4 Flower colour	White with magenta streaks, (0), Greenish/cream with magenta streaks, (1), all white, (2), all magenta, (3)
5 Flower colour pattern	Magenta streaks along the tepals. Strongest on the adaxial surface of the petals but present on the abaxial surface, (0) Magenta streaks along the tepals. Strongest on the adaxial surface of the petals. Absent/faint on the abaxial surface (1) Magenta streaks along the tepals. Strongest on the adaxial surface of the petals. Absent/faint on the abaxial surface. Faint speckling on tips and edges of tepals (2) Magenta streaks absent or very faint. Magenta speckling on the tips of the tepals, (3), Flowers a uniform colour, (4)
6 Flower number	Few, 3 – 10, (0), many 11- 30+, (1).
7 Flower bract retention	Lower bract retained, (0), all bracts deciduous, (1)
8 Offsets	Generally few, 1 – 4, (0), Usually several, 5-10+, (1)

Taxa matrix

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
cathayanum	1	1	2	0	2†	0	0	?
cordatum v. *cordatum*	1	1	2	1	3‡	0	0	0
cordatum v. *cordatum* f. *rubra*	1	1	2	3	3	0	0	0
cordatum v. *glehnii*	1	1	3	1	3	1	0	0
giganteum v. *giganteum*	0	0	0	1	1	1	1	1
giganteum v. *yunnanense*	0	0	1	0	0	1	1	1
giganteum v. *yunnanense* f. *rosea*	0	0	1	3	4	1	1	?
giganteum v. *yunnanense* f. *alba*	0	0	1	2	4	1	1	?

‡ As I've never seen a *cathayanum*, this is a very uncertain assignment, based on the photograph of the flower of *C. cathayanum*, Kew 2007297 shown on Plate 3, J, p15. It should be noted that this is very similar to the flower colouring of cordatum 2010:16 shown on Plate 2, D, p. 9

* See Appendix 4, p. 64

† Whilst a few *cordatum* show colour pattern 2, the majority exhibit pattern 3.
These characteristics lead to a provisional taxonomy key for the genus.. I'm not happy with this as the identification depends on the geographical distribution of the plant.

TAXONOMY KEY

1 a Distribution, China **2**

b Distribution, Japan **6**

2 a Stems 1.5 – 3+ m. Leaves spread regularly up the stem. 10 – 30+ flowers. Flower bracts lost before flower is fully open. Flowers show no zygomorphism. **3**

b Stems 0.5 – 1.5m. Leaves not spread regularly up the stem, bunching in the middle. 3 – 20 flowers. Flowers retain the lower flower bract for some time after opening. Flowers show slight to pronounced zygomorphism about a horizontal plane. ***Cardiocrinum cathayanum*** *

3 a Stems green, robust. Flowers have a green tinge, which becomes cream in full sun, with slight to medium bands of magenta on the adaxial surfaces of the sepals and petals and faint colour on the abaxial surface of the petals. Never white. The corolla is not divided. ***Cardiocrinum giganteum* v. *giganteum*.**

3 b Stems darker green, sometimes streaked with or completely purple, more gracile. Flowers white with little or no green tinge. Corolla is divided on mature flowers. **4**

4 a Flowers are white with slight to strong bands of magenta mainly on the adaxial surfaces of the sepals and petals but some on the abaxial surface of the petals. ***Cardiocrinum giganteum* v. *yunnanense***

4 b Petals are a uniform colour abaxially and adaxially, either white or magenta **5**

5 a Flowers are white with no trace of magenta. ***Cardiocrinum giganteum* v. *yunnanense* f. *alba*** †.

5 b Flowers are magenta with no trace of white. ***Cardiocrinum giganteum* v. *yunnanense* f. *rosea*** †

6 Leaves not spread regularly up the stem, bunching in the middle Flowers retain the lower flower bract for some time after opening. Flowers show slight to pronounced zygomorphism about a horizontal plane.

a Stem usually 0.5 – 1.25m. Few flowers, (3 – 7). **7**

* See p. 18 for my inability to distinguish between *C. cordatum cordatum* and *C. cathayanum*.
† It isn't known if this taxa is stable

b Taller, more robust stem to 1.5m. Up to 20 flowers. ***Cardiocrinum cordatum* s. sp. *glehnii*.**

7 a Flowers are white with slight to strong bands of magenta mainly on the adaxial surfaces of the sepals and petals but some on the abaxial surface of the petals. ***Cardiocrinum cordatum cordatum***

b Flowers are completely red on the adaxial surdaces and mostly red on the abaxial. ***Cardiocrinum cordatum cordatum* f. *rubra***

Plate 4

A

C. yunnanense, 2014:111

B

C. giganteum yunnanense, 2015:125

C

Far Reaches Farm Nursery white *yunnanense*

D

C. giganteum yunnanense f. *rosea*, 'Big & Pink'

E

C. giganteum yunnanense 2013:82
Seedling of *C. giganteum yunnanense* f. *rosea* 'Big & Pink'

F

Close up of flower of *C. giganteum yunnanense* 2013:82

G

Dissected flower of *C. giganteum yunnanense* 2013:82

H

Left: Leaf of 2013:82,
Right: comparable leaf of a different strain of *yunnanense*

Plate 5

A

C. cordatum cordatum f. *rubra* 2019:167

B

C. cordatum cordatum f. rubra 2019:167

C

C. cordatum cordatum f. *rubra* 2019:167

D

C. giganteum giganteum seed pod

E

C. cordatum glenhii seed pods

F

Empty seed pods, *C. giganteum giganteum* on the left, *yunnanense* on the right

G

Seedlings in raised bed

H

Seedlings in pot

I

Self-seeded plants at the monocot stage

PROPAGATION

In nature, *Cardiocrinum* have two different systems of propagation, from seed and by offsets.

From seed

Cardiocrinum are self-fertile hermaphrodites and it is usual for all flowers to give rise to seed pods, (Plate 5, D, E & F, p. 36). The fact that the scent from the flowers is more prominent in the evening, (see p. 3), suggested to us that they might be moth pollinated but we've seen no evidence of that.

The pods ripen in late Autumn, November/December with us, and gradually open up so that the seed can be wind dispersed over a period of time, (Plate 5, F). I once counted 545 seeds in a pod which means, for a plant with 20 flowers, about 10K in total and, for the plant with 61 flowers, (see p. 34), about 30K. If anyone is interested in a statistically significant sample, I'll be happy to provide the pods!

Sowing the seed

Seed should be sown as soon as it is ripe. It can either be sown in pots or straight into the ground. The best method would be to sow it where you wanted the plants to grow, but we appreciate that this isn't always possible.

If using pots, fill a broad pot with well drained compost, saturate it, leave it to drain and then sow the seed on the surface and cover with a thin layer of compost, perlite or vermiculite; basically to stop the seed blowing away or being washed out when watering.

Leave the pot where it can be exposed to the weather. i.e. don't keep it frost-free. If sowing directly into the soil, either broadcast it or sow in a shallow, (12mm), trench.

Cardiocrinum are moncots, so when the seed first germinates you get a single leaf, like a blade of grass, (see Plate 5, G, H & I, p. 35).

My wife was once showing visitors around the collection who claimed that they never got any self-seeded *Cardiocrinum*. When she showed them a patch of moncot leaves, (Plate 5, A), one exclaimed, "Oh, I've been weeding those out!" The difference is small but important! *Cardiocrinum* seedling leaves are a little broader and thicker than a blade of grass.

Phartyal, Kondo, Baskin & Baskin [1], (PKBB), state that *C. giganteum giganteum* and *C. cordatum glehnii* both exhibit deep simple morphophysiological dormancy, (MPD). i.e. the seed embryo is not fully developed when the seed is dispersed and has to grow within the seed before germination takes place. If this is the case, then it is highly likely that the genus as a whole has this property. The main effect of this is that it takes a relatively long time for germination to occur. PKBB state that stratification can reduce germination time from 16 to 10 – 11 months.

[1] Seed dormancy and germination in the giant Himalayan lily (*Cardiocrinum giganteum var. giganteum*): an assessment of its potential for naturalization in northern Japan, Phartyal, Kondo, Baskin & Baskin, *Ecological Research*, July 2012, Volume 27, Issue 4, pp 677–690.

We sow one pot of seed from each strain of plant which flowered in the current year as there is a sugestion that vegetative propagation leads to loss of vigor.[1] [2] We certainly get fewer offsets from the *Cardiocrinum giganteum* species than the numbers reported by Mr Cox [1] but the plants which have flowered have produced much the same number of offsets.

It is reported that, if the seed is sown as soon as it is ripe it should germinate the next year but if seed is stored before being sown then it can take two years to germinate, i.e. two cold periods, but that this time can be reduced by stratification, see PKBB above and below.

We sow the seed as soon as the pods start to open but have never had any germination in the next year. Sowing in November results in the first germination occuring in the March of the year after the next. i.e. in 16 months.

Stratification consists of exposing the seed to alternating warm and cool temperatures. The regime used by PKBB was a 25/15 °C (120 days) → 15/5 °C (90 days) → 0 °C (90 days) → 15/5 °C (60 days) temperature sequence. This is not a sequence that can be matched outside of a Biological laboratory and a more realistic regime would be alternate periods of ~ 1 month warm, (room temperature), and I month cool, (Fridge at 2°C). I have not tried this for *Cardiocrinum* but do use it successfully for Rowan seeds and I would be interested to hear from anyone who has tried this method.

The use of immature seed

It has been reported [3] that sowing immature seed leads to germination in the following year. In 2016, I sowed seeds every two weeks from pods taken from the middle of September until the pods had ripened in November. None of the seeds had germinated by the spring of 2018

The use of Gibberellic acid

Gibberellic acid, GA3, a plant growth hormone, can be used for a variety of purposes including aiding the germination of seed as an alternative to stratification.

My attention was drawn to an article in the German gardening magazine *Gartenpraxis* on the use of Gibberellic acid with *Cardiocrinum* seed. [4]

Seed was soaked for 24 hours in a 1000ppm solution, (i.e. 1g GA3 in 1l. of water), and then sown as usual. For seed so processed in May, germination was reported to occur within four weeks. [5]

This was tried in February 2018 with newly ripe seed from 2017 and 40 year old seed at the start of spring 2018 with no success. * In view of the report in "*Gartenpraxis*", I think this is worth trying again with a variety of concentrations of GA3 in Autumn to see if a

[1] Variation in *Cardiocrinum giganteum*, Peter Cox, *The Plantsman*, June 2009, p. 93 .
[2] The Genus *Cardiocrinum* in Cultivation, Victoria A Matthews, *The Plantsman*, December 2002, p. 205
[3] Private correspondence.
[4] Private correspondence. Els Rammeloo (Mrs), Secretary; Vlaamse Vaste Planten Vereniging, [VVPV], editor VVPV-Magazine
[5] *Gartenpraxis*, 5, 2009, p. 32
* The 2017 seed did germinate in March 2019 but this is what one would expect with no treatment.

year can be removed from the germination time. However, there is a report that "GA3 did not substitute for the above temperature requirements.", [1] (the stratification regime outlined on p. 38).

Even though the seed starts to germinate as described above don't throw away what's left as some will continue to germinate each spring for up nine years after the initial batch.

Viability

The viability of the seed varies. In general, we find that *giganteum* taxa produce a higher rate of germination, (~100/pod, ~20%), than the *cordatum* but, even with *giganteum* taxa, there can be a very low rate of germination, (~4 - 5/pod, ~1%). There are no obvious external indicators of high or low viabilty of a pod, leaving aside those few pods which fail to develop and which, presumably, contain no viable seed.

Growth

It is reported that it takes the plants seven to nine years to flower when grown from seed. However, our first plants from seed, (*Cardiocrinum giganteum* v. *yunnanense*), flowered five and a half years after sowing and four years after germination. Seedlings of *C. cordatum* took about the same times.

From offsets

When a *Cardiocrinum* has flowered it is liable to leave a number of offsets. I say 'liable' because the number is variable and, occassionally, a plant will leave no offsets. It's been suggested that a plant forms one offset per year but this cannot be the case, as is indicated by the occassional absence of any offsets and the fact that a bulb which has grown for, say, three years may have more than twice this number of offsets.

If you intend to grow from offsets rather than seed, you can cut off the flower raceme after the tepals have fallen in the hope that the remaining vigour of the plant will go to forming and enlarging the offsets[2]. I know of no proof that this works but it seems plausible!

The offsets should be harvested when they have gone dormant, (i.e. the parent plant has died), which will be in late Autumn, (November – December with us). The *giganteum* taxa tend to have more offsets than the *cordatum* but this is a very loose rule.

Very small offsets, <15mm, are better grown on for a year ot two in a protected nursery bed if possible but anything larger can be planted out in its final position.

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[1] Seed dormancy and germination in the giant Himalayan lily (Cardiocrinum giganteum var. giganteum): An assessment of its potential for naturalization in northern Japan; Ecological Research 27(4) · July 2012 https://www.researchgate.net/publication/235969777_Seed_dormancy_and_germination_in_the_giant_Himalayan_lily_Cardiocrinum_giganteum_var_giganteum_An_assessment_of_its_potential_for_naturalization_in_northern_Japan

[2] G Jekyll, *Lilies for English gardens*. A guide for amateurs. Compiled from information published lately in "The Garden", with the addition of some original chapters.[London]"Country life" [etc.]1901, 5

Chitting and flakes

Whilst seeds and offsets are the natural means of propagation for *Cardiocrinum*, chitting and flakes are worthy of invetigation for a genus so closely allied to the Lilies. This became of interest when Far Reaches Farm announced its first, all pink, *Cardiocrinum* and was looking for methods to bulk up its stock. As I couldn't find any references to these methods of propagation I carried out some experiments.

The results are that I was not able to grow plants from cut, (chitted), bulbs but had limited success with flakes, provided each included a part of the basal plate. * However, it was often the case that I got one viable flake from one bulb, so this is not a useful method of propagation.

I think more time could usefully be spent investigating these methods with a view to increasing the rates of success.

* It could be argued that, as the flake actually has part of the basal plate attached, this is, in fact, an example of chitting!

CULTIVATION

Four factors must be kept in mind when growing *Cardiocrinum*: they need shade, they are greedy feeders, they don't like to get wet and they don't like to be disturbed.

One of the earliest growers of the genus in the UK was Miss Gertrude Jekyll who left much valuable information in a book, "*Lilies for English Gardens*", created from a series of articles previously published in "*The Garden*".[1]

Planting offsets

As mentioned above, a *giganteum* bulb in its flowering year may be 200mm in diameter so a hole must be dug large enough for such a bulb and its roots.

It is sometimes quoted that a dead sheep or cow(!) should be included but that is the formula for vines. I've been told that Major George Sherriff recommended a dead Yak but Miss Jekyll only recommended a rabbit! .

"On that day, having dug a sizable hole and added some leaf mold and sand, the famed gardener [Miss Jekyll] also tossed in a freshly killed rabbit. Then she counseled, 'Now, always seat the bulbs clockwise,' a task she accomplished with a firm rightward twist before filling in the hole with topsoil." [2]

We dig a hole of about one cubic foot and fill it with a mixture of compost or leaf-mold, the excavated soil and slow-release fertilizer, (we use Blood, Fish and Bone meal in lieu of a rabbit!), although a larger volume will produce a taller plant. I would council against the "firm rightward twist" which is liable to damage the rather brittle roots of the bulbs. The bulb is planted with its nose just at the surface as a growing bulb will produce a leaf from the tip of each scale. It may be that this is also part of the source for the reports of a 'basal rosette' of leaves, (see p. 4), as, in its flowering year, a plant will have basal leaves until the stem is fully grown.

Small bulbs should be planted a little deeper for protection and any bulb will find its own depth. Seedlings will pull themselves down from the surface of a pot 30 - 40mm into the compost as they develop into a bulb.

We don't give *C. giganteum* any more feeding once they're planted but *C. cordatum* types are given a liquid feed each Spring until their flowering year.

These are plants of woodland shade and experiments with growing them in an open, sunny location have resulted in smaller plants with fewer offsets probably due to a lack of moisture in the soil and increased transpiration. However, they do grow and flower and their reduced size might be a benefit in a smaller garden.

In their growing years, *Cardiocrinum* produce a rosette of large, heart-shaped leaves. When they are going to flower, the growth is vertical from the earliest days of spring, as shown on Plate 6, B & C, p. 45.

[1] G Jekyll, *Lilies for English gardens*. A guide for amateurs. Compiled from information published lately in "The Garden", with the addition of some original chapters.[London]"Country life" [etc.], 1901

[2] Brooklyn Botanic Garden, *Plant and Garden News*, Vol 17, Number 3, 2002

Hardiness

Some authorities recommend covering the nose of the bulb with bracken for winter protection [1]. We haven't done this and there've been few losses, (but see *cordatum* below). There would be the risk of the straw or bracken getting wet and compressed which might cause the bulb to rot. Miss Jekyll recommended using "a few Fir boughs, or something that will "break" the frost"[2] i.e. in more modern parlance, something to create a micro-climate without holding moisture which might rot the bulb. It is the case that, in their natural habitat, many of the bulbs will be under snow at the coldest time of year.

We've had one or two winters with sub -10°C temperatures and a number of smaller bulbs have died. This has been particularly true of *C. cordatum* offsets and I'm now growing these on for a year or so in a sheltered location before planting them out, as mentioned on p. 36.

Transplanting seedlings

As mentioned above, *Cardiocrinum* don't like to be moved, particularly out of their dormant season, (November to March).

If you're able, sow the seed where you want your plants and then weed-out or, if you can't bring yourself to do that, pot up any unwanted seedlings. The largest, most vigorous plants we have had have been self-seeded in this way. The problem for a collection is that you can't be certain of a self-seeded plant's parentage! It's like Rowans: seeds distributed by birds are cleaned of the skin and flesh, scarified by their passge through the birds digestive system and then deposited with a measure of feriliser. The only thing that birds can't do is cprrectly label the resulting seedling!

Potting up young seedlings should be done when they get their first true, heart shaped leaf or, for *cordatum* types, which can be slow to reach this stage, at the end of the year of germination.

Problems may arise when plants are potted on. If a plant is repotted out of its dormant period it's liable to flower at a very small size without leaving any offsets, (see Plate 6, D, p. 45)! I find this happens more often with *cordatum* types than *giganteum* taxa but it has happened with both.

However, with care, plants can be grown to the flowering stage in pots, allbeit a little smaller than in open ground, Plate 6, E, p. 45.

The main point about growing them in pots is never let them get too wet. I use a well drained compost made from two parts coir to one part sharp sand with added trace elements. Any feeding is provided by a liquid feed which is alternated with plain water during the growing season and the pot should never be saturated .

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[1] P. Cox, Variation in *Cardiocrinum giganteum, The Plant Finder,* June 2009, 93

[2] G Jekyll, *Lilies for English gardens*. A guide for amateurs. Compiled from information published lately in "The Garden", with the addition of some original chapters.[London]"Country life" [etc.]1901, 6

Watering should be stopped the moment the plant goes dormant. For small seedlings this can be as early as July and I never water or feed from October to March. As far as I'm aware, I've never lost a plant through drought but I've lost many due to them getting too wet.

Locations

As said earlier, *Cardiocrinum* like shade. We also have a National Collection® of Rowans, ("Sorbus, the pinnate leaved species"), which we use to provide shade for the *Cardiocrinum*. They can, in fact, cope with very deep shade. You may have heard that you can plant *Hostas* either in shade or in dry conditions. Well, *Cardiocrinum* are quite happy in deep shade and dry! We grow them within two or three feet of mature Oaks and a *Sequoiadendron giganteum*. However, they're very forgiving. Even if you don't have deep shade they'll grow in partial shade or even full sun, though not so large as elsewhere in the latter case.

It may be that you feel your garden is too small for such a large plant as *C. giganteum giganteum* but we had a friend who had a small patio at the rear of her house where she grew some outstanding Hostas in pots and always one *C. gig. yunnanense,* also in a pot.

For the smaller garden, you might be happier with *C. cordatum cordatum* at ~ 4' – 5' or *C. cordatum glehnii* at ~ 5' – 6', the former of which is shorter than our *Lilium lancifolium*.

Companion planting

What do you grow with them? The short answer is anything which can cope with the same degree of shade.

We try to use a series of plants, either as ground cover or as accent planting.

The ground cover we're using at the moment is a mixture of Wild strawberries, (*Fragaria vesca*), both the red and white fruited varieties, *Arisarum proboscideum, Asarum europeus*, a vigorous Bugle, (*Ajuga reptans* 'Silver Beauty'), miniature *Persicaria (affinis?),* which grows to form a solid mat, drifts of pink and white *Colchicum*, patches of Wild Woodruff, (*Galium odoratum*) and *Arum maculatum* mixed with *Arum italicum pictum.*

For accent planting we use *Trillium* and *Ariseama*, particulaly *Ariseama grifithii*, Foxgloves, especially my wife's pale pink selections of *Digitalis purpurea,* 'Redhall Blush', and any other woodland plant which takes our fancy; *Beesia* and *Jeffersonia* are valued although they are slow to bulk up.

Problems

The only real problem with *Cardiocrinum* comes at the end of the flower development. As has been mentioned, all of the bulb is converted to flowering stem over the course of about four months and the plant is held in the ground only by its root system at the foot of the stem.

Miss Jekyll describes it thus, "The roots look like those of a young tree or the great spreading ones of *Eremurus robustus*. The flowering stems have need of these great

roots, for they rise to a height of from ten to fourteen feet, …" [1] This gives the impression of a strong and resistent root system but, in fact, the plants at this stage are very prone to being blown over.

If you grow only a few specimens in an area open to wind, I'd suggest staking them all in their flowering year. However, even if they're blown over, they can be lifted and staked and then will continue to grow, flower and develop seed. Even if they're not lifted, they will continue to grow but the raceme will turn through 90° in 24 hours, so they look a little pecullar.

[1] G Jekyll, *Lilies for English gardens*. A guide for amateurs. Compiled from information published lately in "*The Garden*", with the addition of some original chapters.[London]"*Country Life*" [etc.]1901, 5

Plate 6

A

C. giganteum giganteum young leaves

B

C. giganteum giganteum in a growing year

C

C. giganteum giganteum in its flowering year

D

C. cordatum flowering in its pot

E

C. giganteum yunnanense in a pot

F

C. cordatum glehnii with virus?

G

Quadruple stemmed *C. gig. giganteum*

H

Double stemmed *C. gig. giganteum*

ANOMALOUS GROWTH

One of the problems with cultivated plants is that situations can arise due to the close proximity of the plants and their intensive cultivation which are less likely to arise in the wild.

If plants are well fed and protected, they are likely to grow taller and have a larger inflorescence than wild taxa but they are also more likely to exhibit disease and variations from normal development.

Diseases

Cardiocrinum are susceptible to all the diseases of the Lilies: Lily Beetle, Lily viruses, slugs, etc.

We have little problem with slugs, neither with *Cardiocrinum* nor *Hostas*, (our problem with *Hostas* is Pea fowl!).

We have had problems with lily virus; probably the Lily Symptomless virus. The symptoms, (!), which we see are distorted leaves as shown on Plate 6, F, p. 45. I'm not sure of this identification because the literature I've read state that there are three main virus diseases of the *Liliacea*, Tulip Breaking Virus, Cucumber Mosaic Virus and the Lily Symptomless virus. What we've seen is certainly not a breaking or mosaic virus, hence the assumption of Lily Symptomless virus even though there are symptoms.

At one level the identity is of secondary importance, what matters is that plants become diseased, probably via an aphid transferred virus. The problem is that other damage can produce the leaf distortion that we see. If we're quite convinced that a plant is diseased, it is lifted and destroyed and the area is left fallow of *Cardiocrinum* for a few years. If we feel it may just be due to damage, the plant is isolated until next year's growth can be examined.

The plant shown in Plate 6, F died shortly after being moved to quarantine it but the offset to its right, (which does show slug damage!), was left for two seasons, showed no sign of disease and eventually flowered normally.

Leaves which are lanceolate rather than cordate tend to appear from time to time which only last for one season and which often occur in conjunction with the usual heart-shaped ones. It's felt that this is not necessarily due to disease but could be apical damage due to late frosts early in the season. Remember, each scale of the bulb will produce a leaf during the growing years and it's conceivable that one apex could be damaged whilst the rest are not. If growing in pots, such plants are quarantined to see how they appear the following year when they often have standard *Cardiocrinum* foliage.

Premature blooming

As mentioned on P. 28, *Cardiocrinum* are liable to premature flowering if disturbed outside of their dormant period.

This means that they should not be planted out either as offsets or as seedlings too late in the year. Anything I've planted in April, due to late snow, has flowered later that year, sometimes with stems as short as 500mm for *C. gig. yunnanense*! In 2016 we had a large number of plants flower on short stems, some of which had been planted out the previous November and one or two which had been in the ground for two years . I think that this might have been due to a very mild winter, (lowest temperature -2°C and only one day of snow on April 28th). It raises the possibility that, if global warming is going to result in warm, wet winters for this area, there may be serious consequences for the future of the collection.

Mutiple stems

We have seen two examples where a plant has produced multiple stems in its flowering year, Plate 6 G & H, p. 45. The first example, shown in Plate 6 G, flowered but the second died before the flowers had opened.

I've no idea what caused this effect: again, it was possibly some damage to the apical tip early in the season.

Faciation

It can be considered that faciation is closely allied to the above phenomenon of multiple stem growth; where the several stems are fused into one.

We've had one example of this with *C. gig. yunnanense*, 2009:87, Plate 7, A, p. 49. This had 61 flowers but, on close examination, could be seen to be three fused stems, (Plate 7, B). It's really only when you see the bare stem in two views at 90° that you can see the faciation. It was also only when we had the bare stem that we could be certain that it had 61 and not 58 , 59, 60 or 62 flowers. In fact, we ran a visitors quizz of 'find the number of flowers'!

The possible polycarpism of *C. cordatum*

It has been reported that, occassionally, *C. cordatum* exhibits polycarpism [1]

Whilst I've never actually seen this, this species does exhibit different behaviour with regard to offsets within the collection from that of the *C. giganteum* taxa.

I don't know the details of the development of offsets but, by the time a *C. giganteum* stem has ripe seeds, there are liable to be a number of separate offsets around the base with their own leaves. In fact, we've seen an offset flower in the same year as its parent plant, shown on Plate 7, C.

As well as these large offsets there are likely to be a number of smaller ones amongst the roots of the plant held closely to but separate from the stem.

The situation with *C. cordatum* is slightly different. As well as the large offsets with leaves and the smaller ones amongst the roots, there are also growths which appear to be offsets which haven't yet separated from the stem. It is as if, having flowered later in the

[1] Bleddyn and Sue Wynn-Jones , Crûg Farm Nursery, personal communication.

year than the *giganteum* taxa, some offsets are still in the process of forming by the time the stem dies.

It's worth reporting that these proto-offsets do **not** contain part of the basal plate of the plant as has been suggested by some of those who refuse to believe that *Cardiocrinum* are monocarpic and clutch at straws in an attempt to prove that an offset is actually the plant that has flowered.

Plate 7, D & E, p. 45 are photos of the root of a *C. cordatum cordatum* taken in 2011. Neither of these structures had any discernable roots of their own. The old root was re-planted but no growth was seen in the following year.

In 2013, a similar situation was seen on another *C. cordatum cordatum*, as shown on Plate 7, F, G & H. There were five growths on this root, only one of which appeared to be an offset, (labelled). Again this root was re-planted and examined in the Spring of the following year when two young plants were found growing near but separate from the dead stem.

It does seems that the conjecture that these growths seen in Autumn are immature offsets is correct and that the species is monocarpic.

Plate 7

A

Faciate *C. gig. yunnanense* , 2009:87

B

Triple faciate stem

C

C. gig. yunnanense with a flowering offsets to its right.

D

C. cord. cordatum root, 2011

E

C. cord. cordatum root, 2011

F

C. cord. cordatum root, 2013, view (i)

G

C. cord. cordatum root, 2013, view (ii)

H

C. cord. cordatum root, 2013, view (iii)

Plate 8

A

C. gig. giganteum 'Queen Fabiola' ?

B

C. yunnanense, 2009:26

C

C. yunnanense
2009:13

D

ID = K000523920

All references,
http://specimens.kew.org/herbarium/**[ID]**

E

ID = K000523921

F

ID = K000523919

G

ID = K000523922

CAVEAT EMPTOR

Buying bulbs

We sell bulbs, washed and bare rooted, between the start of November and the end of February and you would pay between £4 and £12 per bulb depending on the species and size of the bulb.

If you bought at the garden or from one of the local plant sales to which we donated bulbs, you would get a plant in a pot within the same price range.

In each case, the plant/bulb would be labelled with the code of the parent plant so that you could trace its origin back to the original strain in the collection using the on-line data base.[1]

Few other sellers offer this degree of information: in fact, it's often difficult to know **what** you're being sold!

C. giganteum giganteum and *C. giganteum yunnanense*

If you want to buy bulbs with a known provenance from a commercial concern you'll need to use a specialist nursery such as Crûg Farm Plants [2] or Pan-Global Plants [3] but you can pay up to £25/bulb and their carriage charges are around £20 minimum.

Most other suppliers only advertise "*Cardiocrinum giganteum*" with a picture of *yunnanense*!

In fact, what they're selling is probably *yunnanense* but do ask for clarification before you buy. Also be sure to ask how old it is and when it's due to flower. Don't buy anything that is more than two or three years old unless grown from seed and refuse any bulb which is "guaranteed to flower this year"! If it does, you're liable to be left with no offsets unless it already has some. We once bought a bulb of *C. g. giganteum* which was about 70mm in diameter, planted it in June only to have it grow to about 1m later that year, then flower without leaving a single offset. A *giganteum* bulb in its flowering year should be 150 - 200mm in diameter and would need at least an 18" pot to contain it and transplanting it would probably effect its flowering, (see p. 38).

If you buy plants in leaf rather than bulbs, it's a good idea to leave them in the pot until they've gone dormant before you plant them out. However, be careful not to over-water, particularly if the growing medium is peat-based, as they may rot-off.

There are some doubtful suppliers out there. For a while someone was offering *Cardiocrinum giganteum* on eBay, (illustrated with a picture of *yunnanense*!), at £250, though the supplementary print did state that "THESE ARE NOT AVAILABLE UNTIL MARCH 2019 WHEN THE PRICE WILL BE REDUCED ACCORDINGLY." Presumably they were phishing to see if anyone was fool enough to pay £250.

[1] http://www.redhall.org.uk/GardenOpening/cardio_db.htm
[2] Crûg Farm Plants, https://www.mailorder.crug-farm.co.uk/Browse.aspx
[3] Pan-Global Plants, http://www.panglobalplants.com

It can actually be quite difficult to find a supplier of *C. giganteum giganteum* other than from a specialist nursery. It seems that most people prefer *yunnanense* but I'd suggest that a mixture of both compliment each other, as shown in the picture on Plate 2, p. 9.

C. cordatum cordatum and *C. cordatum glehnii*

These are not very common but can be found on-line.

The red flowered form of *C. cordatum cordatum* was offered in the UK at £86 in 2017 and for £75 in 2018. However, it can be easily bought from a nursery in Japan [1] for £47 - £50 including carriage and a CITES certificate.

C. cathayanum

There are still some people offering plants with this name on the internet. I am unaware of anyone who is offering the genuine species: most of the pictures shown look like *yunnanense,* see p. 17

Buying seed

This is bandit country!

The quality of description of what is on offer is deplorable and sometimes borders on the fraudulent.

Illustrations

It does seem that, in many cases, the sellers have just looked for any old image of a *Cardiocrinum* with little attempt to either obtain the owner's permission, (someone lifted an image of *C. cordatum glehnii* off our website and used it to advertise seeds on eBay Australia!), nor to match it to the taxa of the seed on offer, (the seeds being advertised in Australia were *yunnanense*!).

As with bulbs, the seeds are often described as *C. giganteum* but the image is of *yunnanense* and there are instances of *glehnii* pictures used to illustrate seeds from what is labelled as '*yunnan*': e-mail the seller for clarification!

[1] Yuzawa Engei, http://yuzawa-engei.net/07Overseas/index.html

Number and cost

The table below shows a sample of the seeds on sale in November, 2018.

Seeds in a packet	Cost, (inc. carriage) GBP	Cost/seed, GBP
10	15.90	1.59
10	11.98	1.20
5	4.99	1.00
10	7.45	0.75
5	3.13	0.63
10	3.74	0.37
20	6.38	0.32
20	3.62	0.18
20	2.24	0.11
20	1.94	0.10
100	5.75	0.06

NB some suppliers make no mention of how many seeds are actually in one of their packets!

This brief investigation shows that there is a twenty-six fold variation in the cost of the seeds being sold: hence my comment about fraud! If the seller who is charging £1.59 per seed were able to sell a whole pod, this would bring in ~£700: selling all the pods on one plant would generate an income of ~£16000. For Redhall, where we have about 70 plants in flower each year, we could raise over a million and the world would be knee-deep in *Cardiocrinum*: **if** they were all viable!

Viability

As mentioned on p. 39, *Cardiocrinum* have a relatively low viability, (1% - 20%), with no obvious external indicators for a particular pod or seed. This means that, for packets of 5 seeds, it is possible that there will be **no** viable seed in such a small amount and statistically you shouldn't expect more than one.

It is very unlikely that the sellers have carried out any viability testing as this would take at least 11 months using stratification and I can't find any reference of the TZ test [1] being used for *Cardiocrinum*. In any case, if an actual germination test was carried out, the results would be out of date as the batch of seed being tested would have aged and thus lost some vitality by the time the result was known.

Instructions

It's also the case that many sellers of seed give no or misleading instructions on growing them. I've seen complaints on a website that, "I gave them six weeks but nothing germinated". When my wife sells seeds from the collection, she offers a packet of not less than 20 seeds. This is labelled with a photo of the correct taxon. It also includes a leaflet with full information on their germination, stressing the need for at least two cold periods, and information on the early cultivation of the seedlings, (see appendix 5, p. 70).

The moral of the story is **caveat emptor**.

[1] https://2020seedlabs.ca/what-is-a-tetrazolium-chloride-test/

APPENDICES

1 DNA plant barcodes

The system of DNA barcodes for organisms is based on the concept of identifying one or more genes which can be considered typical of the genus and species and using the sequencing of these genes to identify the organism.[1]

For plants, the chosen genes are the matK and rbcL chloroplast genes.

In general, it's not considered possible to identify a taxon beyond the species level [2] although claims have been made to differentiate *C. giganteum giganteum* from *C. giganteum yunnanense.* [3] and *C.cordatum glehnii* from *C.cordatum cordatum.* [4] However, this process also used the trnL-F gene sequence.

The criteria for identifying a taxon are arbitrary but the following definitions, based on the work done by Meier, [5] are in frequent use. [6]

Best close match, (BCM). Distance < 1%, (97% correct ID),
Close match, (CM). 3% > Distance ≥ 1%, (60% correct ID)

The 'Distance' figures refer to calculations made from the variations between the two sequences concerned. [7]

Comparisons were made using one or both of the online BOLD Plant sequences IDS [8] and the Align Sequences Nucleotide BLAST [9]

The DNA was extracted and sequenced from ~4 inches square leaf samples from collection plants by the DNA Sequencing Facility of the Natural History Museum, (NHM), in London.

DNA from an offset of *C. cathyanum* Kew 2007-297 was provided by the Royal Botanic Garden Kew, (RBGK), which was also sequenced by NHM.

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[1] The Consortium for the Barcode of Life. What is DNA barcoding? Published online, http://barcoding.si.edu/whatis.html

[2] Choosing and using a Plant DNA Barcode. Published online, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3102656/

[3] Evaluation of seven DNA barcodes for differentiating closely related medicinal Gentiana species and their adulterants, p.2 *Chin Med.* 2013; 8: 16, Li M, quoting, [11], Ling KH, Lam H, Shaw PC, Cheng L, Techen N, Khan LA, Chang YS, But PP. Cardiocrinum seeds as a replacement for Aristolochia fruits in treating cough. *J Ethnopharmacol*. 2010;8:429-432. doi: 10.1016/j.jep.2010.04.040.

[4] M. Nishizawa, S. Kubota and M.Ohara Development of 13 microsatellite markers in Cadiocrinum cordatum var. glehnii, *Molecular Ecology Resources*. Published online, http://kubota.tyonmage.com/publications/MER2010B.pdf

[5] DNA Barcoding and Taxonomy in Diptera: A Tale of High Intraspecific Variability and Low Identification Success *Syst. Biol.* 55(5)715-728,2006

[6] Turning DNA barcodes into an alternative tool for identification. Published online, https://www.ippc.int/sites/default/files/documents//1300372559_POSTER-deMeyer_KJETT.pdf

[7] Distance methods. Published online, http://ib.berkeley.edu/courses/ib200a/labs/ib200a_lab07_PAUP_distance.pdf

[8] BOLD IDS, http://www.barcodinglife.com/index.php/IDS_OpenIdEngine?edu=1#plantTab NB This link no longer exists and BOLD doesn't seem to have any comparison software: just use BLAST.

[9] Nucleotide BLAST, http://blast.ncbi.nlm.nih.gov/Blast.cgi?PAGE_TYPE=BlastSearch&BLAST_SPEC=blast2seq&LINK_LOC=align2seq

It should be noted that the majority of the comparisons made fall into the BCM category. In fact, if the BOLD matK sequence for *C. giganteum yunnanense* is check with the BLAST IDS, 14 matches are found within a 2% variation; the majority of these are Lilies and the list includes **all** forms of *Cardiocrimum* represented in the database! i.e. there is very little variation in the DNA of the marker genes and so any identifications have a high level of uncertainty.

In some cases there are gaps in the gene sequence. As I have no way of knowing what these missing sequences are, they are assumed to match the compared sequence. i.e. the figures quoted are minimum values for the distances.

The matK gene is considered to give the greatest discriminatory power [1] so, after initial sequences were developed in 2014, only the matK and trnL genes were sequenced as the rbcL gene seemed to be just telling us that the samples are *Cardiocrinum*.

The NHM used the 1R_KIM and 3F_KIM primers to sequence a fragment of the matK gene as described in the *Journal of Systematics and Evolution*, online article, "New universal matK primers for DNA barcoding angiosperms".

"In systematics, the full-length matK sequence is amplified and sequenced with primers designed within the trnK region (Wang et al., 2006); however, for DNA barcoding, a fragment of 600-800 bp is usually sufficient. " [2]

Sample codes

For collection samples, the first code is the accession number of the actual sample, the second is that of the original strain. The accession numbers consist of the year of planting followed by the database record number.

matK genes

C. cathayanum

1. ex Kew 2007-297
2. BOLD, GBVU2911-13

C. cordatum

3. BOLD, GBVC3452-11
4. BOLD, GBVC3453-11
5. Collection, 2010:15, (2010:15)
6. Collection, 2013:108, (2004:4)
7. Collection, 2011:32, (2009:10)
8. Collection, 2011:48, (2010:16)

C. cordatum glehnii

9. Collection, 2011:33, (2005:6)
10. Collection, 2011:50, (2011:50)
11. Collection, 2012:59, (2012:59)

[1] Choosing and using a Plant DNA Barcode.

[2] New universal *matK* primers for DNA barcoding angiosperms, Jing Yu, Jian-Hua Xue and Shi-Liang Zhou, *Journal of Systematics and Evolution*, 49, 3, 2011 176 – 181, first published online 16 MAY 2011, http://onlinelibrary.wiley.com/doi/10.1111/j.1759-6831.2011.00134.x/full

C. giganteum giganteum
12. BOLD, GBVU2910-13
13. Collection 2011:31, (1998:18)
14. Collection 2013:96, (2009:11)

C. giganteum yunnanense
15. BOLD, GBVT2686-13
16. Collection2012:61, (2012:61)
17. Collection, 2013:82, (2013:82)
18. Collection, 2013:92, (2013:92)
19. Collection, 2012:129, (2002:1)
20. Collection, 2012:55, (2006:7)
21. Collection, 2013:95, (2009:13)
22. Collection, 2014:110, (2014:110)

20 – 22 were formerly *C. cathayanum* hort.

trnL genes
C. cathayanum
1. ex Kew 2007-297

C. cordatum
2. Collection, 2010:15, (2010:15)
3. Collection, 2013:108, (2004:4)
4. Collection, 2011:32, (2009:10)
5. Collection, 2011:48, (2010:16)

C. cordatum glehnii
6. Collection, 2013:98, (2005:6)
7. Collection, 2011:33, (2005:6)
8. Collection, 2011:50, (2011:50)
9. Collection, 2012:59, (2012:59)

C. giganteum giganteum
10. Collection 2011:31, (1998:18)
11. Collection 2013:96, (2009:11)

C. giganteum yunnanense
12. Collection, 2012:61, (2012:61)
13. Collection, 2013:82, (2013:82)
14. Collection, 2012:92, (2013:92)
15. Collection, 2012:129, (2002:1)

C. cathayanum hort.
16. Collection, 2012:55, (2006:7)
17. Collection, 2013:95, (2009:13)
18. Collection, 2014:110, (2014:110

Overall comparisons

Table 1, matK genes

2	0.00																			
3	0.25	0.16																		
4	0.38	0.46	0.20																	
5	0.24	0.27	0.00	0.12																
6	0.24	0.27	0.00	0.12	0.00															
7	0.24	0.27	0.00	0.12	0.00	0.00														
8	0.24	0.27	0.00	0.12	0.00	0.00	0.00													
9	0.24	0.27	0.00	0.12	0.00	0.00	0.00	0.00												
10	0.24	0.27	0.00	0.12	0.00	0.00	0.00	0.00	0.00											
11	0.24	0.27	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.00										
12	0.89	0.56	0.40	0.64	0.54	0.54	0.54	0.54	0.54	0.54	0.54									
13	0.67	0.81	0.49	0.61	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.27								
14	0.67	0.81	0.49	0.61	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.27	0.00							
15	0.67	0.48	0.26	0.46	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.24	0.00	0.00						
16	0.89	0.81	0.49	0.61	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.00	0.24	0.24	0.24					
17	0.67	0.81	0.49	0.61	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.23	0.00	0.00	0.00	0.00				
18	0.67	0.81	0.49	0.61	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.23	0.00	0.00	0.00	0.24	0.00			
19	0.89	0.81	0.49	0.61	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.00	0.24	0.24	0.24	0.24	0.24	0.24		
20	0.85	0.96	0.57	0.71	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.00	0.28	0.28	0.28	0.00	0.28	0.00	0.00	
21	0.85	0.95	0.57	0.71	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.00	0.28	0.28	0.28	0.00	0.28	0.00	0.00	0.00
22	0.73	0.81	0.49	0.61	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.27	0.00	0.00	0.00	0.24	0.00	0.00	0.24	0.28	0.28
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21

cathayanum *cordatum* *glehnii* *giganteum* *yunnanense*

Table 2, trnL genes

2	0.00														
3	0.00	0.00													
4	0.00	0.00	0.00												
5	0.00	0.00	0.00	0.00											
6	0.00	0.00	0.00	0.00	0.00										
7	0.00	0.00	0.00	0.00	0.00	0.00									
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00								
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00							
10	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12						
11	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.00					
12	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.12	0.00				
13	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.00	0.00	0.00			
14	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.00	0.00	0.12	0.00		
15	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.12	0.12	0.00	0.12	0.12	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	

cathayanum *cordatum* *glehnii* *giganteum* *yunnanense*

Discrimination

matK, Table 1-means

cathayanum, (cath)	0.00				
cordatum cordatum, (cord)	0.27	0.05			
cordatum glehnii, (glehn)	0.23	0.01	0.00		
giganteum giganteum, (gig)	0.74	0.52	0.51	0.00	
giganteum yunnanense, (yu)	0.75	0.50	0.59	0.05	0.03
	cath	cord	glehn	gig	yu

The matK sequences are distinguishing between the species but not between varieties. The variations between *C. cathayanum* and *C. cordatum* types are small and comparable with the internal variations found with the *giganteum* types.

trnL, Table 2-means.

cordatum cordatum, (cord)	0.00	0.00			
cordatum glehnii, (glehn)	0.00	0.00	0.00		
giganteum giganteum, (gig)	0.12	0.12	0.12	0.00	
giganteum yunnanense, (yu)	0.19	0.19	0.19	0.05	0.06
	cath	cord	glehn	gig	yu

The trnL gene indicates differences between *C. cordatum* and *C. giganteum* types but not between *cordatum* and *cathayanum*. There are also differences within the set of *C. giganteum yunnanense*. It isn't considered that the current trnL gene sequences add anything to the identification of the taxa so these comparisons have been removed from this edition.

Comparisons within taxa

matK genes, (Tables 3 to 10 are abstracted from Table 1)

C. cathayanum, Table 3

Sample		
2	0.00	
	1	Sample

C. cordatum cordatum, Table 4

Sample					
4	0.20				
5	0.00	0.12			
6	0.00	0.12	0.00		
7	0.00	0.12	0.00	0.00	
8	0.00	0.12	0.00	0.00	0.00
	3	**4**	**5**	**6**	**7** Sample

C. cordatum glehnii, Table 5

Sample

10	0.00		
11	0.00	0.00	
	9	**10**	Sample

C. giganteum giganteum, Table 6

Sample

13	0.27		
14	0.27	0.00	
	12	**13**	Sample

C. giganteum yunnanense, Table 7

Sample

15	0.24						
17	0.00	0.00					
18	0.00	0.24	0.00				
19	0.24	0.24	0.24	0.24			
20	0.28	0.00	0.28	0.00	0.00		
21	0.28	0.00	0.28	0.00	0.00	0.00	
22	0.00	0.24	0.00	0.00	0.24	0.28	0.28
	15	**15**	**17**	**18**	**19**	**20**	**21** Sample

Comparisons across taxa

C. giganteum gigateum and *C. giganteum yunnanense* , Table 8

giganteum samples

12	0.24	0.00	0.23	0.23	0.00	0.00	0.00	0.27
13	0.00	0.24	0.00	0.00	0.24	0.28	0.28	0.00
14	0.00	0.24	0.00	0.00	0.24	0.00	0.00	0.00
	15	**15**	**17**	**18**	**19**	**20**	**21**	**22**

mean = 0.10

yunnanense samples

C. cordatum cordatum and *C. cordatum glehnii*, Table 9

glehnii samples

9	0.00	0.01	0.00	0.00	0.00	0.00
10	0.00	0.01	0.00	0.00	0.00	0.00
11	0.00	0.01	0.00	0.00	0.00	0.00
	3	**4**	**5**	**6**	**7**	**8**

mean = 0.00

cordatum samples

C. cordatum types and *C. cathayanum* , Table 10

cathayanum samples

1	0.25	0.38	0.24	0.24	0.24	0.24	0.24	0.24	0.24
2	0.16	0.46	0.27	0.27	0.27	0.27	0.27	0.27	0.27
	3	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**

mean = 0.28

cordatum samples

Species previously known as *C. cathayanum* (hort.)

Table 11

cathayanum hort. samples

20	0.85	0.96
21	0.85	0.95
22	0.73	0.81
	1	**2**

mean = 0.86

cathayanum samples

Table 12

cathayanum hort. samples

20	0.57	0.71	0.56	0.56	0.56	0.56	0.56	0.56	0.56
21	0.56	0.71	0.56	0.56	0.56	0.56	0.56	0.56	0.56
22	0.49	0.61	0.59	0.59	0.59	0.59	0.59	0.59	0.59
	3	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**

mean = 0.58

cordatum samples

Table 13

cathayanum hort. samples

20	0.00	0.28	0.28	0.28	0.00	0.28	0.28	0.00
21	0.00	0.28	0.28	0.28	0.00	0.28	0.28	0.00
22	0.27	0.00	0.00	0.00	0.24	0.00	0.00	0.24
	12	**13**	**14**	**15**	**15**	**17**	**18**	**19**

mean = 0.15

giganteum samples

As described on page 17, these results were used to produce the diagram on that page which indicates that the samples labelled as ***C. cathayanum*** hort. are *C. giganteum*.

There were some differences within the *yunannense* taxa and some identities between *giganteum* and *yunnanense* types.

As there were different numbers of bases in some of these comparisons, in 2018 I decided to normalise the available collection sequences to the smallest common value of 705bp, (sample 20, 55o2, ***C. giganteum yunnanense*** formerly ***C. cathayanum hort.***), and recalculate the alignments. The results are shown in Table 14 below.

matK differences for *giganteum* and *yunnanense* taxa from the collection, Table 14

14	0							
16	2 (0.28)	2 (0.28)						
17	2 (0.28)	2 (0.28)	0					
18	0	0	2 (0.28)	2 (0.28)				
19	2 (0.28)	2 (0.28)	0	0	2 (0.28)			
20	2 (0.28)	2 (0.28)	0	0	2 (0.28)	0		
21	2 (0.28)	2 (0.28)	0	0	2 (0.28)	0	0	
22	0	0	2 (0.28)	2 (0.28)	0	2 (0.28)	2 (0.28)	2 (0.28)
	13	**14**	**16**	**17**	**18**	**19**	**20**	**21**

The values in the table are the number of bp differences with the 'distances' shown in parentheses The variations were in the same two bp in all cases and occurred at positions 142, (T/C), and 503, (C/T).

These results suggest that, for the samples concerned, the taxa can be split into two groups with zero internal differences in the matK areas sequenced.

Group 1: samples 13, 14, 18, 22
Group 2: samples 16, 17, 19, 20, 21

Group 1 contains both of the *giganteum giganteum* samples but this should not be seen as an indication that samples 18, (2013:92), and 22, (2014:110), are actually *C. g. giganteum* rather than *C. g. yunnanense* but that the matK chloroplast gene only delimits species rather than varieties. However, the results do suggest that there are two strains of *C. g. yunnanense*.

An attempt was made to equate these two groups to geographic locations but there was too little source data to give any meaningful result. Whilst the BOLD data has details of the institutions lodging the information, there is no data for any of the *Cardiocrinum* specimens which gives the geographic source of the sample. Of the collection samples only16, (*C. g. yunnanense*, 2012:61) and 18, (*C. g. yunnanense*, 2013:92), have any information as to the source region.

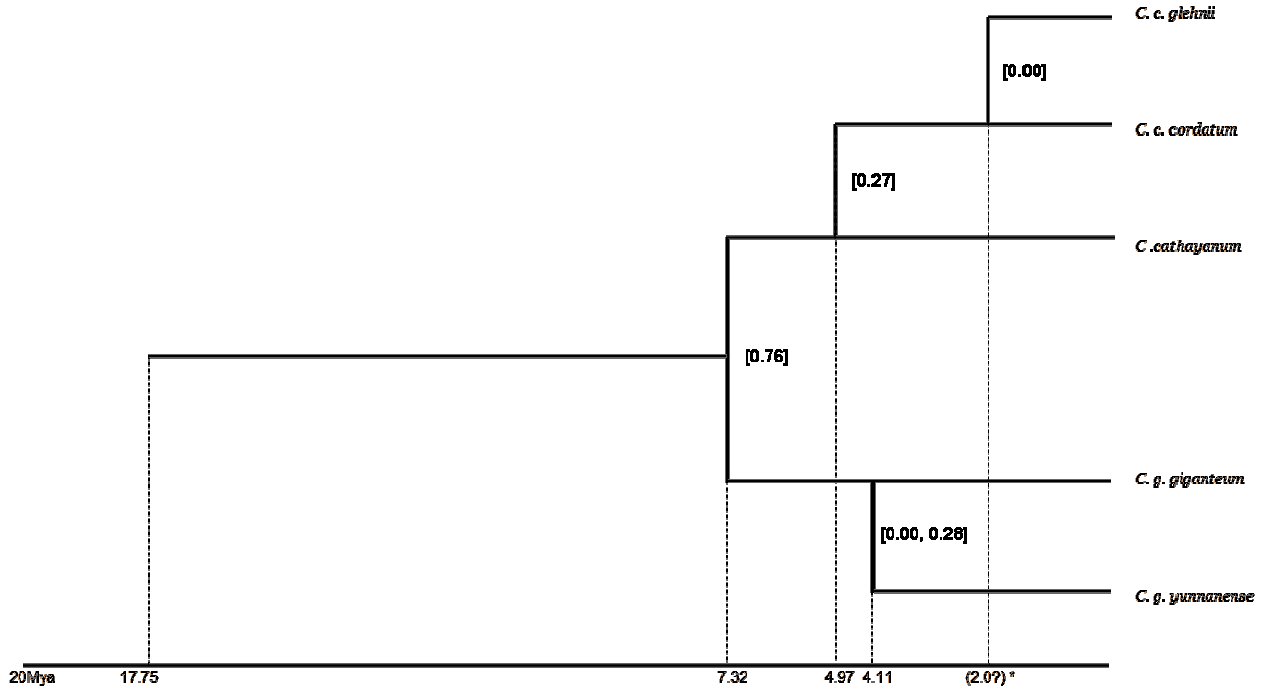
Sample 16, (Group 2), came from seed from Baoxing, Sichwan province, China and sample 18, (Group 1), came from material collected near Kalimpong, West Bengal, India.

It was also considered if these groups could shed any light on the Bronze/Olive foliaged plants, (samples 16, 21 & 22). However, samples 21 and 22 are in different groups.

2 Phylogenetic trees

The original edition used the data from the DNA sequences of the various matK genes shown in appendix 1 and the data from the taxa matrix on p. 33 to generate phylogenetic trees using a variety of software. [1]

However, the limited amount of data available, (*C. c. glehnii* was only represented by the data in the taxa matrix), and the work of LHCSMXS has persuaded me to remove this and rely on their results to show the relationships between the various taxa as shown in the tree below and on p. 24



See p. 24 for the explanation of this tree.

[1] Wikipedia, List of phylogenetics software, published online,https://en.wikipedia.org/wiki/List_of_phylogenetics_software
Wikidedia, List of phylogenetic tree visualization software, published online https://en.wikipedia.org/wiki/List_of_phylogenetic_tree_visualization_software

3 Digital imagery as a botanic recording medium.

1 What should be stored

This would vary from organism to organism but a check-list should be produced showing the desirable aspects to be recorded with a minimum specification.

2 Photographic aspects

Statements of,

- minimum resolution,
- recommended colour calibration card/s to be included in all pictures,
- picture formats for storage.

In the later case this should include raw image data as it is inevitable that, over time, new storage algorithms will become available. Such algorithms would not be concerned with data compression but with data correction: the ability to rescue partially degraded images.

Currently, I'd suggest the following,

- Primary, raw camera data,
- Secondary, .png or .tif as a lossless format and
- .jpg for cataloguing, etc.

Whatever format's are chosen, the documentation should include a detailed description of the algorithms concerned.

3 Storage media

Currently this would be high quality DV or BluRay discs. Writeable versions of these media can be had which are specifically tailored for long life and, with the system specified for biological image storage, the increased market might lead to a drop in price! The media would use gold reflective layers where applicable and would write by literally burning a layer rather than switching a dye colour: we're not talking re-writeable here!

Consideration should be given to a backup system. Whilst this will double the cost of storage. It would minimise the risk of lost data.

There should aslo be full documentation of both the digital algorithms and physical process involved in the storage.

Both writing and reading machines would be required and these should also be fully documented on the basis that, some day, a reading machine would have to be built from scratch!

4 Updating

Whilst the most durable system available at the time should be used, it will be necessary to copy the data at suitable intervals, either because a significantly superior storage format or media has become available or because any medium will fail in time.

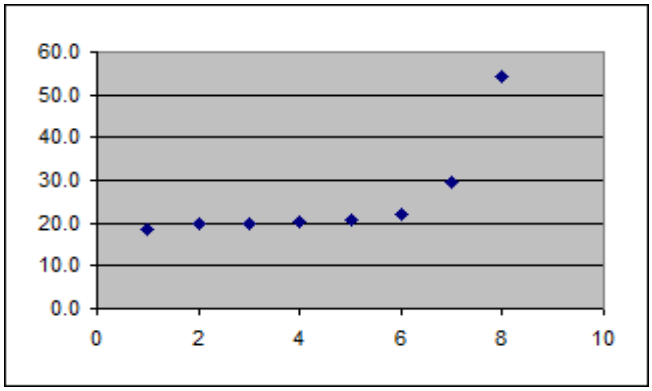
4 The leaf distribution

The arrangement of the leaves on a flowering stem differs on different forms of *Cardiocrinum*. The *giganteum* taxa tend to have a regular progression of leaves from the base to the inflorescence whereas the *cordatum* types tend to bunching of the leaves in the middle of the stem and the same structure is described for *C. cathayanum*, (see p. 16).

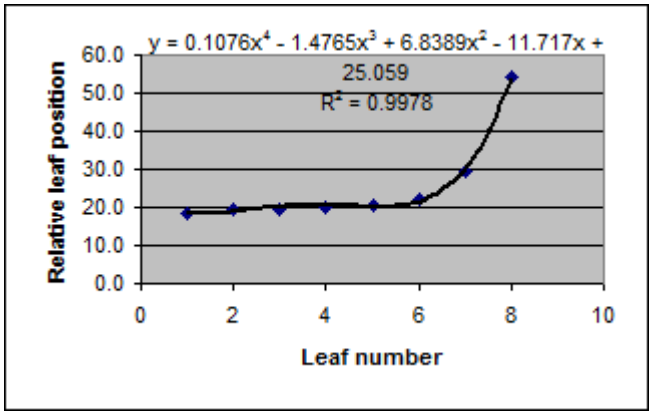
For some of the plants that flowered in 2014, the leaf positions on the stem were measured as follows,

- the distance of the leaf from the ground, Δd_n, (n = 1 to number of distinct leaves)
- the height of the flower stem, h

This data was then normalised by calculating $\Delta d_n/h$ and then entered on an Excel spreadsheet and a scatter chart displayed.



The Excel TrendLine facility was then used to plot possible lines of best fit* based on both linear and polynomial functions.†



The order of the equations of best fit were recorded with their R^2 values and the y-axis intercept for the best fit in the table below for *giganteum* and *cordatum* taxa. The cell of the selected best fit order has a grey background. ‡

---

* The criteria for a 'best fit' was taken as an R^2 value ≥0.99, (99%), and the intercept value was taken from the first function to give this value.

† Care must be taken with polynomials as, with a data set of n items, a polynomial of order n-1 will fit ALL points, (R^2 = 1), without being able to make ANY valid prediction of a value outwith this set.

‡ The above illustrative data was from *C. cordatum glehnii*, 84o1, (see table on p. 65)

The plant codes consist of the record number following by a letter indicating the source* and a digit for the generation. These are colour coded as follows which matches the coding used on the garden map of the collection.†

C. cathayanum (hort.), now *C. giganteum yunnanense*
C. cordatum
C. cordatum glehnii
C. giganteum giganteum
C. giganteum yunnanense

e.g. plant 55o2 is a *C. cathayanum* (hort.) which is a second generation offset.

giganteum types

Plant	Height	R^2 order 1	R^2 order 2	R^2 order 3	R^2 order 4	Intercept, (%)
yunnanense	2490	0.9687	0.9979	0.9980	0.9989	14.2
96o1	1110	0.9972	0.9972	0.9987	0.9988	7.7
giganteum	1970	0.9826	0.9928	0.9943	0.9959	12.9
105o2 A	1250	0.9900	0.9900	0.9988	0.9988	7.4
105o2 B	1390	0.9964	0.9985	0.9988	0.9992	-0.39
55o2	2400	0.9965	0.9973	0.9980	0.9989	6.4
101p0 A	805	0.9819	0.9861	0.9926	0.9928	6.5
101p0 B	490	0.9864	0.9928	0.9943	0.9959	12.9

Modal order = 1 mean intercept = 8.4

cordatum types

Plant	Height	R^2 order 1	R^2 order 2	R^2 order 3	R^2 order 4	Intercept, (%)
15p0	1030	0.9032	0.9965	0.9986	0.9982	29.9
90o1 A	1110	0.9752	0.9971	0.9981	0.9999	3.7
90o1 B	1050	0.9773	0.9992	0.9983	0.9998	2.3
44o1	1330	0.9962	0.9979	0.9983	0.9997	5.6
38o1	1400	0.9342	0.9907	0.9974	0.9980	23.2
59p0	1725	0.9446	0.9902	0.9974	0.9980	28.5
84o1	915	0.5461	0.8526	0.9771	0.9978	25.1

Modal order = 2 mean intercept = 14.0

Analysis

The first thing to make plain is that this data can't be used to identify plants. Whilst there seem to be some trends, there is nothing definite enough to be used to give an identity.

The *giganteum* types do have a tendency to distributions which match a linear graph. The exceptions to this are the two uncoded plants and the pair of *C. cathayanum* (hort.), 101p0 A and B, which needed cubic & quadratic expressions! In the latter case, the reason may be linked to the small size of these plants. They were grown from imported,

* p = purchased plant, o = offset from collection plant, s = bulk seedlings & d = selected seedling.
† http://www.redhall.org.uk/GardenOpening/cardio_map/c_map1.htm

dried bulbs which only started to grow in May and then flowered in late June at ~300mm tall!

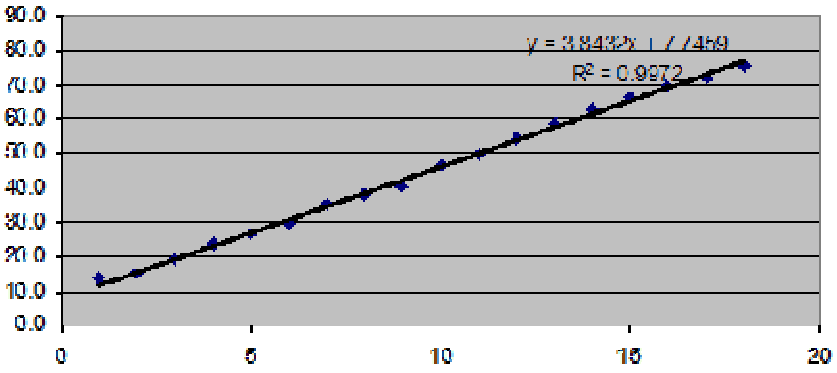
The intercepts are of the order of 8% which indicates that the leaves extend over most of the stem.

The *cordatum* types have a more irregular leaf pattern, leading to quadratic or higher order functions being required to describe them. The exception to this is the *C. cordatum glehnii*, 44o1. However, 90o1 and 44o1 are both descendents from our original *cordatum*, 4p0, which shows that there are variations within a generation as these are both offsets from the original plant. The intercepts are of the order of 14% which indicates that there is bunching of the leaves with the lower stem being bare.

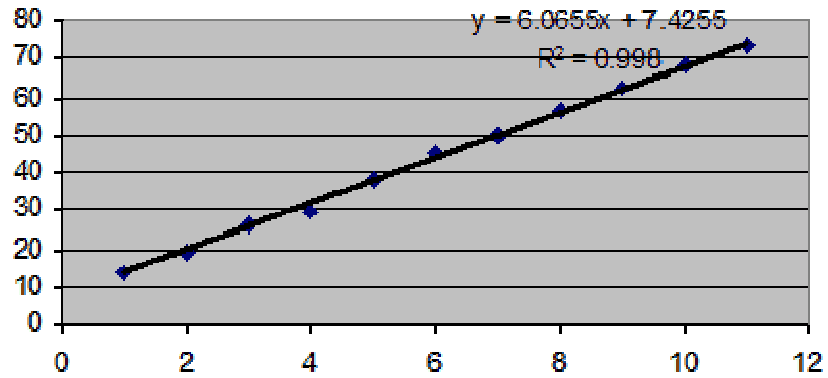
The leaf distribution shown by 15p0, 38o1, 59p0 and 84o1 are very similar to that described by Wilson for *C. cathayanum* and it would be interesting to make this analysis of a *cathayanum*, if I could find one.

Sample Data

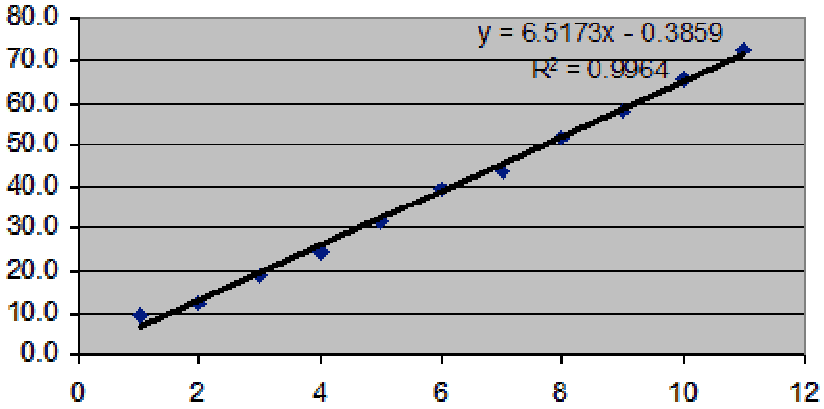
C. g. yunnanense, 96o1



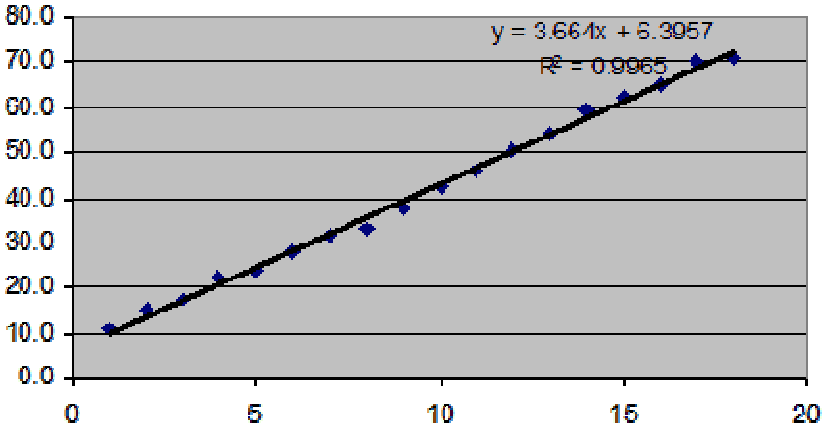
C. g. yunnanense, 105o2 A



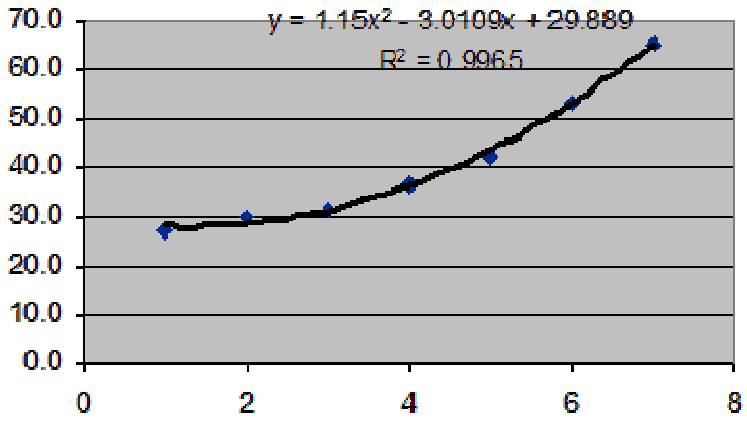
C. g. yunnanense, 105o2 B



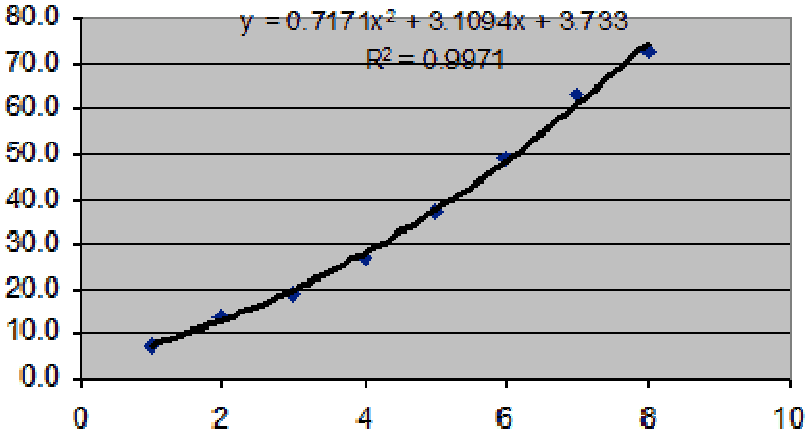
C. g. yunnanense), 55o2



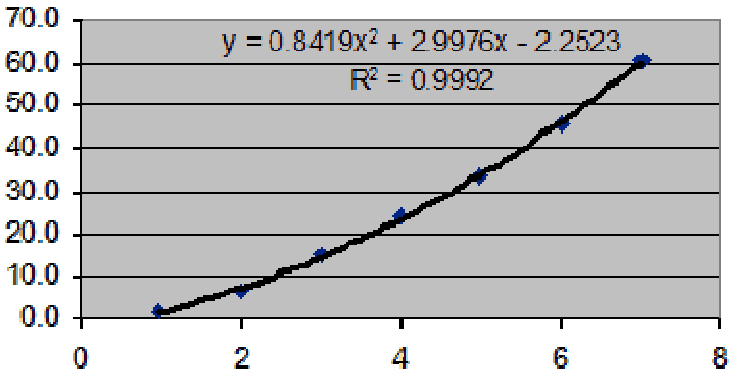
C. c. cordatum, 15p0



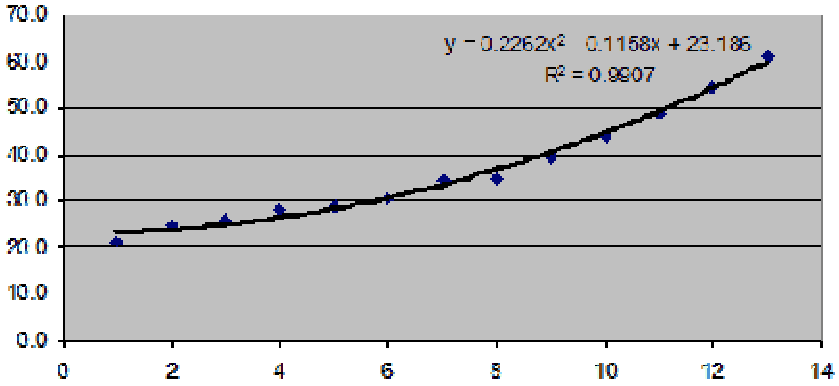
C. c. cordatum, 90o1 A



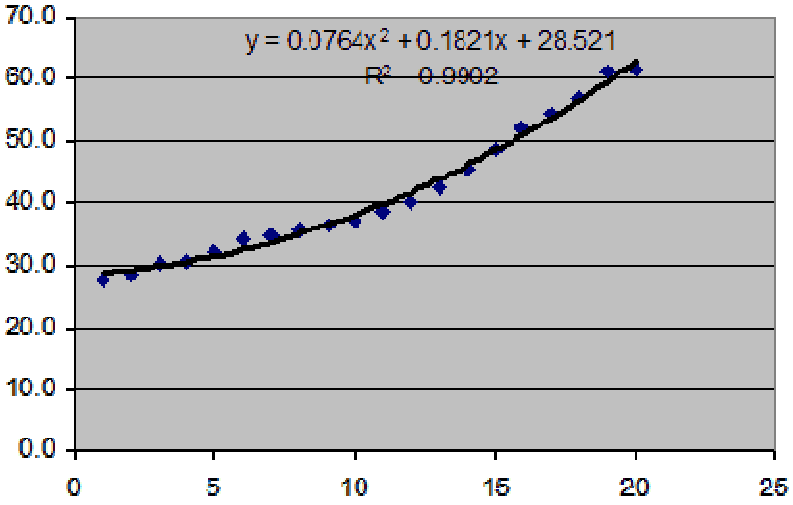
C. c. cordatum, 90o1 B



C. c. glehnii, 38o1



C. c. glehnii, 59p0



5 Leaflet provided with seeds

Redhall seeds

Thank you for buying **Cardiocrinum** seeds from the **UK National Collection.**

These are lovely plants with excellent scent which, in the right conditions, eg. a still evening, will fill the garden with fragrance. They are happy in any reasonable garden soil either in shade or partial shade although they require rich feeding to get themselves established. Being Himalayan plants they will stand extreme conditions. (Our garden is 500 feet up at the foot of the Angus Glens in Scotland, not far from where "Scott of the Antarctic" came to train!)

What I do with the seeds, which has been regularly successful, is to sow them in a seed tray full of coir and sharp sand mix but any well drained potting compost should do. Sow them right away, space them out well and cover very sparsely with compost or vermiculite. Expose them to the winter weather but perhaps with some shelter from exceptionally heavy rain which might wash them out of the pots or disturb emerging roots. (Snow is O.K.!)

They require two periods of cold to germinate. You could try putting the tray into a fridge for 30 days, letting them warm up for another 30 days, then exposing them to cold winter weather or another period in the fridge.

Even when they're not in flower, the foliage is worth having. When considering that they can take 7 years to reach flowering stage, this is a bonus. Being monocarpic, they flower, then die, but leave behind offsets which can flower in two or three years - and hundreds of seeds.

So – this is a long-term project needing some patience, but it is worthwhile. If you plant some every year then re-plant the offsets, you will have some flowering, giving great pleasure, every year. You can leave the offsets to form a clump but the resulting plants will be over-crowded and will perform less well than if you dig them up, when dormant, and give them refreshed, nutritious soil and room for the bulb to grow.

When they germinate, they have one leaf, rather like a blade of grass. At this stage I have planted them into a Nursery bed and allowed them to grow on. They seem to prefer this to being kept in pots although you could keep them until they have developed one true leaf.

If you have any questions or problems please contact me at info@redhallseeds.co.uk and more information can be found at the Cardiocrinum National Collection website, www.redhall.org.uk/GardenOpening/cardio.htm

I wish you success and pleasure from the plants.

Best Wishes
Moira Guthrie Bolt

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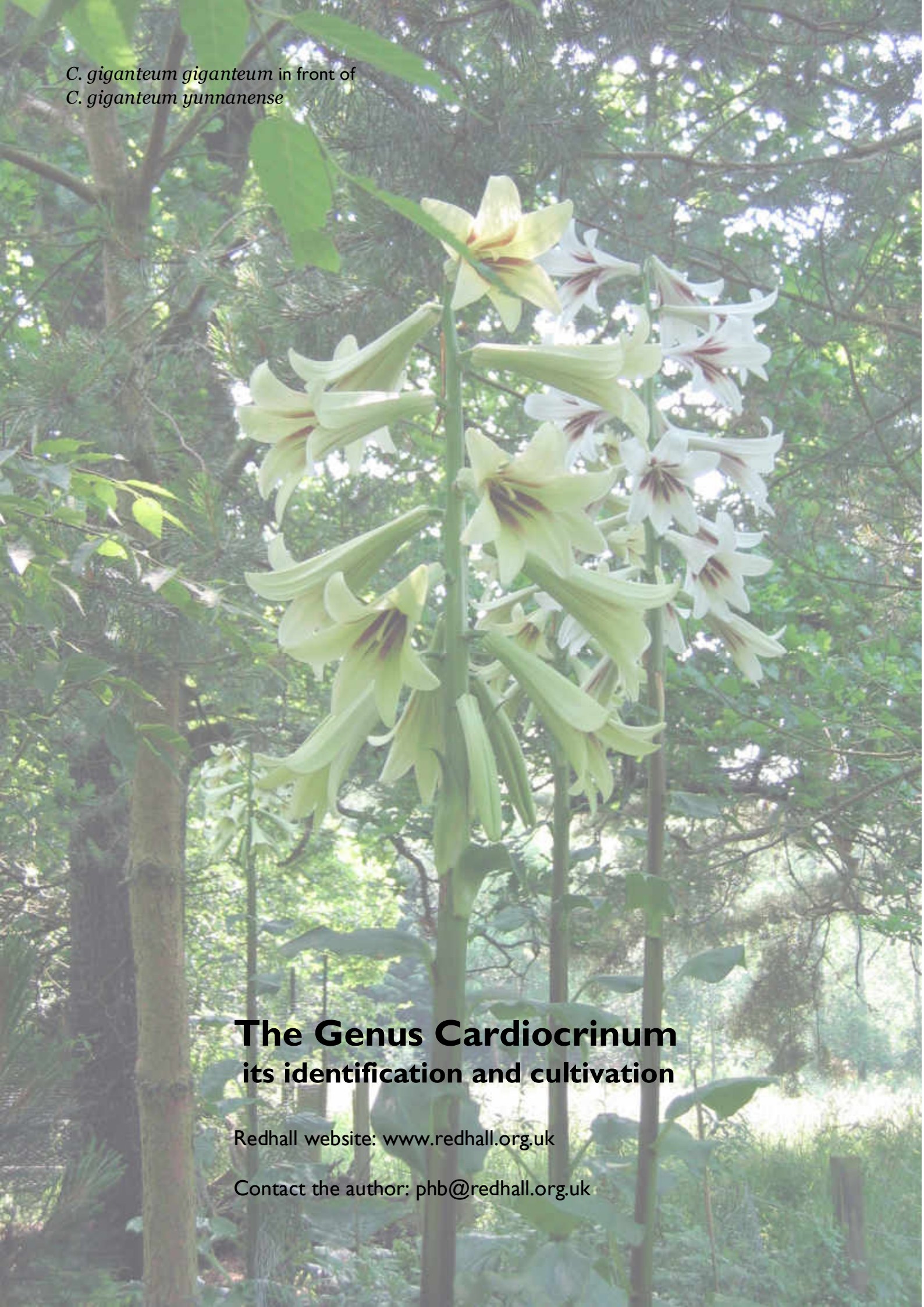

C. giganteum giganteum in front of
C. giganteum yunnanense

The Genus Cardiocrinum

its identification and cultivation

Redhall website: www.redhall.org.uk

Contact the author: phb@redhall.org.uk