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Special 2007 anniversary issue

Taxonomy and plant conservation

the tercentenary of the birth of Carl Linnaeus (1707-1778)

20 YEARS 1987-2007

BGCI

 

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Cover Photo: *Sarracenia flava* L. a species described by Linnaeus in *Species Plantarum* **1**:510 (1753) in cultivation at the Royal Botanic Gardens, Kew (Photo: BGCI)

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Submissions for the next issue should reach the editor before 20th March, 2007. The theme of this issue will be climate change. We would welcome contributions. Please send text on diskette or via e-mail, as well as a hard copy. Please send photographs as original slides or prints unless scanned to a very high resolution (300 pixels/inch and 100mm in width); digital images need to be of a high resolution for printing. If you would like further information, please request *Notes for authors*.

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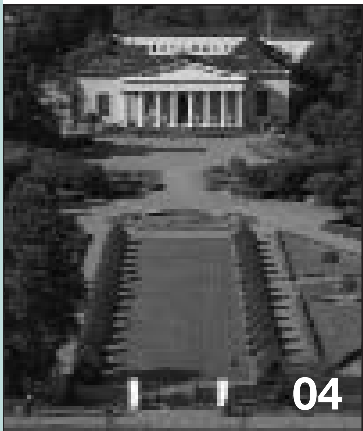
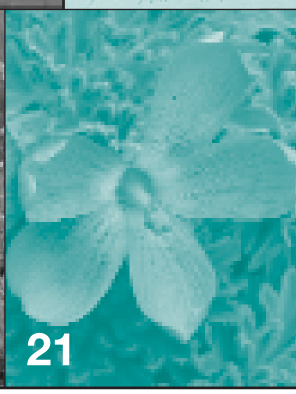




Editorial

Right: *Dracaena draco* is under threat in the wild (IUCN Category: Vulnerable). The Botanic Garden 'Viera y Clavijo', Las Palmas, Spain has undertaken a successful programme to restore the island's last laurel forests and reintroduce the Dragon Tree to the wild. (Photo: BGCI)

The diversity of plant species is a fascination to all botanists, an inspiration to gardeners and, although generally taken for granted, provides the basis for all life on earth. Species diversity represents millions of years of evolution and is the most important visible expression of biodiversity, giving character to ecosystems and shape to genetic diversity. Understanding and recording plant diversity depends on naming species. In this issue of *BGjournal* we mark the 300th anniversary of Linnaeus, the founder of modern species nomenclature and variously described as "the Prince of Flowers" or "the Father of Botany".

Botanic gardens have an extremely important role to play in studying, naming, cataloguing and displaying plant diversity. All these roles are clearly important as a basis for plant conservation. As pointed out by Tim Entwisle in this issue, having a focussed collections policy is a basic requirement for each botanic garden to manage its plant resources to maximum effect. Managing information on plants in the collections is also an important requirement recognized by botanic gardens around the world. Collection policies and management of collections depend on taxonomy and plant nomenclature, the often invisible sciences that determine the nature of botanic gardens.

In the wider scheme of things, plant species are being lost both literally with the increasing pace of extinctions and within the conservation debate. The ecosystem approach dominates discussion of biodiversity conservation whereas mammals and birds are used as indicators of biodiversity status and health. The Convention on Biological Diversity (CBD) *Global Strategy for Plant Conservation* (GSPC) was developed to address both the relative invisibility of plants in international conservation fora and, more critically, the actual loss of plant species.

The GSPC is currently the subject of an in-depth review and the progress towards meeting its ambitious targets will be highlighted within CBD over the next two years. The contribution that botanic gardens are making to the GSPC is remarkable, individually and collectively through BGCI and the Global Partnership for Plant Conservation. Target 1 of the GSPC, as highlighted by Vernon Heywood, Karen Wilson and Frank Bisby in this issue, calls for *A widely accessible working list of known plant species, as a step towards a complete world flora*. There is a good likelihood of this target being met and this achievement in itself will validate the importance of the GSPC. Linnaeus described and catalogued around 9,000 plant species, laying the basis for a global working list of known plant species. He believed that this represented roughly half the world's flora. Now we know that closer to 300,000 vascular plant species exist.

Target 2 of the GSPC depends on the classification and naming of plants. It calls for *A preliminary assessment of the conservation status of all known plant species, at national, regional and international levels*. At present, progress towards meeting Target 2 is slow at an international level, not because of the lack of data but because of lack of organization of the information on conservation status. This is an issue of concern, resulting in the invisibility of plants in global species assessments and conservation planning. Botanic gardens, however, are playing a major role in assessing the conservation status of plant species and recording this information, for example in the TROPICOS database maintained by Missouri Botanical Garden and the taxonomic publications produced by the Royal Botanic Gardens, Kew.

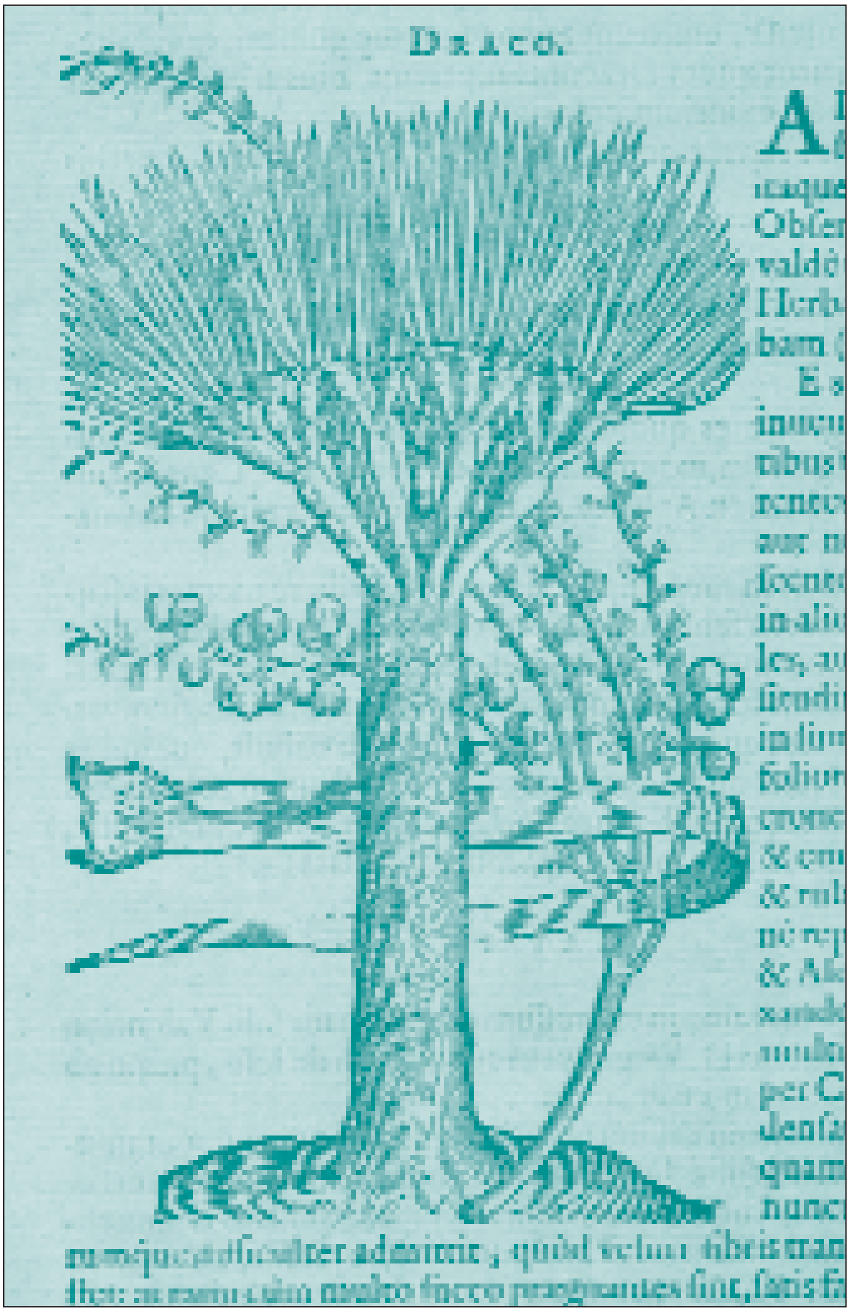
Targets 1 and 2 underpin the other 16 targets of the GSPC and are fundamentally important for botanic gardens to do their work. BGCI is taking a lead role in facilitating Targets

8 and 14 of the GSPC, reflecting the key responsibilities of botanic gardens in ex situ plant conservation and education. Target 8 calls for *60 per cent of threatened plant species in accessible ex situ collections, preferably in the country of origin, and 10 per cent of them included in recovery and restoration programmes*. A major tool for monitoring Target 8 at a global level is the BGCI PlantSearch database. The development of this online database represents an ambitious attempt to record the diversity of plant species in cultivation in botanic gardens and link this to conservation data. At present there are over 150,000 taxa recorded in PlantSearch provided by 637 gardens, of which over 11,000 species are recorded as globally threatened.

Managing the PlantSearch database is a major challenge for BGCI and I would like to begin a dialogue about the priorities for developing the database as a conservation planning tool for all botanic gardens. A few years ago, Dr James Cullen reviewed the data maintained by BGCI, organized the plant names according to Dick Brummitt's *Vascular Plants: Families and Genera* of 1992 and eliminated misspellings, synonyms and misplaced names. Currently BGCI screens all plant names in PlantSearch against the International Plant Names Index (IPNI) (www.ipni.org) as a means of eliminating invalidly published names. Looking ahead, do we need to promote a standard naming system for gardens, to allow for easy collaboration both nationally and internationally? Is there any value in recording cultivars in the database? How do we give due prominence to plants of particular value, such as medicinal species and crop wild relatives? How do we address the lack of currently compiled information on globally threatened plants within the IUCN Red List? Do we need to continue the policy of not revealing the location of plant species in collections? Your views on the utility of PlantSearch and its future development will be extremely valuable.

There will be good opportunities to discuss the links between plant taxonomy, nomenclature, conservation evaluations and conservation actions at the 3rd Global Botanic Gardens Congress in Wuhan in April this year. During the Congress we will be celebrating 20 years of BGCI. Various other BGCI anniversary events are planned throughout the year, starting with a public lecture by Wangari Maatthai, the Nobel Prize winner, in London on 8 February. Another event, organised jointly by BGCI, IUCN and ArtDatabanken will take place in Uppsala in Sweden – an international meeting on 3 May entitled *Secrets of Species*. This links to the Linnaean Tercentenary celebrations in Sweden and will be used to promote the fundamental importance of plant conservation. Throughout 2007 there will of course be events around the world to celebrate the 300th anniversary of Linnaeus. A summary of these is given on page 31. One of the best memorials to Linnaeus is the commitment of botanic gardens to classifying, naming and conserving plants, so that none of the plant species known to Linnaeus or subsequently described are needlessly lost.

Sara Oldfield



Left: *Dracaena draco* (L.) L. was named by Linnaeus from a description and illustration published by Clusius in 1601. Now considered Vulnerable in the wild, it is one of the most commonly cultivated, globally threatened plant species, as recorded in the PlantSearch database. © Natural History Museum, London (NHM)

Author: Magnus Lidén

The legacy of Linnaeus

Där man får tänka och skriva vad man will, där blomstra studier. Där religionen är fri blomstrar landet. Där teologin regerar fungerar intet.

Where there is freedom of speech, science prospers. Where there is religious freedom, the country prospers. In a theocracy nothing prospers

(C. Linnaeus, *Diaeta naturalis* [1733] 129, A. Uggla 1958).

Some of what Linnaeus wrote in the 18th century during a long, productive life may seem alien, or even bizarre, to the modern mind. Did he really believe that swallows hibernate on the bottom of lakes, or that God created, once and for all, immutable species in a single act? At other times he feels very modern, for example, when he comments on superstition, diet, or discusses in detail the behaviour of an insect. Our Swedish national hero has suffered disparate judgments: the romantic picture of the Flower Prince unveiling the secrets of Flora while surrounded by hordes of admiring pupils seems hard to reconcile with the self-sufficient book keeper, jealously guarding his territory while meticulously pigeonholing each and every dry specimen to its appropriate box according to the *Methodus* (Linnaeus, 1736).

Background: The original drawing for Linnaeus' Garden.

Below: Linnaeus' summer house at Hammarby, in the countryside southeast of Uppsala, is one of the best preserved 18th-century houses in Sweden and has hardly changed since Linnaeus' time.

Both pictures are true. Linnaeus was a direct and spontaneous person, normally not hampered by protocol. He made friends but also enemies; his disciples adored and loved him but some of his colleagues in science did not. But was he really a great scientist? Did he make any theoretical or experimental breakthrough, like Darwin or Kepler, or did he just compile things in a new framework? J. Sachs (1875) even argued that Linnaeus had delayed the progress of botany. He was perhaps not a profound theoretician; much (but not all) of his thoughts on ecology, economics, metaphysics or morals were common ideas at the time, and he could occasionally contradict himself. However, genius can take different forms.

Nomina si nescis, perit et cognitio rerum

Without names, no knowledge

It is indisputable that Linnaeus was of immense importance for the development and popularization of botany. Although botanical terminology has developed since his *Fundamenta Botanica* (1736) and *Philosophia Botanica* (1751), it still owes its clarity and precision to Linnaeus. His precise and logical descriptions of taxa are more similar to present-day format than to those immediately preceding him. The Sexual System enabled new and old genera to be classified and recorded in a simple and straightforward manner – he did bring order to a former chaos. The binomial system for naming species is more ingenious than Linnaeus himself understood at the time, and – it is my firm conviction – will survive as long as taxonomy. His encyclopaedic project *Species Plantarum* (1753) is a fantastic achievement based on an encyclopaedic knowledge (containing many mistakes, of course, like all encyclopaedias). Numerous are his contributions based on observation in the field and in the botanic garden on, for example, ecology, aetiology, phenology and ethnobotany – *Omniam mirare, etiam tritissima* (wherever you look, there is something worthy of a thesis). And, of course, we must thank him for "the Swedish thermometer", reversing Celsius' temperature scale, otherwise we would have had a human body temperature of 63 degrees.

Deus creavit, Linnaeus disposuit

God created, Linnaeus classified

But, enough of praise. What about his classification of plants? It has been disproved, hasn't it? It was newspaper headlines some years ago! As Linnaeus was aware, the Sexual System was completely arbitrary. There are no observations that could disprove or corroborate it. It cannot possibly be “wrong”. However, the lower ranks, genera and species, were treated by Linnaeus (as by us today) as natural taxa, i.e. as individual entities with an existence independent of our observation. This clash between two principles led to inconsistencies, like the placement of, for example, a species with three stamens (*Galium triandrum*) in Class Tetrandria. Linnaeus’ sense for naturalness simply made him unable to divorce this species from its 4-staminate relatives in the rest of *Galium*.

The truth is, as all botanists know when not making propaganda, that the Sexual System was already becoming obsolete in the early 19th century – certainly to Linnaeus’ delight, had he still been alive. Commonly, the starting point for the quest towards a natural system is taken to be *Genera Plantarum* by Antoine Laurent de Jussieu (1789). That is to grossly underestimate the attempt made by Linnaeus. He considered the search for a natural system an important undertaking, and in *Systema Naturae* (1758) he lists 58 *Ordines Naturales* in the Plant Kingdom. A majority of these we still recognize today, as families, subfamilies or orders. The treatment by de Jussieu is much more elaborate (it is a complete classification down to the level of genus), but its theoretical foundation is not stronger. It is interesting to note that de Jussieu actually did not believe his own system to be “true”. He considered the pattern of life to form a continuum, which could not possibly be reflected by a hierarchical system of groups within groups.

During the 18th century, a continuum-view of the order of nature was widespread – from Buffon to de Jussieu and Lamarck – and did not completely give way to the “Linnaean” paradigm of an inclusive hierarchy until A. P. de Candolle.

Apart from that, the search for the natural system has been a story of continuous improvement from the time of Linnaeus until today, without any drastic paradigmatic shifts as to how the general pattern of plant biodiversity is depicted. However, we have not only perfected our picture of the natural system; since Darwin we also believe we understand its background: taxa are explained by common ancestry.

It is less well known that Linnaeus also thought about the reason for the occurrence of natural taxa beyond the simple “God’s plan”. He came up with the modern explanation that each of his *Ordines Naturales* had a single origin, thus explaining the whole Plant Kingdom with only 58 creations. These 58 originally created plants crossed with each other to form the natural genera, which in turn crossed with each other to form the species. The crossings did not result in intermediates and chaos, because the lineages were held together by the female seed-producing inner tissue, the medulla, which he considered the most important in reproduction, the male part, the bark (which produced the stamens), only adding superficial variation. The idea is consistent with his view of an increasing land mass that could be extrapolated backwards to a quite small and comprehensible Eden where all animals and plants were within reasonable reach and present in a reasonable number when God brought them before Adam so he could name them (1. Moses 2:19). These fantastic speculations nevertheless give the same basic explanation for the occurrence of natural taxa as we do today – common ancestry. To be fair, it was not all speculation: Linnaeus had correctly observed that land is rising in the mid-Swedish coastland with which he was familiar, and his finds of marine fossils high above sea level confirmed his thesis (*Skånska resa*, 1751). He noted that they could not be explained by The Flood.

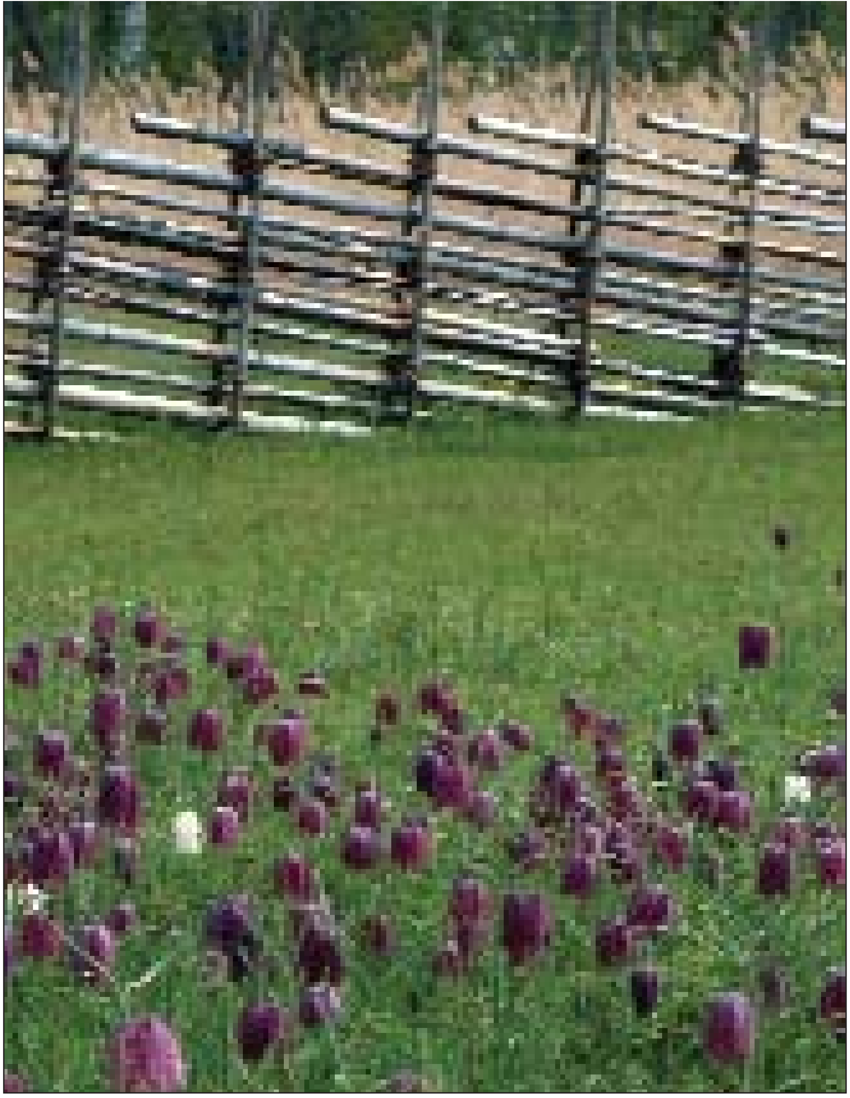
Characterem non constituere genus

Characters do not make the genus

Like many icons, Linnaeus has been subject to (sometimes deliberate) misinterpretation. If you want to make your point, it is of course easier if you can denigrate the Master by turning him into a straw-man of your own making. For instance, Linnaeus has been portrayed as an Aristotelian or an Essentialist, partly because of his love for catchy aphorisms, but perhaps more because it fits a simplified picture of science as a steadily progressing

Above: The Baroque Garden at Uppsala Royal Palace became the new botanic garden in 1790. The Linnaeanum, in the background, which dates back to 1800, will house exhibits and an information centre during the Linnaeus jubilee this year.

Left: What better crown for the Prince of Flowers, than his own *Fumaria nobilis* L. (now *Corydalis nobilis*).



Right: *Fritillaria meleagris* was naturalised in the garden before Linnaeus' time. Here it is naturalised with a traditional Swedish Gärdesgård (a fence made from thin raw spruce (*Picea abies*) stems cut into halves and tied together with tiny spruce-stems or spruce-roots).

voyage from ignorance to understanding. However, traces of Aristotelianism and Essentialism survive alongside other world views in present day scientific papers as well as in the 18th century, even in the same individual.

The truth is that Linnaeus was not overly concerned about ontological questions; his approach is pragmatic. Consequently, there are inconsistencies in his works. Although he used terms like "essential", there is little to suggest that he embraced an Essentialist philosophy. For him these words were equivalent to "taxonomically useful" (see, for example, a brilliant essay by Winsor 2006). You could with equal justification argue that he was an explicit non-Essentialist; the famous phrase above this paragraph is echoed in the modern idea of "taxa as individuals".

Gud skapade världen till en blomstertapet och satte människan däruppå att spatsera, leva och sig förnöja

God made the world a flowering tapestry and put man thereupon to stroll, live and be happy

Linnaeus was a brilliant teacher, as was testified unanimously by many of his pupils. Much of his teaching was in the field, and his *herbationes* took the form of veritable triumphal processions. His known students amount to about 500, many of whom made great careers. No fewer than 74 came from other countries. The same appealing traits – quick intelligence, pedagogical skill, charm and persuasive abilities – earned him benefactors from the early years, from Stobaeus in Lund, Celsius and Rudbeck in Uppsala to Gronovius, Boerhaave, Burman and Clifford in Holland. The rapid spread of his system is explained first and foremost by its clarity and utility, but without well-timed promotion, money and authority provided by senior scientists, its success would have been less certain. Linnaeus made these men immortal in the names of plant genera. What more could anyone ask for?

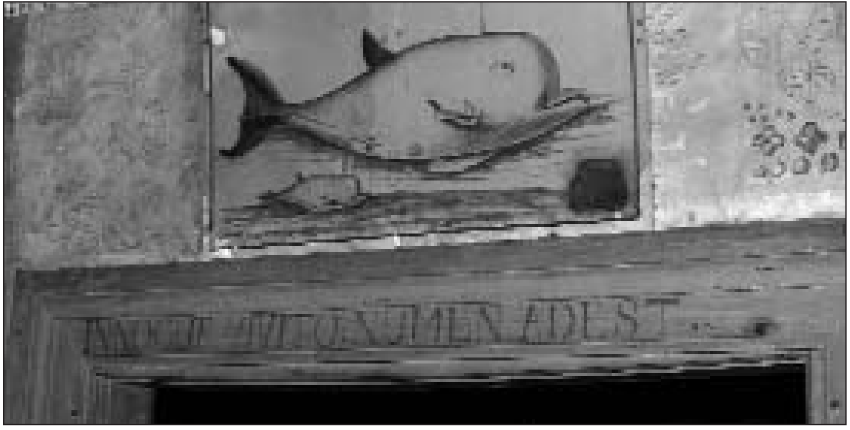
Nu begynte hela marken fägna sig och le, nu kommer Flora och sover hos Febus

Now the earth begins to thrive and smile, *now* Flora comes and sleeps with Phoebus

So starts his Lapland diary. It shows a side of Linnaeus that is very important for his status as a national Swedish monument - his personal and poetic prose, full of love and amazement and yet with remarkable descriptive economy. There are few 18th-century Swedes who can still be read with pleasure, but Linnaeus can. Consequently, his travelogues and other works in Swedish are time and again printed in new editions and read by new generations. Unfortunately, few have been translated into other languages.

In Latin, his language is personal and efficient, not only in the telegrammatic staccato of works such as *Species Plantarum*. He tells us that the ideal scientific prose (such as his own) should have a clear style with short and precise words and without tautology, and that such writing is easier and more entertaining to read than one that is needlessly embroidered. This recommendation still holds.

Right: Linnaeus' house in Linnaeus' Garden was turned into a museum in 1937. In the foreground *Corydalis nobilis* still thrives. It was introduced in 1765 and Linnaeus predicted it would have a grand future as an ornamental. The Linnaeus Garden had been abandoned by the end of the 18th century but was restored in 1920.



Left: The picture of the whale (with young), above the door to his bedroom at Hammarby has a proverb which reminds us of God's omnipresence *Innocue vivito: numen adest* (lead a righteous life - God is everywhere).

Homo, nosce te ipse
Homo, know thyself

Linnaeus is the authority for *Homo sapiens*. In *Systema Naturae* Linnaeus "describes" *Homo sapiens* with the above profound phrase, taken from the inscription on the Delphi temple to Apollo (Gr: *gnothi seauton*) - which gives food for thought for the spiritually inclined, not least today with the revival of the original gnostic Christianity. Linnaeus himself was, as is well known, deeply religious and rarely missed a sermon if he could avoid it. He knew the Old Testament and the Apocrypha well, and frequently alluded to them in his writings. References to the Gospels or to Jesus are wanting. He thinks that we have been put on Earth to praise the blessed creation of the Lord, and this is our Paradise. He did not seem to entertain the idea of a life after death. Linnaeus' God is not only the Creator, he is also the Nemesis, and it follows that sinners are punished in this life; *innocue vivito – numen adest* (lead a righteous life – God is everywhere). Much of his religious and ethical speculations were made available only long after his death, when a collection of notes to his son was published as "Nemesis Divina". Here we are able to see the dark aspects of Linnaeus, and it refutes the criticism that he was uninterested in the social and political arena.

But did he "know" himself? As W. T. Stearn points out (1971), Linnaeus wrote his autobiography five times, and was obviously the human being he himself had studied most closely, and so is the natural choice of type specimen for the species name *Homo sapiens*. An additional guideline for the choice of Linnaean types is that the chosen element should conform to the original description accompanying the name.

Botanic gardens and *Linnaeus2007*

Hortus Upsaliensis (now Linnaeus' Garden), laid out in 1655 by Olof Rudbeck the Elder, was greatly transformed and enriched by Linnaeus. It was essential for his teaching, and important for his botanical works. His demonstrations in the garden were extremely popular, and could attract half the students at the University (which seriously upset envious professors whose students did not attend their lectures). Not only are there numerous references to "HU" in his herbarium, books and letters, it is also indirectly obvious how often he owes his ideas and conclusions to observations in the garden.

This is no less relevant today. As a systematist, I am grateful to botanic gardens for the opportunity to study my plants throughout their life cycle, thus gaining knowledge unavailable from herbarium specimens or restricted field studies. The potential for new discoveries based on botanic garden material in areas unrelated to pure botany – biotechnology, chemistry, and so on – is underexploited. This needs to be stressed to balance the current somewhat one-sided message that the main justification for botanic gardens is plant conservation. Sadly (as I consider conservation important), I cannot credit Linnaeus with much insight in the latter field, although he did emphasise the significance of botanic gardens for *education* in a broad sense. However, his naming system has greatly facilitated communication between botanists working in botanic gardens all over the world.

It is 300 years since Carl Linnaeus was born "when the cuckoo was announcing the imminence of summer". In Sweden, Uppsala University, the Royal Swedish Academy of Sciences and the Swedish Linnean Society, and others, are collaborating to highlight *Linnaeus2007*. The objective is to stimulate interest in natural science among the young, where there has been a serious decline in the last decade. The Tercentenary has also prompted a general evaluation of Linnaean material. Events, exhibitions, flower shows, tours and festivities are planned all over Sweden, especially in Uppsala and indeed in several other countries.

Information can be sought on www.uu.se/linne2007/, www.linnaeus.uu.se and www.botan.uu.se. If you have not made a pilgrimage to these revered sites, this is the time to come. I would like to welcome you to Linnaeus' Garden, Linnaeus' Garden at Hammarby and Uppsala Botanic Garden this summer!

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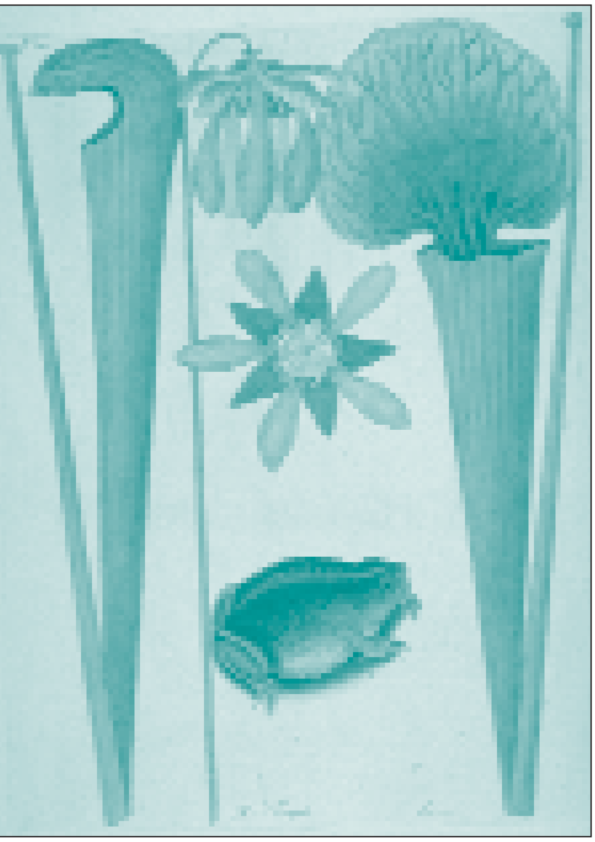
Linnaean names and their types: a permanent reference point



Above: The type of Sarracenia flava L. is a Mark Catesby illustration. © NHM

Right: The type of Sagittaria lancifolia L. in Linnaeus' herbarium in London. © Linnean Society of London (LINN)

It is essential for anyone studying and working with living organisms to know their correct scientific names. As Peter Raven of Missouri Botanical Garden (in Jarvis, 2007) writes, "Precise names are important because all of our food and most of our medicines come from plants, either directly or indirectly; the ecosystems that they dominate protect our topsoil and regulate our watersheds, determine local climate, and absorb greenhouse gases and other pollutants. Moreover, we are just beginning to understand plants properly at a molecular and cellular level, applications that demand precise ways of naming and understanding them."

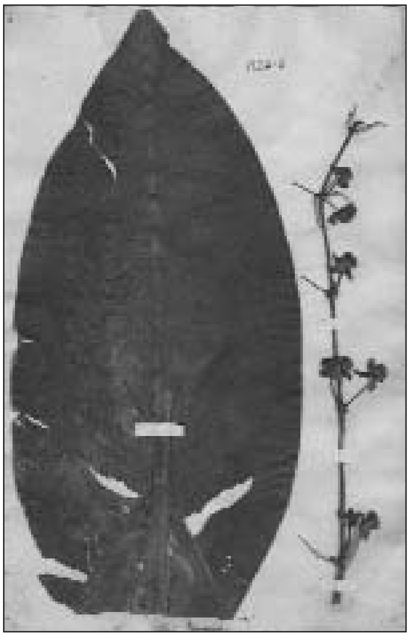
In day-to-day life, using common or vernacular names to communicate about organisms can often work well enough between people who share the same language, and who are familiar with the same geographical area.

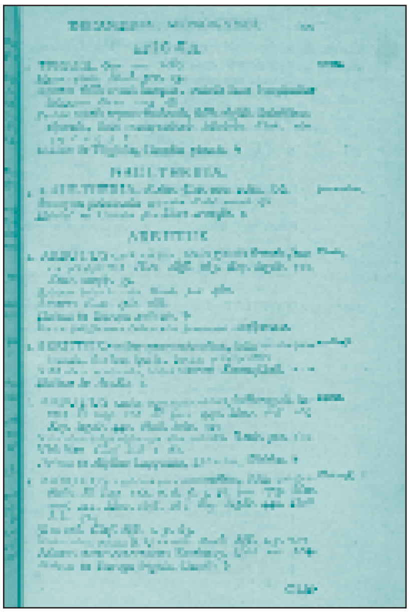
However, there can be pitfalls. Use of the name "bluebell" in the United Kingdom can, depending on area, risk confusing the blue-flowered bulbous plant of deciduous woods (*Hyacinthoides non-scripta* (L.) Rothm.) with the low-growing bellflower of open ground (*Campanula rotundifolia* L.). Horticulturally interesting groups of plants, too, provide scope for confusion, with the vernacular "geranium" referring to a member of the genus *Pelargonium* (not to the crane's-bill genus, *Geranium*), and "veronica" used to indicate species belonging to the genus *Hebe* (rather than the speedwell genus, *Veronica*).

These problems are only compounded when many different languages are involved, over a wide geographical area. Hence the immense utility of the binomial naming system introduced for plants by the Swedish physician Carl Linnaeus (1707-1778) in 1753. Still in use today, it provides a fundamental framework for the scientific naming of plants. Consisting of a genus name (e.g. *Ginkgo*) and a species name (e.g. *biloba*) in Latin form, these binomials are used according to an internationally agreed set of rules which are laid out in the International Code of Botanical Nomenclature (ICBN) (McNeill & al. 2006). As McNeill & Turland write in the Preface to the ICBN, "Unambiguous names for organisms are essential for effective scientific communication; names can only be unambiguous if there are internationally accepted rules governing their formation and use".

How binomials arose

Before Linnaeus' introduction of binomials, organisms were given descriptive Latin names, which not only acted as a tag, but also described their features. These names were initially fairly brief, but, as more species became known, names became longer and more difficult to remember.





For example, what was known as *Arbutus folio serrato* (Arbutus with saw-toothed leaves) in 1623 had become *Arbutus caule erecto, foliis glabris serratis, baccis polyspermis* (Arbutus with upright stems, hairless, saw-toothed leaves and many-seeded berries) 130 years later. Linnaeus' corresponding binomial (now cited followed by an abbreviation of the author's name, in this case "L.") was *Arbutus unedo* L. This idea proved so simple and useful that others started to coin their own names for species they were describing for the first time. By the 1770s, most biologists had adopted them and the majority are still in use today. Linnaeus named more than 9,000 plants, including most major crop and medicinal plants and many commercially important ornamentals, as well as numerous common tropical species, and most of the common wild plants of Europe. His landmark work, *Species Plantarum* (1753), marks the starting point for the use of these names.

The Type Method

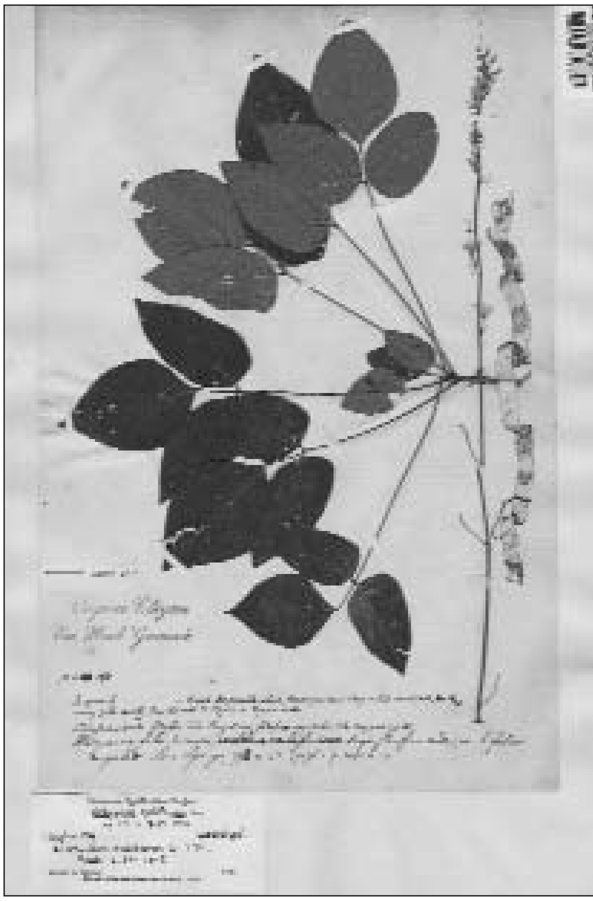
Linnaeus (1751) himself wrote in *Philosophia Botanica*, "If you do not know the names of things, the knowledge of them is lost too". Today, stability in plant naming is established by what is known as the type method – when a new species is identified, a dried, pressed specimen of the plant, demonstrating its typical characters, is preserved and designated as the "type" of the name that is published for it. The type specimen provides a permanent reference point for everyone and establishes the name's use. Any name can be checked against its type specimen, and if two names are found to apply to the same species, the earlier of them becomes the correct name to use. Although the type system developed gradually from the middle of the 19th century, it was not formally adopted in a Code of Botanical Nomenclature until 1930.

The **Linnaean Plant Name Typification Project**, based at the Natural History Museum in London, has been working to establish type specimens retroactively for the 9,000 plant names of species (and a small number of varieties) coined by Linnaeus, so that the names can be correctly used. When the Project was set up in 1981, information on Linnaean typifications was widely scattered and it was not known how many names had been typified. Many choices (typifications) had been published piecemeal over the years, and in a wide variety of publications, so a major part of the Project's work has involved making a huge literature search in order to draw this information together.

Linnaeus and his sources of information

Carl Linnaeus was a born encyclopaedist in an age that fostered and encouraged the methodical cataloguing of everything, from the organisms that make up the natural world to the listing and defining of words themselves – the 18th century saw the publication of the first dictionaries and encylopaedias. It was also a golden age of exploration – when James Cook departed on his epic voyage around the world in 1768, on board was the young Daniel Solander, a favourite pupil of Linnaeus. Inspired by Linnaeus' teaching, many of his students (known as the "Apostles") set off on journeys to America, to Egypt, to India and Japan, collecting plants and seeds to take back to the great master in Sweden.

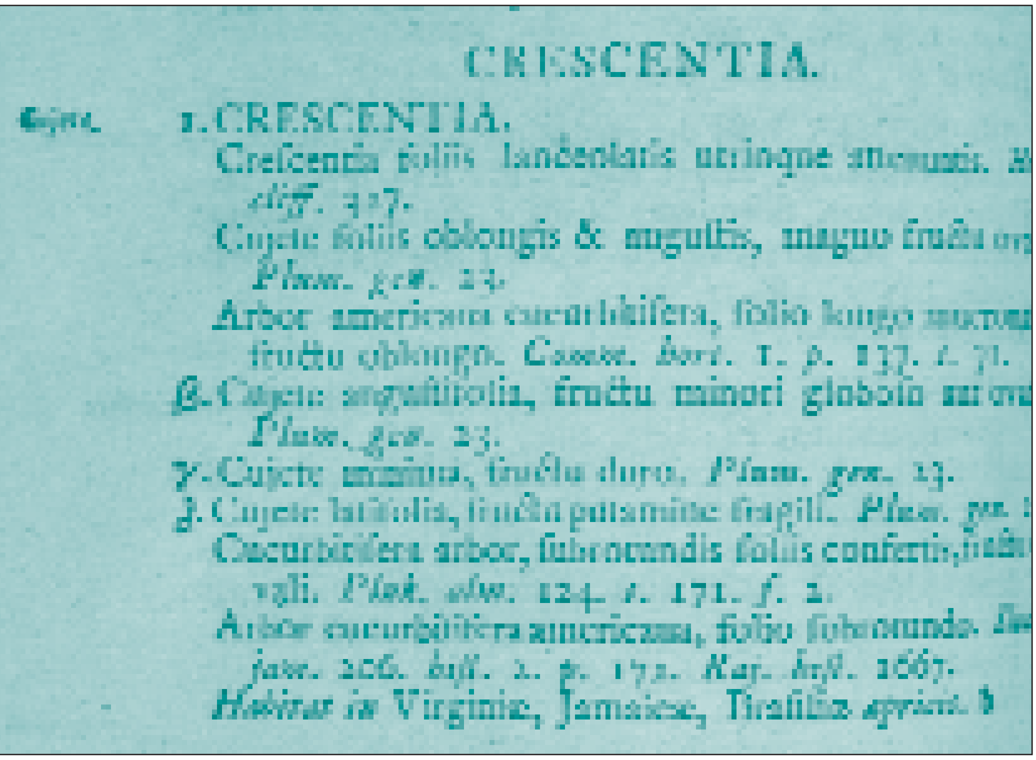
Left: Linnaeus' *Species Plantarum* (1753) showing the account of *Arbutus* with the species names (*Unedo, acadiensis, alpina* and *Uva-ursi*) placed in the margin. © NHM



Linnaeus' own travels were more modest. He knew his native Sweden well, and lived in the Netherlands for three years, making short trips to Germany, Paris and England during that time. However, wherever he was, he continued to observe and list and describe everything he saw, not just plants but also mammals, birds, fishes and minerals, as well as people and their habits and customs. He also examined the herbaria of other collectors, such as the North American plants collected by John Clayton and in the possession of Linnaeus' friend

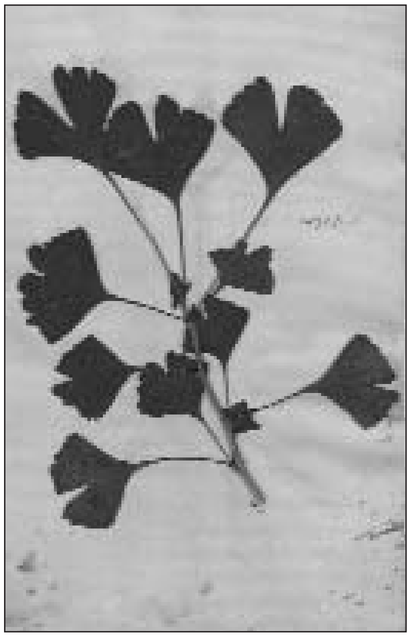
Above: The type of *Alyssoides utriculata* (L.) Medik. in Linnaeus' herbarium. © LINN

Above centre: The type of *Desmodium nudiflorum* (L.) DC. is a specimen collected by John Clayton in Virginia. © NHM


CRESCENTIA.

Cujete. 1. CRESCENTIA.
Crescentia foliis lanceolatis utrinque attenuatis. H
cliff. 317.
Cujete foliis oblongis & angustis, magno fructu ov
Plum. gen. 23.
Arbor americana cucurbitifera, folio longo mucron
fructu oblongo. Comm. hort. 1. p. 137. t. 71.
β. Cujete angustifolia, fructu minori globoso
Plum. gen. 23.
γ. Cujete minima, fructu duro. Plum. gen. 23.
δ. Cujete latifolia, fructu putamine fragili. Plum. gen.
Cucurbitifera arbor, subrotundis foliis confertis, fructu
vali. Pluk. alm. 124. t. 171. f. 2.
Arbor cucurbitifera americana, folio subrotundo. Sl.
Jam. 206. hist. 2. p. 173. Raj. hist. 1667.
Habitat in Virginia, Jamaica, Tirasilia apricis. ♄

Above: Linnaeus' original account of *Crescentia cujete* L. (1753). No specimens were cited but there are references to his earlier *Hortus Cliffortianus* (1738), and works by others including Commelin, Plumier, Plukenet and Sloane. © NHM



Right: The type of *Ginkgo biloba* L., the maidenhair tree, in Linnaeus' herbarium. The British horticulturalist James Gordon sent living material to Linnaeus in 1769. © LINN

Johan Gronovius in Leiden, and the Ceylon collections made by Paul Hermann 70 years earlier. By 1746 Linnaeus had made a start on the work which is perhaps his most well-known, *Species Plantarum*. Then aged 39, he had been collecting plants and recording them all his life and had written guides to the floras of Lapland and Sweden as well as books on his philosophical approach to botany and accounts of the plants, native and non-native, to be found on estates such as the Hartekamp in the Netherlands, home to the keen plantsman George Clifford, which contained such exotics as the banana.

In other words, when Linnaeus described and classified plants, he was drawing on a very wide range of sources of information, and his notion of what constituted a species could be very broad, taking in under a single name what we would regard today as a number of different species. Because the 18th-century Swede did not work according to our modern type concept, only very rarely can we be sure that he based his concept of a particular species on a single specimen (a "holotype"). For names other than these, it is necessary to choose a type (a "lectotype") from among the specimens and illustrations that Linnaeus used in arriving at his concept of the species in question. A good comprehension of his working methods is essential for anyone undertaking the task of analysing Linnaean names and designating types.

The literature survey revealed that around a quarter of all Linnaean names had been the subject of typification, but it was necessary to establish whether these type statements had been validly chosen, and where more than one type statement existed, which one should take priority. Before being accepted, each typification statement was carefully assessed. It was important to ensure that, for example, the chosen material was not collected after Linnaeus described the name (in which case it clearly could not have contributed to forming his concept of the species he was naming). For instance, in naming the the small tropical tree, *Crescentia cujete* L. (calabash) in 1753, Linnaeus used as his sources a number of published descriptions and illustrations from other authors (including one that is identifiable as an entirely different species, *Amphitecna latifolia* (Mill.) Gentry). However, Linnaeus could not have used the specimen (now in Linnaeus' own herbarium at the Linnean Society of London (LINN)) that Gentry (1974: 831) chose as the lectotype. This is because the material is marked as having come from Patrick Browne (author of *The Civil and Natural History of Jamaica*, published in 1756) and we know from his letters that Linnaeus did not acquire Browne's specimens until 1758, five years after *Crescentia cujete* was published. It follows that Browne's specimen was not eligible to be selected as the lectotype, so the next choice (made by Wijnands 1983), of an illustration published by the English apothecary, Leonard Plukenet and cited by Linnaeus, is the lectotype of this name.

Designating new types

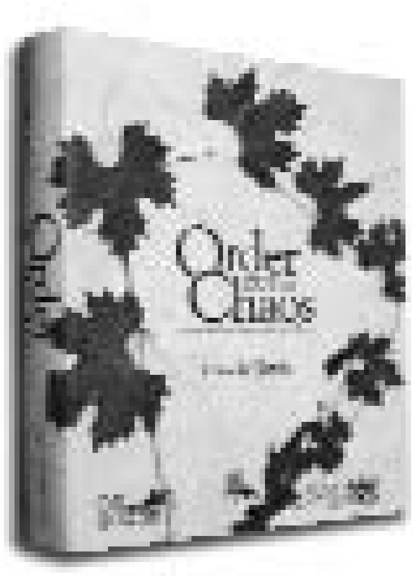
For the many names that, at the start of the Project, did not have a designated type, studies were made of the preserved specimens and illustrations that Linnaeus used. Working in close collaboration with many hundreds of specialists in different plant groups from around the world, we have designated type specimens for well over two thousand more of his names. In concentrating on some of the larger flowering plant groups (e.g. the families Apiaceae, Asteraceae, Boraginaceae, Brassicaceae, Caryophyllaceae, Convolvulaceae, Cyperaceae, Ericaceae, Fabaceae, Lamiaceae, Orchidaceae, Poaceae, Ranunculaceae and Rosaceae), type choices have been published by nearly 200 specialists from 34 different countries. In addition, because Linnaean binomials are also the earliest for plant groups such as the ferns and fern-allies, liverworts, lichens, some algae and some fungi, we have also published detailed accounts of Linnaeus' lichen (see Jørgensen *et al*. 1994) and algal (see Spencer *et al*. in press) names.

Linnaeus often drew his knowledge of species, particularly from tropical areas, from descriptions and illustrations (for specimens were simply unavailable). As a consequence, about 25 per cent of Linnaean names have illustrations as their lectotypes. They include, for example, threatened species such as *Dracaena draco* (L.) L. (dragon tree), *Prunus lusitanicus* L. subsp. *lusitanicus* (*palo de loro*), *Cedrela odorata* L. (Central American cedar) and *Santalum album* L. (sandalwood).

The majority, however, do have herbarium specimens as their types. Although many of these are found in Linnaeus' own herbarium (LINN), e.g. *Datisca cannabina* L. (false hemp), *Ginkgo biloba* L. (maidenhair tree), *Isoplexis* (*Digitalis*) *canariensis* (L.) Loud. (*cresto de gallo*) and *Drosera rotundifolia* L. (round-leaved sundew), others can be found in additional herbaria that were studied by Linnaeus. Examples include the type of the night-flowering cactus, *Selenicereus grandiflorus* (L.) Britton & Rose in the herbarium of the Anglo-Dutch banker and plantsman, George Clifford, now at the Natural History Museum in London (BM), and those of *Mandragora officinalis* L. (mandrake) and *Parnassia palustris* L. (Grass of Parnassus), which are in Joachim Burser's herbarium in Uppsala (UPS). Some, such as *Epifagus virginiana* (L.) W. Bart. (beechdrops) are in John Clayton's herbarium of Virginian plants (BM), while others, e.g. *Pavetta indica* L. can be found in Paul Hermann's Ceylon herbarium (BM).

Project Publications

Much of the information we have assembled during the Project is accessible online via the Natural History Museum website (http://www.nhm.ac.uk/research-curation/projects/linnaean-typification), and May 2007 will see the publication of a major book, *Order out of Chaos*, a comprehensive, 1,200 page guide to Linnaean Plant Names and their types. A co-publication between the Linnean Society of London and the Natural History Museum, this contains not only a detailed catalogue of all Linnaean binomials for plants, it also details Linnaeus' own publications and those of other botanists that contributed to his understanding of plants. Significant plant collectors are enumerated, with examples of important specimens from Linnaeus', and other, herbaria. Its publication coincides with the tercentenary of Linnaeus' birth. A valuable contribution to the botanical literature, it will be of use to students, botanists, historians and conservationists worldwide, and another aid to nomenclatural stability. For further information, see *Book notices and taxonomic resources*.



Acknowledgements

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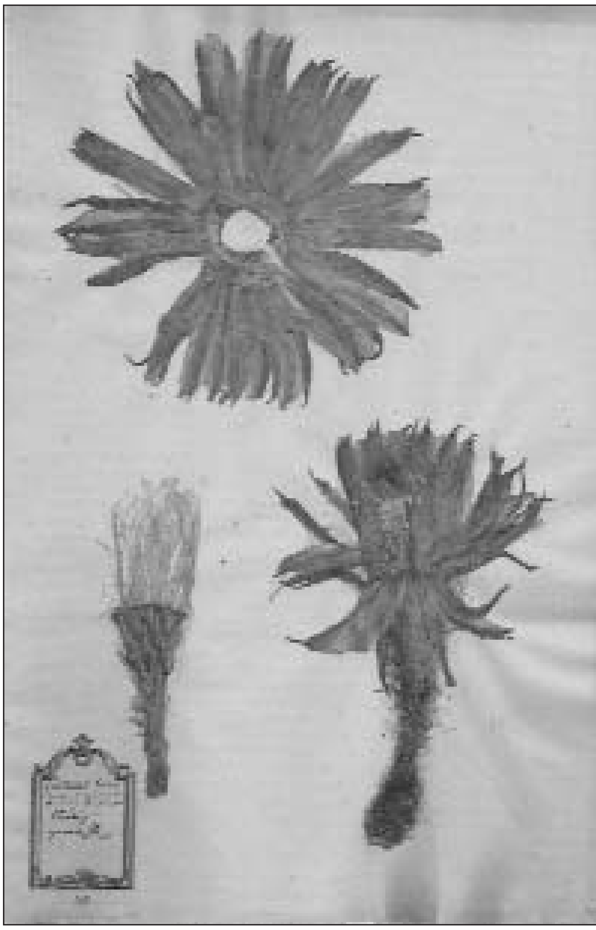
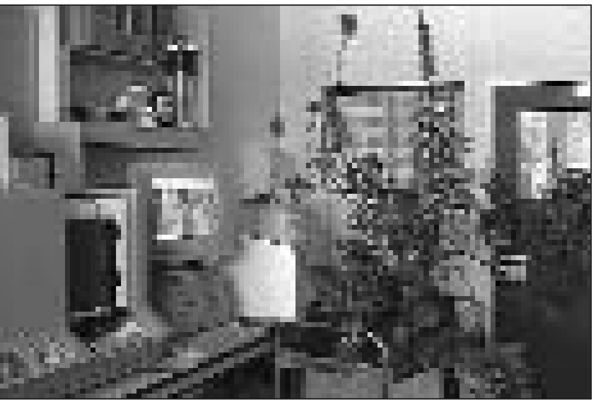
Left: Caption: Jacket of "Order out of Chaos" by Charlie Jarvis. © LINN and NHM



Below: The type of the cactus *Selenicereus grandiflorus* (L.) Britton & Rose is in the herbarium of the Anglo-Dutch horticulturalist, George Clifford. © NHM

Author: Vernon Heywood

Taxonomy and plant conservation



Above: An ABI Prism automated DNA sequencer showing trnL-F chloroplast DNA sequences for the endangered *Isoplexis (Digitalis) chalcantha* and relatives. (Photo: A. Culham)

Human society is dependent for survival on our performing daily, countless acts of classification, both of the natural and physical world. As humans we are primarily dependent on visual inputs in our classificatory activities, in finding the way around our environment and choosing which parts of biological diversity suit our particular purpose, which explains the morphological bias in biological classification. A recent editorial in Science (Wheeler *et al*. 2004) noted that "Society has a growing need for credible taxonomic information in order to allow us to conserve, manage, understand, and enjoy the natural world", yet there is widespread mistrust of the activities of taxonomists, and the state, aims, theory and practice of classification and taxonomy are the subject of almost endless debate (e.g. Wortley *et al*. 2002; Vane-Wright 2003). Much of the debate revolves around two fundamental issues - the relationship between taxonomic and phylogenetic measures of diversity (Humphries 2006) and between taxonomy and phylogenetic reconstruction (phylogenetic systematics), and the nature and delimitation of species. Added to this, another recent debate concerns the way in which taxonomists "do business", as Vane-Wright (2003) terms it.

Some aspects of taxonomy and systematics, notably our knowledge of the relationships of the flowering plants, have undergone dramatic developments in recent years, as the result of the accumulation and analysis of molecular and phenetic data sets using cladistic and other methods (Soltis *et al*. 2005). This has led to drastic changes in the circumscription of some well known families and the merger of others. Thus, the inclusion of the duckweeds, Lemnaceae, in the Araceae and of teak (*Tectona*) in a recircumscribed Lamiaceae may be disconcerting for some.

The realignment of families suggested as a result of molecular phylogenetic studies may be of considerable interest in comparing the floras or faunas of different areas and in determining their phyletic distinctiveness, but in practice it seldom affects decisions on what to conserve, where to conserve or how to conserve. Of course, the same is true of much of the work published in journals of conservation biology: it rarely informs the decisions of, say, the protected area manager. On the other hand, the use of DNA sequence and finger-printing data can be incorporated along with morphological data at the species and infraspecific level in biodiversity assessment and conservation (Caesar *et al*. 2006; Culham 2006), for example, in determining more accurately which populations of species to conserve. Although there are now many examples in the literature, it will be some time before such procedures are routinely applied. Another approach, known as DNA barcoding, has been heralded by some as a panacea for the problem of accurate species identification in the field, but the application is dependent on the basic classification of the groups concerned being available and the building up of a database of the sequence data of correctly identified samples of known taxa against which new samples can be compared.

A parallel development to the molecular advances has been the revolution in computer capacity and the development of electronic systems for databases and information systems - biodiversity informatics - which have facilitated the availability, storage, access and exchange of taxonomic and associated data.

In 2007 we shall be celebrating the 300th anniversary of the birth of Linnaeus, who laid the foundations for many of today's taxonomic and nomenclatural procedures, although now greatly modified and with a totally different scientific philosophy. It is remarkable that despite the major molecular and bioinformatic developments, the procedures of basic taxonomy, such as field work, floristics, herbarium studies and essentially morphological description and key construction, with the results published in stylised products such as Floras, remain in use. In fact it was such front-line work of morphologically based taxonomy carried out over the past two to three centuries that provided the basis and context that made the success of molecular systematics possible and allowed the results to be communicated effectively, at least for higher organisms.

Concern has been expressed that molecular systematics and biodiversity informatics have tended to draw effort away from traditional taxonomic work and reduce the number of students who are willing to work in this area, and the dying out of naturalists. This could have very serious consequences for biodiversity conservation. It is notable that in the *Global Strategy for Plant Conservation* adopted by the Parties to the Convention on Biological Diversity (CBD), the emphasis is on issues such as inventory, training and capacity building, not on research.

The social dimensions of taxonomy

Should taxonomists be concerned about the the practical needs of the various user groups of taxonomy? I have myself always insisted that one of the aims of taxonomy is to provide a service to the rest of biology, while others regard such a requirement as superfluous. For example, in presenting what I termed a new paradigm for taxonomy (Heywood 2001), I suggested that, *inter alia*, it should be socially responsive to the needs of society and be both scientifically sound and practicable. As I noted, "No longer can taxonomists judge the value of their work just by the reactions of their taxonomic peers. As with other branches of science in this post-modernist world, a range of societal needs has to be met". This evoked the response from Schaal & Leverich (2001) that "We do not need to justify our fields by making tenuous connections to practical issues" and "Early biosystematists would be very surprised at this turn to social relevancy, since much of our discipline's research has traditionally been in the pursuit of pure science". Such a response contrasts with the theme of the Third BioNET-INTERNATIONAL Global Taxonomy Workshop (3GTW) held in Pretoria, South Africa: *Partnerships for Demand-Driven Taxonomic Capacity Building*.

Of course, no-one would argue that the pursuit of science should be constrained by the need to be practical but, from its very origins, taxonomy has been a means of communicating information about the identity and also, in folk classifications, the properties of organisms (Heywood 1985), so by its very nature it comprises both purely scientific and practical aspects. This can lead to conflicts where the science leads to results that may be onerous to apply in practice, such as the acceptance of groups that are not morphologically recognizable. Likewise, the application of certain species' concepts and definitions where the criteria cannot readily be met or would lead to consequences unacceptable to many, such as the multiplication of the number of species recognized, is clearly limited. This is not a new situation if one recalls the decades when the biological species concept dominated taxonomic thinking, although a majority of plant taxonomists did not in practice follow it (even though many claimed to do so!). This gap between theory and practice was what I termed double-think - doing one thing while professing to be doing something else (Heywood 1983).

Species have to be used by a wide range of interest groups including biodiversity and conservation practitioners and as Cracraft (2000) uncompromisingly states:
"… we should be careful in seeking justification for a particular species concept if it cannot embrace the vagaries of real-world data with aplomb. No hemming. No hawing. It must work. This does not mean that we should abandon theory and philosophy, ontology and epistemology, individuality, reality, pattern versus process, and all the other notions that orbit around discussions of species concepts. But we must keep our feet firmly planted on the ground".

Taxonomy, systematics and biodiversity conservation

Despite the disagreements about its nature and aims and the difficulties of defining species and other taxa, taxonomy has a pivotal role to play in the assessment and conservation of biological diversity and is in fact one of the main disciplines that led to its emergence as a concept. Taxonomic diversity is one of the main components of biological diversity and the species is one of the most used units to measure it, although there are of course many other measures that can be applied.

Of course, it does not help that several different species concepts - morphological/phenetic, biological, evolutionary, phylogenetic - are currently in use by taxonomists and what is more, there is little likelihood of reaching agreement on a unified concept in the foreseeable future (Cracraft 2000). Because different species are not equivalent in terms of their evolutionary history, species diversity is regarded as insufficient when attempting to maximize the amount of phylogenetic diversity in the selection of protected areas, and so-called complementarity-based methods have been applied in a number of instances to achieve this (Rodrigues & Gaston 2002).

A recent editorial in *Nature* (29 September 2005), entitled "Bridging the gulf", calls for ecologists and conservationists to work more closely with economists. Equally, efforts should also be made to bridge the gulf between taxonomists, conservation biologists and practitioners. It seems surprising that the problems of conservation have been largely regarded as the concern of the ecologist (and subsequently of the conservation biologist), while the taxonomist's role has remained somewhat vague, despite being key for our knowledge of the environment (Heywood 1971, 1973b). Both groups need to cooperate more closely: on the one hand, taxonomists should consider how they might contribute more effectively to conservation planning and on the other hand, conservationists should be prepared to familiarize themselves with the nature of the taxonomic process, its advantages and limitations. It is often, incorrectly, assumed that taxonomic knowledge will be available or at least can be produced on demand for all groups that they work on. Recommendations for closer cooperation between taxonomists and conservationists have been made by

Right: The threatened bromeliad *Vriesea botafogensis* growing in the wild in Brazil. Although formerly regarded as a synonym of *V. saundersii* it is now again recognized as a distinct species. (Photo: Claudio Ricardo Peixoto França)

Golding & Timberlake (2003), Heywood (2003a), Lowry & Smith (2003), Leadlay and Jury (2006) and others.

It is not normally realized, especially by decision makers, just how incomplete is the inventory and state of knowledge for most groups of organisms and that the vast majority of species described in the literature are "herbarium" or "museum" species, based on a small number of often unrepresentative samples (often just the original collection), about which we only know a few morphological facts, and their existence as coherent, repeatable population-based phenomena is only suppositional (Heywood, 1988: 48). Completion of the inventory has been given high priority by the CBD and the *Global Strategy for Plant Conservation* gives as Target 1 for the year 2010: *A widely accessible working list of known plant species, as a step towards a complete world flora*. Even for such well-studied groups as the Flowering Plants, little is known of the majority of species apart from some basic facts of their morphology and localization: for most of them, their demography, reproductive biology, breeding system, genetic variability and so on is unstudied. Yet the fact is that for many purposes, conservationists require information beyond identification and description of species such as data on breeding and movement of species. This has led to calls for taxonomists to take into account the needs of conservation in designing Floras and other taxonomic outputs. Golding & Smith (2001), for example, note that Flora volumes are a prime resource for the preparation of Red Data Books and are relied upon, along with herbarium specimens, as a source of data for this purpose, especially in many developing countries. They point out that Floras (and for animals, Faunas) are often used to make best estimates and inferences regarding the distribution ranges of the taxa concerned and their degree of rarity. As Floras were not designed for this purpose, Golding and Smith suggest a 13-point strategy to facilitate this purpose, including:

- Stating if the plant is only known from the type specimen
- Citing as many collections/localities as possible so as to give a general indication of the frequency of the taxon
- Citing endemic status within the area concerned
- Giving as much information as possible of the distribution and habitat data, especially in the case of endemics
- Citing collections from National Parks if possible

Whatever reservations one may have about such a strategy, the point made is a valid one that taxonomists should consult more often with conservation colleagues about the ways in which they (and their products) might be made more useful for a range of conservation purposes.

A particular case where taxonomic tools such as Floras and Faunas are critical for conservation is in the preparation of lists of threatened species (Red Data Lists or Red Books). In fact, it is the lack of taxonomic information that has been largely responsible for the dearth of threat assessments for species in tropical countries. A much closer alliance should be established between Red List authorities and taxonomists and I have suggested (Heywood 2003b) that consideration should be given to nominating a Taxonomic Focal Point or Centre in countries where Standard Floras and identification manuals are outdated or non-existent.

While much effort has been made in recent years to improve the criteria for the definition of the IUCN categories of threat, little attention has been paid to the problems posed by the different species concepts used by different authors, let alone the major development in taxonomic thinking in recent decades. This need is well put by Cracraft (2000), who reminds us that "systematics is the fundamental science of biodiversity … and species are arguably systematics' elementary particles, and there are practical consequences to every species concept if those elementary particles are not discovered and understood properly".

The consequences of inaccurate taxonomy can be serious or even fatal. Accurate taxonomic information is an essential underpinning for much work in biological conservation. Correct identification of species is an essential step in many conservation strategies as it provides not only the key to the associated literature but establishes the basis for repeatability (Miller et al. 1989). The value of accessions in botanic gardens, for example, depends critically on their correct identification if they are to be used as conservation resources or as reference material, a requirement not, alas, met by many collections.

The use of classifications in Floras and handbooks is bedevilled by problems of synonymy which can be confusing to many users. It is simply an historical fact that the same species or other taxon can have several to many synonyms. Failure to understand the significance of synonymy can have unexpectedly serious consequences.

The potentially serious consequences of mistaken designation of synonyms at the specific and infraspecific level are pointed out by Leme (2003), who notes that they can lead to "nominal extinction" through their disappearance from official endangered species lists and inclusion in ecological or floristic studies, so that they do not benefit from conservation action. For example, the bromeliad *Vriesea botafogensis* Mez., which is endemic to the cities of Niterói and Rio de Janeiro (Brazil) and threatened with extinction by human activities, was reduced to a synonym of another species endemic to Rio de Janeiro, *V. saundersii* (Carrière) Mez in 1955 and thus could have become extinct by nomenclaturally caused neglect until it was restored as a separate species in 1994.
Synonymy is a major deterrent to the use of taxonomic data and this is likely to continue for many years until adequate synonymic checklists are available for all countries or regions. The increasing use of electronic databases and information systems is likely to

provide some relief, in that information on a taxon may be achieved by entering a variety of names other than the currently accepted or "correct" one under the Code. Eventually, alternative classifications will be offered so that a species will no longer necessarily belong to just one higher taxon in any classificatory system.

Conclusion

It is incontestable that the conservation and sustainable use of biodiversity requires accurate taxonomic knowledge of its components. However, taxonomic data alone will not of course lead to effective action: conservation also depends on multidisciplinary cooperation that includes taxonomy, and political will. While this may seem self-evident, it arises as part of the ongoing debate as to whether one ought to give priority to conserving ecosystems or species, not that they are alternatives. For example, Brooks *et al*. (2004) argue for species data being a better option for planning protected areas than relying on broad-scale attributes, a viewpoint vigorously rebuffed by Cowling et al. (2004), who comment that data do not save species. On the other hand, without an accurate knowledge of species, much of conservation will be in the dark.

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Botanical buffet - the importance of living collections for plant systematics

Botanic gardens have plenty of uses, but I want to talk about just one aspect here: how important are the living collections for systematics and taxonomic research? As the head of a major world botanic garden, I often pontificate on the importance of the collection for science. The link to horticulture (and the development and maintenance of cultivars) is relatively easy to explain. The link to conservation is also relatively straightforward (see Makinson 2006), although often overplayed in terms of the *ex situ* importance of the living collection seen by most visitors. But do we need the collection for systematics, for discovering how plants have evolved, their relationships, and how they are best classified? Well, yes we do.

Firstly let me narrow the definition down a little. Prompted by Makinson (2006), I will exclude seedbanks and other forms of storing genetic material (e.g. tissue collections), and discuss only the whole plants that populate our botanic gardens. These are what Makinson calls "whole-plant live collections", and which I will lazily call "living collections". Systematics science and botanic gardens have had a close association since the time of Linnaeus, but why, and is this link still relevant?

I can think of a dozen, somewhat overlapping, reasons why living collections are important for systematics but have grouped them

Right: *Alloxylon pinnatum* at Mount Tomah Botanic Garden, Sydney. (Photo: Botanic Gardens Trust, Jaime Plaza) here into three main areas. These are: the range of material, the value of living material and the access to other information. Hay and Herscovitch (1997) covered some of the same ground in their passionate plea for the responsible sharing of living collections. Like them, I've drawn examples from the science programs at the Botanic Gardens Trust to illustrate my points.

Above: Rock Garden at Mount Tomah Botanic Garden, Sydney featuring proteas. (Photo: Botanic Gardens Trust, Jaime Plaza)

Range of material

A botanic garden collects together plants from many different places and grows them in a relatively contained area (although up to 400 ha in the case of our Mount Annan Botanic Garden, or 900 ha for the Xishuangbanna Tropical Botanical Garden in southern China…). This provides easy access to a wide range of living plants and efficiencies in sampling. So our systematist can observe and sample a great diversity of plants in the one place. This saves the costs of organizing extensive field trips which may or may not be successful.

Our understanding of plant diversity is organised around plant families. Over 80 per cent of the approximately 450 families are easy to recognize and are, for the most part, thought to be monophyletic. The Angiosperm Phylogeny Group has rebuilt the evolutionary tree for flowering plants from molecular data (Chase *et al*. 1993) which is helping us understand the taxonomy of plant families. Almost half of the 499 species sampled in the 1993 paper, representing about 265 families, were from botanic gardens (in later papers the percentage was even higher, driven partly by Mark Chase's move to the Royal Botanic Gardens, Kew). It would have taken many more years to complete and we would have a much poorer knowledge of the phylogeny of angiosperms today if the rich living collections held by botanic gardens around the world, including those in Sydney, were not available for this research.

Left: Bromeliads in the Tropical Centre at Royal Botanic Gardens Sydney. (Photo: Botanic Gardens Trust, Jaime Plaza)

Botanic Gardens Trust scientist Peter Weston and his colleagues have published extensively on the phylogeny and biogeography of the iconic southern hemisphere family Proteaceae. For their paper on South African Proteaceae (Barker *et al*. 2002), all but a couple of the 50 species sampled were from botanic gardens in South Africa and Australia - many are rare and difficult to sample in the wild.

Botanic gardens also hold unique collections of species or variants which no longer exist in the wild (e.g. *Sophora toromiro* from Easter Island), or are inaccessible due to political or regulatory constraints.

There is often more variety in botanical material available, particularly at the generic level, in a botanic garden than would be possible to access through even extensive field collecting. A large number of genera can sometimes be sampled in one place. Darren Crayn, a systematist at the Botanic Gardens Trust, made extensive use of the collections held at Marie Selby Botanical Gardens in Florida, when he was working as a post-doc at the Smithsonian Tropical Research Institute in Panama. He identified CAM (crassulacean acid metabolism, usually found in plants living under arid conditions) photosynthesis by measuring C12 to C13 ratios (reflecting the different enzymes used in CAM and C3 photosynthesis, and their different affinities for C13) in 56 of the 57 genera of Bromeliaceae, and 1,873 of the approximately 2,890 species. Crayn found that CAM photosynthesis and the epiphytic habit had evolved several times. At least 90 per cent of the taxa sampled were from living collections (Crayn et al. 2004), so this work was made practically possible by collecting from botanic gardens.

There is also an opportunity cost in not bringing plant material into cultivation. Our systematist can swan along the Amazon or the Roper and collect bits

Right: Proteaceae garden. (Photo: Botanic Gardens Trust, Jaime Plaza)

and pieces of intriguing new species, but we don't know what will be useful in 10 or a 100 years' time. We don't know what bit of the plant might provide useful data once back in the laboratory examining our pickings. We add value by collecting propagation material and maintaining that plant in the living collection. There is a cost, of course, in caring for any plant introduced into a botanic garden, but there is often a greater cost in not introducing it when you have the opportunity…

Value of living material

Many characters, e.g. morphology, chemistry (including genetic markers), chromosomes, and so on, are best examined from living material. It is usually easier to sample in a botanic garden than in the natural habitat and a botanic garden may be able to provide more material than is available in the wild.

In a recent treatment of the waratahs (*Telopea* and its relatives), 14 of the 16 taxa examined were grown in botanic gardens, making it straightforward to assess characters from leaf anatomy and floral development using living material (Weston & Crisp 1994). The results of the analysis supported continental breakup (from Gondwana) and climate change as the key drivers behind the present diversity of waratahs and where they occur in the Southern Hemisphere.

Systematists can observe a plant throughout its life history, seeing features that may not be visible at the time of a field visit (e.g. buds, flowers, fruits…). They can also watch how fruits develop, how a flower opens or even the germination of seed and its early growth. Ken Hill and Lawrie Johnson used seedlings grown at the Royal Botanic Gardens in Sydney to help formulate their incisive views on the classification of Australian eucalypts, including rearrangements to the generic and subgeneric classification (e.g. Hill & Johnson 1995).

Most systematists value living collections as an adjunct to extensive herbarium collections. A plant that is taken directly from the wild and preserved is a true representative of the taxon and will provide information to many generations of taxonomists. However, examination of a living plant helps to avoid misinterpretation and misunderstanding of the morphology. Botanic Gardens Trust Honorary Associate, Alistair Hay, grew and studied extensive collections of aroids as part of his detailed monograph of a genus of the Araceae (e.g. Hay & Yuzammi 2000). The accuracy of the taxonomy relied on detailed observations on developing flowers, including their colour, odour and pollen shed. Inflorescences are difficult to find in the field, and a single herbarium collection will rarely include all stages of development.

It is usually easier to sample in a botanic garden than in the natural habitat, the hard work having been done already by the original collector. Our systematist can choose a day to suit the diary, or work around the flowering time of the plant (which may be well recorded or which can be monitored by a colleague at the botanic garden). The scientists cited here all work in the botanic gardens of the Botanic Gardens Trust in Sydney, and are just part of the expertise available.

A botanic garden may also be able to provide more material than is available in the wild. This can be particularly true of a species that is rare or difficult to sample in its natural habitat. For example, there are fewer than 100 individuals surviving in the natural habitat of the Wollemi Pine (*Wollemia nobilis*) near Sydney. These relictual populations are protected to stop the introduction of life-threatening fire and disease. For over ten years the collections held by the Botanic Gardens Trust have been used to study not only the pine's biology and ecology, but also its surprising phylogeny and classification. The Wollemi Pine is the only species in the third living genus (*Wollemia*) of the conifer family Araucariaceae. It has features in common with the other living genera *Agathis* and *Araucaria* as well as with Cretaceous and early Tertiary fossil groups such as Araucarioides. A successful propagation research programme has responded to the great demand from gardens around the world. This research is based on the botanic gardens' collection.

John Thomson, an Honorary Associate with the Botanic Gardens Trust, needed to repeatedly sample specimens of bracken (*Pteridium*) to improve his extraction technique for DNA fingerprinting, in order to resolve the complex network of hybrids and polyploids obscuring the species level taxonomy in this genus (Thomson 2000). Herbarium material of bracken is typically very fragmentary - sometimes just a few pinnae from an unspecified part of the frond and a piece of stipe. Professor Thomson used the extensive living collections which he had assembled to look at complete fronds, and all the fronds at all stages of development. He found that the pinnae on each frond form a Mandelbrot series, and that the basal (or near basal) pinnae are the most reliable for comparative morphometric purposes (Thomson et al. 2005). It can be difficult to accurately locate the position of a pinna on a frond from the dried fragments held in herbaria.

By growing a wide range of closely related species together, botanic gardens can provide "standard conditions", allowing the morphology and chemistry of plants to be compared without local variations in the environment. Conditions can be controlled even more strongly in glasshouses for experimental studies. For example, key diagnostic characters such as the morphology of the indumentum are known to be environmentally variable in many fern genera. John Thomson (see above) used a "standardised environment" to help him define morphological groups of bracken that matched the results of his extensive molecular sequencing work. He has also been able to use these standard conditions to test the use of chemicals such as ptaquilosides for their use as characters in taxonomy (Smith *et al*. 1994).

Mycologists from the Botanic Gardens Trust Sydney in Australia, and the University of Stellenbosch in South Africa (Crous *et al*. 2000) made good use of the living collections of four botanic gardens in Tasmania and New South Wales to make a first cut of the fungal diversity on the leaves of Australian Proteaceae. Brett Summerell, from the Trust, notes that what would have taken many months and considerable resources to sample from natural habitats, was completed in less than a week, and examining living material was quicker than examining dried material. Their research gives us a snapshot of the fungal species likely to occur in the natural habitats of the host species.

Importantly, the botanic gardens collection is a potentially sustainable source of scientific material and takes the pressure off wild material. A collection can also be part of an educational or horticultural display; the continued growing of the individuals and/or their offspring should be relatively economical as well.

Access to other information

Botanic gardens are institutions dedicated to research into plant diversity. Their facilities and staff underpin systematic research.

By checking the database (whether on computer, on cards, or in the heads of experts, or any combination of these), our systematist can find out quickly whether a plant is held in a given Botanic Garden or not, and if it has reached a stage when it displays critical features (such as flowers or fruits). Additional information, such as what other scientific information may exist (e.g. herbarium collections, DNA extractions, photographs), may also be available. All papers cited here have used data from the various living collections databases to help locate the plant material they have utilised - its origins as well as its location in a botanic garden.

Taxonomists need access to collections of preserved plants (herbarium and spirit collections) and a good botanical library if they are to supply good species descriptions and distribution information, identification tools and sound nomenclature. At the Botanic Gardens Trust, our three key scientific assets are the living collections on all our estates, the specimens in the National Herbarium of New South Wales, and the books, archives and other materials held in the Royal Botanic Gardens Library. While efforts are being made to make label information and images of preserved specimens available on the web, and an increasing amount of scientific literature is available on-line means that some of these data may be available in the field, it's not quite the same - at least not yet.

Much of the best information is held in the minds of our scientists, horticulturalists, teachers and other staff and associates. Together they are perhaps the fourth great scientific asset of the Botanic Gardens Trust. Botanic gardens around the world will either have their own experts in particular plant groups or can locate someone close by.

Conclusion

So this "botanical buffet" is a wonderful thing. Is there a chance that it is an expensive indulgence? It is important to have a focussed collections policy so there is a wide range of species (not only those that by chance are maintained in our botanic gardens collections), be aware that the collection might be a limited genetic subset grown in gardens, be aware of possible errors in record keeping translated into our thinking, and so on. But on balance, the convenience and potential of the living collections in our botanic gardens are too important to ignore, or indeed take for granted.

Right: *Amorphophallus titanum.* (Photo: Botanic Gardens Trust, Simone Cottrell)

Systematics is all the better for having these collections at its disposal. The crux of this relationship is good record keeping that allows the systematist to relate his or her findings back to the natural world - the botanic garden is a great surrogate as long as the primary data is accurate. And the better the systematics, the better decisions we can make about the wise use and management of our natural world (but that's another story).

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Taxonomy is the tool that measures plant diversity – and our level of knowledge

A species without a name does not exist in terms of science and conservation. Each plant species has a unique scientific name that is the tag that allows it to be found, counted, researched, and monitored, and the index key that retrieves everything we know about it from the Internet, books, studies, databases and specimens. The specimens in turn document the physical attributes of the plant, and its geographic distribution.

Taxonomy is the work that gives the plant its scientific name and classifies it among all the other plants in the world. The classification encodes information about which other species are related to our plant, and thus indexes yet more information about our plant - the diseases that attack its relatives and so might also attack our plant, poisonous chemicals or drugs those other species contain that might be found in our plant too, or other species that might be crossed with our plant to introduce resistance traits.

Taxonomy is the same as other areas of biology: it is only as good as the available information. More information is always useful, and sometimes makes us change our minds; in taxonomy a change based on new information takes the form of a change in scientific name. Thus as new information flows in, names sometimes change in response; and new information is flowing in rapidly for tropical plants. Tropical regions are areas of high priority for conservation work because of their rich biodiversity and the rapid rates of habitat destruction; and ironically, tropical organisms are very much less known scientifically than temperate organisms. As a result, taxonomy and conservation run up against each other in these regions, where the plants are being catalogued and identified scientifically at the same time as these areas are being urgently assessed for conservation priority and management.

Left: *Nototriche hartwegii* is a herb of the Mallow family that has recently been found in the high Andes Mountains of Ecuador, adding another species to the country's flora. (Photo: Carmen Ulloa Ulloa)

South America is estimated to have one of the richest floras in the world, if not the richest of all. The estimates of its plant richness vary widely depending on who does the estimate, as do counts of plant species for individual tropical countries, parks and other sites. Generally the estimate of species number for a tropical site starts with a count of the species already known from there, and extrapolates to add some proportion of species expected to be discovered there in the future. This discovery rate is relatively high for tropical areas, with discoveries coming from both boots-on-the-ground exploration and detailed taxonomic study of the plants the explorers collect there. Exploration takes different forms; one widely used approach in South America is the Rapid Biological Inventory (RAP), which documents the plants found, with dried scientific specimens being made for later taxonomic study. RAP inventories

Above: Páramo del Cajas lies above the treeline in the Andes Mountains of Ecuador, and is where *Nototriche hartwegii* grows. (Photo: Carmen Ulloa Ulloa)

make specimens because good taxonomic knowledge of an area's plants is absolutely basic to a good conservation assessment. Knowing the level of taxonomic knowledge of the region is just as essential for conservation as understanding its geology and history of human occupation.

One measure of an area's level of taxonomic knowledge is its rate of change. The rate of change in our taxonomic knowledge of South American plants has recently been measured for two of its most botanically rich countries, Ecuador and Peru. A comprehensive catalogue of all the plant species known from each country was published first for Peru (Brako & Zarucchi, 1993), then shortly afterwards for Ecuador (Jørgensen & León-Yánez, 1999). Aferwards all the subsequent taxonomic changes for these countries' plants were tracked and compiled (Peru: Ulloa *et al*., 2004; Ecuador: Ulloa & Neill, 2005). The original checklist numbers and subsequent taxonomic changes are summarized below:

	Number of Species	Area (km2)	Elapsed Time	Number of Changes	Percent Change
Ecuador	15,901	276,840	5 years	1,246	8%
Peru	17,143	1,280,000	10 years	1,845	11%

The number of changes show specifically the improvement in knowledge of the flora of each country: about what plant species grow there, and about what these plants "are" - widespread common species, local endemic species, rare species of conservation concern, invasive plants, living fossils, species of economic importance, etc.

Where do these taxonomic changes come from? There are three categories of changes, which are shown below as the number of species in each category followed by the percentage this category comprises of the total number of changes for that country:

	New Records	Taxonomic Changes	New Species
Ecuador	337 (27%)	89 (7%)	820 (66%)
Peru	669 (36%)	336 (18%)	840 (46%)

1. "New Records", or range extensions, are species that are already known to science from other regions, which have now been newly discovered in this particular country. These all constitute additions to the country's known plant diversity. These additions depend on good taxonomic knowledge of the whole regional flora, so the same species can be identified throughout the region. Knowing these regional patterns of species distributions is essential for evaluation of the biological uniqueness of an area, and these range extensions often extend or refine the limits of areas of conservation concern.

2. "Taxonomic Changes" result when our improved knowledge of a plant species shows that it needs a different name. These are therefore changes in the scientific name but not usually in the identities or number of the species in the area, and thus do not change the diversity estimates for the flora. These changes do indicate our level of knowledge of the plants: more changes indicate that our knowledge is increasing.

Some taxonomic changes arise from the unfortunate discovery that two plants in different regions actually belong to the same species, so although they previously had two different names, now they have only one name and the other name is subsumed, or "synonymized", under the first name. Other taxonomic changes arise when new information shows that the previous classification was not correct, and the plant now needs to be "moved" to a new genus or a new family. Such name changes can be frustrating to a field biologist – but can assist in finding close relatives of that plant, which may possess for example, resistance genes for a devastating fungus.

3. "New Species" are plants that are presented to science for the very first time, by receiving their first scientific description and their first scientific name. Some of these are surprising organisms that have never been seen before; while others have been "hiding" inside known species, with the same name being unknowingly applied to two different plants until a taxonomist found the confusion. The addition of new species directly increases the known diversity of the region.

When our knowledge of a region's plants is deep, the names are generally stable, few new species are discovered, and few significant range extensions turn up. Thus a high rate of taxonomic change, as in the examples of Ecuador and Peru, shows that our knowledge was limited; while relatively stable names, as for many temperate European and North American plants, shows that our knowledge is rather good. The rate of taxonomic change thus provides a quick estimate of the level of knowledge on which conservation assessments are being based.

Do the numbers above indicate that Peru is richer in plant species than Ecuador? Not necessarily, because Peru covers a much larger area than Ecuador so more plant species would be expected to live there. Here in fact the generally similar numbers of species reported for these two countries together with the large difference in their areas actually suggest that the plants of Peru are less well known than Ecuador's flora. Looking at this in more detail, RAP inventories of some generally comparable areas in these two countries support this taxonomic impression that Peru may be more diverse botanically. For example, the inventory of Serranías Cofá, Bermejo, and Sinangoe in Andean Ecuador (Pitman *et al*., 2002) estimated 2,000-3,000 plant species for the region, while the inventory of the Río Biabo-Cordillera Azul region in Peru (Alverson *et al*., 2001) was done by the same team with the same methodology around the same time and estimated 4,000-6,000 plant species for that region.

Does the higher number of taxonomic changes indicate that Peru has more active taxonomic work underway, and thus our knowledge of its flora is better? Not necessarily, because the larger number of taxonomic changes for Peru's plants suggests that actually the flora was less well known to begin with, so more work was needed to bring its scientific understanding to the same level as that of Ecuador's flora. Thus probably the plant diversity assessments from Ecuador are more taxonomically reliable because of the apparently better knowledge of the flora.

If Peru may have more plant species than Ecuador does, why are the numbers of known species similar for both countries? This indicates in part that Ecuador is probably better explored and known, and also that we are probably much closer to the frontiers of taxonomy in Peru than in Ecuador. The scientific frontier here is the difference between the high number of species that we expect to find in Peru vs. the lower number of species we have actually found. This taxonomic gap, or "taxonomic impediment", is a gap in our knowledge: the plant species we know about now and the species yet to be discovered and named, which do not yet "exist" scientifically.

This taxonomic gap will never completely close, but it will diminish in direct proportion to the amount of time and effort applied to the study of the plants of both these regions. In the meantime this taxonomic gap must be kept in mind, for both local work and regional comparisons, as a confidence limit for our knowledge of species richness and biodiversity.

This taxonomic gap exists for all tropical floras, though its size varies widely between regions. Some on-line indexes to the publication of new plant names allow simultaneous searches by year of publication and country, which allow comparable estimates to be made for the rate of taxonomic change in different regions. An example is the *World Checklist of Selected Plant Families* of the Royal Botanic Gardens, Kew, England: http://www.rbgkew.org.uk/wcsp/home.do Only selected families are indexed here, but this information provides a preliminary estimate of the recent rate of taxonomic change for a given region. However the information in this type of index does not track range extensions, nor indicate the starting level of knowledge of the regional flora. That sort of information depends on detailed taxonomic tracking of a particular flora, as done by Ulloa *et al*. (2004) and Ulloa & Neill (2005).

Looking again now from our taxonomic viewpoint at current estimates of species richness, is South America really the richest continent for plant diversity? We can now see that this answer depends in large part on the size of the taxonomic gap in South America vs. that of other regions. The number of species known from various continents is not greatly controversial, but the total estimated richness depends also on the expected rates of discovery for each region, and those rates are sometimes difficult to estimate accurately. The African flora is well enough known to confirm that South America is more diverse. However the level of knowledge of much of the flora of Asia and Oceania is probably lower than that of South America, so the taxonomic gap cannot even be accurately estimated until taxonomy advances in all of these regions.

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The Catalogue of Life: indexing the world's species

Right: *Grevillea baileyana* McGilliv., Scrub Beefwood, is a tree species in the family Proteaceae.

A list of all organisms is a basic necessity for accessing and organising information about them worldwide - and that list is available now: right? Actually - wrong. Many people are astonished to discover that the taxonomic profession has no comprehensive catalogue of all the world's organisms, or even of all the world's plants. Some ask: "Why can't we just use the list of names in *Index Kewensis*?" Extremely valuable as that resource is, we argue here that IK is not what is needed by society and the biodiversity professions as a working list of plant species around the world.

The members of Species 2000 and the Integrated Taxonomic Information System (ITIS) are collaborating to complete the Species 2000 and ITIS Catalogue of Life by 2011 to meet this need.

What kind of catalogue do we need?

What is needed is a functioning and maintained species checklist that lists as nearly as possible a consensus view of all known species. It needs to combine two extremely important components that are not trivial to deliver. Firstly, it needs to reflect expert taxonomic opinion as to which distinct species exist, and how each is circumscribed. Where opinions are divided, a consensus may not be possible, but then one responsibly chosen view should be given, and access provided to alternatives.

Secondly, the checklist also needs to reflect accurately the accepted scientific name of each species, and the synonyms, other scientific names by which the species, or prior species now included in the present concept, have been named in the past or in other catalogues.

Both these requirements are important for practical reasons of how the catalogue can function. The first is difficult to attain on a global scale, but without it a species may accidentally be in the list twice (under different names), or a broadly drawn species and its sub-components may accidentally be listed alongside each other. It means that there is just one entry for each biological species, and that they can be counted.

The second requirement is important because one of the principal uses of the catalogue is for synonymic indexing. As an example, specimens identified under different names in different herbaria or gardens may be samples of the same species. This can be detected by using the synonymy, which in this case may indicate that two of the names are synonyms of the species now known by the third name. Conversely, using the synonymy prior to an Internet search may allow a user to search for a species under all of the different names by which it is known.

It is estimated that the world has about 1.75 million known and named living species of plants, animals, fungi and micro-organisms, and that the number of vascular plants (flowering plants, conifers, cycads and ferns) is between 223,000 and 420,000 (Scotland and Wortley 2003) and bryophytes number about 25,000 species. People agree that reliable, readily available, core knowledge of the individual species that inhabit this planet is central to understanding biodiversity, conserving it, and using it in a sustainable fashion. For example, a working list of all organisms has been adopted by the UN Convention on Biological Diversity as a target under the Global Taxonomy Initiative (see COP-8 VIII, decision 3), and a working list of all plant species was earlier adopted at COP-VI (decision 9) as Target 1 of the Global Strategy for Plant Conservation.

Access to all knowledge about a species, whether it is a description of its features, geographical distribution, ecological associations, genetic composition, or its usefulness to humans, can be provided by using the species checklist and the synonymic indexing of the scientific names that provide unique tags to access the data.

Why not use vernacular names? Well, there certainly are cases where vernacular names precisely refer to just one species, and where a species has just one vernacular name in one language, but these cases are rare. It is also true that vernacular names are very widely used. However, many species have no vernacular name at all. Where they do exist, the same vernacular name may be used for several different species, leading to confusion as to which is meant. Most organisations agree that vernacular names, and the languages and places in which they are used, do make a useful addition to the species list, but it is clear that scientific names provide a better basis for the list.

Catalogues of species versus catalogues of names

There are three main kinds of lists or catalogues of scientific names of organisms, often confused by people.

Firstly, there are the **nomenclators**, which are alphabetical lists of all names ever published (see example Box 1). There are various of these indexes. For higher plants, this is the impressive *Index Kewensis*, initially funded by a donation from Charles Darwin, and published in hard copy for more than a century. It is now also available electronically as part of the *International Plant Name Index* (IPNI, www.ipni.org), supplemented by the Australian Plant Names Index and the Gray Card Index, which provide more in-depth coverage of infraspecific names than *Index Kewensis*. For fungi, there is *Index Fungorum*, for bacteria the *List of Prokaryotic Names with Standing in Nomenclature* and for animals there is the *Index to Organism Names*.

Secondly, there are **global species lists**, in the electronic world referred to as **Global Species Databases** (GSDs), a term coined by Species 2000. These are, or aim to be, taxonomically authoritative lists of all the known species in a group, with any synonyms listed under the relevant accepted names as a result of revision or scrutiny by one or more taxonomists (see example Box 1). In flowering plants, it is estimated that there are an average of three synonyms for each accepted name (Scotland and Wortley 2003). It is this expert input that differentiates these global lists from nomenclators. There are many global lists, often in hard copy or handwritten on index cards, but increasingly they are being put together electronically and being made available on websites scattered around the world. Commonly these lists include more than just the species' names - protologue and type information and geographic distribution are the most common inclusions.

Thirdly, there are **regional checklists**, which aim to cover all species in a region. These are often variable in terms of taxonomic content and validation, but may be rich in extra information about the occurrence and variation of the species in that region.

All these sources of information (electronic and hard copy) about organisms are scattered and, until recently, it was difficult for people to readily find out the names of whatever species were of interest to them, or to find further information about those species. One had to know where to find the sources of information and then be knowledgeable enough to

A. Example of entries in a *nomenclator,* i.e. a simple list of scientific names and where they were published, without comment on whether the names are still in general use or are now treated as synonyms

Andropogon dulce Burm. f., Flora Ind.: 219 (1768).

Eleocharis difformis S. T. Blake, Proc. Royal Soc. *Queensland* 50: 99 (1939).

Eleocharis dulcis (Burm. f.) Trin. ex Henschel, *Vita Rumph*.: 186 (1883).

Eleocharis ochrostachys Steudel, *Synopsis* 2: 80 (1855).

Eleocharis tuberosa (Roxb.) Roemer & Schultes, *Mantissa* 2: 86 (1824).

Eleocharis variegata (Poir.) Presl **var. *laxiflora*** (Thwaites) C. B. Clarke, *Fl. Brit. India* 6: 626 (1893).

Scirpus laxiflorus Thwaites, *Enum. Pl. Zeyl*.: 435 (1864).

Scirpus tuberosus Roxb., *Fl. Ind*. 1: 213 (1820).

B. The same names as above, now organised as in an *authoritative checklist of species*

Eleocharis dulcis (Burm. f.) Trin. ex Henschel
Synonyms: *Andropogon dulce* Burm. f.
Eleocharis tuberosa (Roxb.) Roemer & Schultes
Scirpus tuberosus Roxb.

Eleocharis ochrostachys Steud.
Synonyms: *Eleocharis difformis* S.T. Blake
Scirpus laxiflorus Thwaites
Eleocharis variegata (Poir.) Presl var. *laxiflora* (Thwaites) C.B. Clarke

Box 1. The difference between a list of names (A) and a list of species (B)

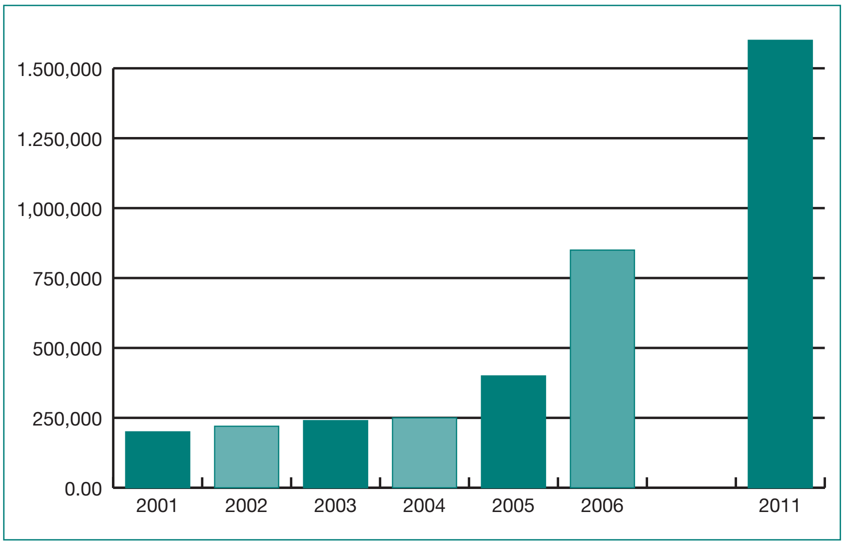

Figure 1 - Progress with compiling the Catalogue of Life
Currently, half of all known species (880,000) are included in the Catalogue of Life *Annual Checklist, drawn from nearly 40 contributing species database projects. The aim is to include all species by June 2011. (Diagram prepared by Yuri Roskov)*

interpret what was found: for example, did the species named A in country X represent the same species as the one named B in country Y? And what about the species named C from another region of country Y: was it the same as A and/or B, or a different species?

The last decade has seen a revolution in this area of research, as in most others, with the explosive development of e-Science. It is now much easier for biologists in different regions to collaborate on research projects, thanks to innovations such as email and video-conferencing, and aided by the availability of analytical software and electronic images of specimens and publications, increasingly accessible on websites. Also, many biologists have been able to travel more readily to extend their research through study and fieldwork in relevant parts of the world. Many biological database projects have started around the world in this decade, making available electronically information about particular groups of plants, animals or micro-organisms (Bisby 2000). These Global Species Databases (GSDs) are key elements in the *Catalogue of Life* because they provide a comprehensive taxonomic snapshot of all the species in a particular group. Regional databases that include all the organisms in a particular region of the world are also important in adding details not covered in the GSDs.

The Species 2000 & *ITIS Catalogue of Life*

Numbers of these database projects, spread around the world, are collaborating to produce a unified, authoritative index of the world's species: the Species 2000 & ITIS *Catalogue of Life*. This is a keystone knowledge set - the gateway to a digital library of biodiversity information on the Internet, using species names to link to other data systems on subjects as varied as specimen data, agriculture, pharmacognosy and conservation uses. The *Catalogue of Life* is available on the web (www.sp2000.org) as a Dynamic Checklist, with live access to contributing databases, and also as an Annual Checklist, available both on the website and on a CD-ROM (Bisby *et al*. 2006).

The Species 2000 & ITIS *Catalogue of Life* is an example of:

- a successful approach to managing complex data in biology
- the computational challenges in managing complex data from multiple sources
- the sociology of international collaboration between database projects in biology.

The genetic diversity inherent in living organisms means that compiling the *Catalogue of Life* is far from a simple exercise of listing names (Bisby 2003, Wilson et al. 2005). This is a knowledge-gathering programme, involving taxonomic expertise in interpreting species and their relationships. The specialist knowledge needed to create and continuously enhance a global species database for a group is the "tip of an iceberg", below which lies layer upon layer of taxonomic processes: from field observation and collections through to monographic revisions and phylogenetic analysis. Names are the mere tags by which this knowledge is accessed.

Indeed, the key component that marks the *Catalogue of Life* as being much more than a list of names is the expert input from taxonomic biologists in all parts of the world to validate the complex biological content. Compilation is further complicated by the fact that understanding of biodiversity is still far from adequate, resulting in many scientific names not yet being in a 1:1 relationship with species. Much further taxonomic research by experts is needed to sort out such problems.

The collaborative input has dictated a distributed model for the *Catalogue of Life*. Even though a centralised model is more efficient computationally, it is sociologically very important to keep the individual data-sets close to the taxonomists who provide the expertise to update the species information. Another advantage of the distributed approach is that the work of aggregating taxonomic knowledge is going ahead in a massively parallel way, rather than in a serial fashion as would happen with a centralised approach.

The success of this distributed approach is seen in the fact that, since 2001, more than 880,000 species have been added to the *Catalogue of Life*: about 50 per cent of the world's known species (Figure 1). The aim is to add the other 50 per cent by 2011, but these species mostly belong to poorly studied groups, especially amongst the insects, and so it will be a major challenge to reach 100 per cent in that time frame.

The *Catalogue of Life* is already proving useful as an index, even though it is not yet complete. For example, the Global Biodiversity Information Facility (GBIF) uses it as the taxonomic backbone for its web

Left: Stands of *Casuarina cunninghamiana* Miq. subsp. *cunninghamiana*, the River She-oak, fringe the rivers of eastern Australia.

portal for biodiversity information (www.gbif.net), as do some members of GBIF for their local databases.

Interaction with other global programmes

Besides interaction with individual taxonomic experts and databases, the *Catalogue of Life* interacts strongly with a wide range of international and national bodies, as both supporters and users of this species index. Species 2000 began as a joint program between the Committee on Data for Science and Technology (CODATA) of the International Council for Science (ICSU), the International Union for Biological Sciences (IUBS) and the International Union of Microbiological Societies (IUMS) in the early 1990s, which led to a workshop funded by UNEP and the Global Environment Fund in Manila, the Philippines, in 1996. Funding for the *Catalogue of Life* comes from many sources, both directly to Species 2000 and ITIS and indirectly through their contributing members, with recent notable contributions from the European Union and GBIF. Species 2000 and its regional groups actively support all the above groups, as well as the Global Taxonomy Initiative (GTI) and other programmes of the Convention on Biological Diversity, and the International Working Group on Taxonomic Databases (TDWG).

Left: Botanists Neil Gibson and Margaret Langley examine specimens collected during a biological survey.

Progress with the World List of Plant Species within the *Catalogue of Life*

Within the *Catalogue of Life* programme, Species 2000 is co-operating with the Royal Botanic Gardens Kew and other stakeholders to bring together the taxonomic sectors that will complete the working list of plant species for the GSPC Target 1. A workshop organised jointly between them in June 2004 started the process of evaluating existing and potential coverage of all groups of flowering plants in a gap analysis. Botanists from around the world spent two days assembling both their knowledge of ongoing databases and projects, and of groups of experts who might be able to assist.
Conclusions drawn from examining the coverage map created included:

- Coverage of families: global checklists were done for 15 per cent of spp., in progress for 22 per cent, and in draft stages for 30 per cent.
- Families that were not started constitute approx. 33 per cent of species.

Left: *Potentilla neumanniana* Rchb., Spring cinquefoil, is a herbaceous perennial in the family Rosaceae, (seen here in the Aarhus Botanical Garden, Denmark).

- Jointly planned activities of the Royal Botanic Gardens, Kew, Missouri Botanical Garden and New York Botanical Garden were likely to account for some 55 per cent of the total, leaving a “gap” of 45 per cent that needs both taxonomic expertise and co-ordination.

The following priorities were agreed:

- The larger missing sectors (thought to be Compositae (Asteraceae), Melastomataceae and Malvaceae) must be started urgently if there is to be any chance of even nearing completion by the 2010 target date.

Right: *Grevillea wickhamii* Meisn. has distinctive bright orange-red flowers and grey, holly-like leaves. The nectar of this and other *Grevillea* species is popular with native butterflies such as the Caper White.

- For the very many smaller and middle-sized families to be started or brought to completion, it is both an issue of focusing appropriate expertise on the task, and providing leadership, co-ordination and funding to the programme of work. A vigorous co-ordinating process, possibly from Species 2000, the International Organization for Plant Information (IOPI) or the Integrated Twxonomic Information System (ITIS) is needed for the 45 per cent of sectors needed from outside the Royal Botanic Gardens, Kew, Missouri Botanical Garden and New York Botanical Garden programme.

Right: *Acacia stenophylla* A.Cunn. ex Benth., has striking seed pods. It is widespread near creeks of inland Australia.

- The coverage map created at the workshop should be publicised and developed, working with the Species 2000 metadatabase and GBIF to keep track of who is doing what.

Since the 2004 workshop, significant progress has been made. RBG Kew has made steady progress with extending its series, *World Checklist of Seed Plants*, covering monocots and selected other groups. The message about the big gap for Compositae has been picked up by GBIF and it is funding a major project, which started in early 2006 and is led by Ilse Breitwieser in New Zealand, with partners in The International Compositae Alliance (TICA) in Europe, including the Bot. Garten and Bot. Museum Berlin-Dahlem, and in the Americas, including the Missouri Botanical Garden and the Smithsonian Institution. In other groups, Species 2000 has recently extended the coverage provided within the *Catalogue of Life*: as well as the extensive coverage provided by the RBG Kew *World Checklist* for a range of families, the *Catalogue of Life* now covers the algae (AlgaeBase), mosses (Missouri BG), conifers (A. Farjon), Leguminosae (the International Legume Database and Information System - ILDIS), Annonaceae (AnnonBase), Lecythidaceae (New York BG), and cycads and six flowering plant families from the IOPI Global Plant Checklist and Species Plantarum Programme (www.iopi.org). Regional datasets coming into the *Catalogue of Life* include Euro+Med PlantBase (part of the *Catalogue of Life* Regional Checklist for Europe) and the North American plants from ITIS and the PLANTS databases (*Catalogue of Life* Regional Checklist for N. America).

Challenges for the future

There are continuing challenges facing this project and taxonomy in general.

One is the need to integrate activities to avoid duplication of effort and to make best use of available funding. Species 2000 is implementing an organisational architecture that is capable of both creating a complete *Catalogue of Life* and maintaining its taxonomic enhancement through time. At a superficial level, this programme is about creating databases and continuing to maintain them, but underlying this is a serious proposal for self-organization within the taxonomic community and for rationalising and structuring taxonomic effort on a global and regional scale. The result of current initiatives is an exciting opportunity to generate endorsement and further resources where all efforts have failed in the past.

Another challenge is how to allow users to choose alternative classifications of species (where they exist) within the *Catalogue of Life* (Bisby 2003). More systematically aware users want to be able to choose which classification they use. Others just want a single, generally accepted classification that will allow them to communicate information about their species of interest using a

Right: *Cycas revoluta* Thunb. is native to the Ryukyu Islands of southern Japan and possibly also to the Fukien province of China.

Left: The alpine zone of the Kosciuszko National Park in southeastern Australia is home to a wide diversity of organisms, but it is a fragile environment of small extent. A rise of only a few degrees in the average temperature would have drastic consequences for endemic species of plants and animals.

set of stable, accepted names. Our data structure and user interface aim to allow all users to choose whichever of the available classifications they prefer for their group of birds or legumes or whatever.

The overarching challenge globally for taxonomy is to study and document the living species that are not yet known and named. The Global Taxonomic Initiative has emphasized the shortage of systematic /taxonomic resources (both people and natural history collections) to document the organisms of this world before extinction strikes. About 1.7 million species of organisms have been given scientific names, but anywhere from 2 to 50 million species or even more (DIVERSITAS 2000; Wilson 2003) are still not formally described, most of them micro-organisms or small invertebrates such as insects. Without names as unique tags for species, we are floundering to understand all the wonders of our biodiverse world, let alone to conserve and sustainably manage them.

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Left: Aroids are very popular as potted plants. This colourful species grows in the Fortuna highland area of Panama.

Book notices and taxonomic resources

Plant Identification: creating user-friendly field guides for biodiversity management
Reviewed by Helen Pickering

This is a practical book. It provides considerable detail on how to produce a variety of identification guides. Early chapters address the main issues of biodiversity, donors and the need to involve local rural communities as both producers and consumers of such tools. Later chapters provide detailed information on all aspects of creating a field guide; collecting and organising data, types of illustration, technology, presentation, printing and distribution. The range of field guides discussed include: printed checklists, illustrated manuals and laminated sheets that can easily be carried into the field and used under adverse climatic conditions,

The field guides discussed are aimed at a narrow range of stakeholders, working in a variety of botanically related projects, from the timber and agro-industry to conservation in national parks. For these, it will be extremely useful.

Anna Lawrence and William Hawthorne, 2006
Earthscan, London, UK, 268 pp.
People and Plants Conservation Series,
ISBN-10 1-84407-079-4
ISBN-13 978-84407-079-4
Earthscan, 8-12 Camden High Street,
London NW1 0JH, UK
Tel: +44 (0)20 7387 8558
Fax: +44 (0)20 7387 8998
E-mail: earthinfo@earthscan.co.uk
Internet: www.earthscan.co.uk

Plant systematics: a phylogenetic approach (second edition)

This is an introductory text that incorporates phylogenetic principles and methods throughout. Orders and families are recircumscribed to represent monophyletic groups, largely following the most recent classification of the Angiosperm Phylogeny Group. The sources of taxonomic evidence are discussed, including morphology, anatomy, embryology, chromosomes, palynology, secondary plant compounds, proteins and DNA. Molecular taxonomic methods are fully presented, and throughout the book reference is made to the results of recent studies, both molecular and morphological. A chapter on the history of plant classification puts current systematic methods in a historical context. Issues relating to variation in plant populations and species, including discussion of speciation, species concepts, polyploidy, hybridization, breeding systems and introgression are carefully considered. Botanical nomenclature and field and herbarium methods are discussed in two appendices.

The text is illustrated using analytical drawings, many of which have been developed as part of the Generic Flora of the Southeastern United States project. The book is accompanied by a CD-ROM containing over 2,200 colour photographs illustrating the diagnostic characters of (and variability within) the vascular plant families covered in the text, including many images showing floral and fruit dissections. The text assumes no prerequisites other than introductory botany or biology.

Walter S. Judd, Christopher S. Campbell, Elizabeth A. Kellogg, Peter F. Stevens and Michael J. Donoghue, 2002.
Sinauer Asscociates Inc., USA, 576 pp.
ISBN 0-87893-403-0, (Hardback) $94.95 (approx £61.99/$121).
Sinauer Associates, Inc., 23 Plumtree Road P.O. Box 407, Sunderland, MA 01375-0407, USA, Tel: +1 (413) 549-4300,
Fax: +1 (413) 549-1118,
E-mail: orders@sinauer.com,
Internet: http://www.sinauer.com.

Angiosperm Phylogeny Group, or **APG**

The Angiosperm Phylogeny Group, or APG, refers to an international group of systematic botanists who came together to try to establish a consensus view of the taxonomy of flowering plants that would reflect new knowledge in angiosperm relationships. The results from these collaborations were largely attempts to deal with the deficiencies in prior angiosperm classifications as seen by phylogenetic theories based on analysis of DNA.

The rapid increase in knowledge has led to many proposed changes in classifications, and these pose problems for all users of classifications. By bringing together researchers from major institutions worldwide, and publishing jointly, the APG have sought to provide a stable point of reference. This system deals mostly with higher ranks and, as there are still severe limits to our knowledge, a firm classification is not possible in all cases. This made angiosperms the first large group of organisms to be systematically reclassified largely on the basis of molecular characteristics (APG 2003).

Angiosperm Phylogeny Group (2003). An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG II. *Botanical Journal of the Linnean Society* **141**: 399-436 [Available online: Full text (HTML) http://www.blackwell -synergy.com/links/doi/10.1046/j.1095-8339.2003.t01-1-00158.x/full/ | Full text (PDF) http://www.blackwell-synergy.com/links/doi/10.1046/j.1095-8339.2003.t01-1-00158.x/pdf].

Angiosperm Phylogeny Website
Stevens, P. F. (2001 onwards). Version 7, May 2006 [http://www.mobot.org/MOBOT/research/APweb]

Taxonomy and plant conservation: the cornerstone of conservation and the sustainable use of plants

This book was reviewed in the last issue of *BGjournal*. It has many useful papers on the practice of taxonomy and how it is necessary for conservation. It has several chapters which directly address the gap between plant taxonomy as a science (where molecular approaches are becoming ever more important and debates rage about cladistics) and use of the products of that science by practitioners in other disciplines, who need usability and stability in the names that can be applied to particular organisms.

Etelka Leadlay and Stephen Jury, 2006.
Cambridge University Press, UK, 300 pp.
ISBN 978-0-521-60720-9 (Paperback) £35.00,
ISBN 978-0-52-84506-9 (Hardback) £70.00.
Cambridge University Press, The Edinburgh Building, Cambridge CB2 2RU, UK,
Tel: +44 (0) 1223 326050,
Fax: +44 (0) 1223 326111,
E-mail: directcustserve@cambridge.org,
Internet: www.cambridge.org

The secret life of trees

Although this is a popular book exploring the way trees work, what they are, and how they came to exist, it has an extremely good chapter called 'Keeping track' which describes identification and why it is difficult which would be very helpful for the layman and teacher.

Colin Tudge, 2005.
Allen Lane, UK, 320 pp.
ISBN: 0713996986 (Hardback) £20.00 (approx. $39/€30); Penguin, UK, 452 pp.
ISBN: 0141012935 (Paperback) 2006 £8.99 (approx. $18/€14)
Allen Lane, 80 Strand, London WC2R 0RL,
Penguin, 80 Strand, London WC2R 0RL

Order out of chaos: Linnaean plant names and their types

This 1,200-page book is a welcome addition to the botanical literature, bringing together as it does all the known published information about Linnaean type specimens and publishing for the first time a significant number of newly designated types. To quote from the book's Foreword by Peter Raven of Missouri Botanical Garden, "For conserving plant species, understanding them, and working with them in any way, the stability of names to which this volume makes such a singular contribution is an absolute necessity."

For 25 years the Linnaean Plant Name Typification Project, based at the Natural History Museum, London, has been gathering information on Linnaean types, in other words the botanical specimens or illustrations that fix the permanent usage of the names coined by Linnaeus in the 18th century. Hundreds of botanists around the world have been consulted in the process of assessing existing type designations and making definitive choices of type. Valuable to taxonomists and scholars worldwide, this handsomely illustrated book is published in Linnaeus' Tercentenary year. Publication May 2007 (pre-publication discount available).

Charlie Jarvis, 2007.
The Linnean Society of London and the Natural History Museum, UK, 1,200 pp.
Linnean Society, Burlington House, Piccadilly, London W1J 0BF, UK,
Tel: +44 (0) 20 7434 4479
Fax: +44 (0) 20 7287 9364
E-mail: info@linnean.org
Internet: www.linnean.org
The Natural History Museum, Cromwell Road, South Kensington SW7 5BD, UK,
Tel: +44 (0) 20 7942 5000
Internet: www.nhm.ac.uk

Systematic collections

Order or systematic beds displaying living plants in taxonomic groups have been a part of botanical gardens since, or almost since inception. There is an extremely informative article on order beds by Dr. David Frodin on the Chelsea Physic garden website (www.chelsea physicgarden.co.uk/garden/docs/orderbeds.doc).

The Botanical Gardens of France and French-speaking Countries (Jardins Botaniques de France et des pays francophones - JBF) held a workshop on systematic collections at their recent workshop in Montpellier in May, 2006. The programme and presentations can be found at http://www.bgci.org/jbf-fr/Programme/.

Reconstructing the Tree of Life: Taxonomy and Systematics of Species Rich Taxa

Of relevance to both systematic and evolutionary biologists, *Reconstructing the Tree of Life: Taxonomy and Systematics of Species-Rich Taxa* draws from taxonomy and phylogenetics to provide both a systematics and evolutionary biology perspective. Detailing a broad range of organisms, the text addresses the task of reconstructing and making best use of the tree of life. Featuring the contributions of leading experts, who examine recent progress and consider future developments, it also discusses global diversity issues and the taxonomic problems of dealing with large and species-rich taxa. The book is divided into three parts: introduction and general concepts, reconstructing and using the tree of life, and taxonomy and systematics of species-rich groups (case studies). It introduces, with examples, the concept of species-rich groups and discusses their importance in reconstructing the tree of life as well as their conservation and sustainable utilization in general. The book highlights how phylogenetic trees are becoming "supersized" to handle species-rich groups and the methods that are being developed to deal with the computational complexity of such trees. It discusses factors that have led some groups to speciate to a staggering degree and also provides case studies that highlight the problems and prospects of dealing with species-rich groups in taxonomy.

Edited by Trevor R. Hodkinson and John A.N. Parnell. December 2006. CRC Press, 360 pp.; Systematics Association Special Volumes - Volume: 72
ISBN 0849395798; Cat No. 9579. (hardback) £68.99 (approx. $135/€103).
CRC Press UK, 24 Blades Court, Deodar Road, London, SW15 2NU, UK.
Tel: +44-(0)20 7017 6000
Fax: +44-(0)20 7017 6747
www.crcpress.co.uk

Linnaean celebrations 2007

Scientific Meetings

20 February
Meeting at the Linnean Society. Sir David King speaks on climate change.

16-17 April
Festschrift at the Royal Botanic Gardens, Kew. "Plant Genome Horizons - Vistas and Visions".

23 April
Joint meeting of the Linnean Society and the Geological Society. "Dark energy and the history of chemosynthetic life in the deep sea".

A meeting to celebrate the 300th anniversary of the birth of Linnaeus, the Bicentenary of the Geological Society, the International Year of Planet Earth and the 30th anniversary of the discovery of deep sea hydrothermal vents.

8 May
Joint meeting of the Linnean Society and the Zoological Society. "A Celebration of the Tercentenary of the Birth of Carl Linnaeus". Discussion meeting organised by Dr Vaughan Southgate. Speakers include Professor Charles Godfray, Dr Sandy Knapp, Dr Andrew Polaszek and Dr Tim Littlewood.

11-23 June
Uppsala University. "Unlocking the Past - Linnaean collections past, present and future". Meeting beginning in London (11-12 June), continuing in Uppsala (14-15), finishing in Gotland (17-23 June).

14 September
Royal Horticultural Society in association with the Linnean Society. "Linnaeus and the Iconotype".

1-2 October
Royal Netherlands Academy of Arts & Science. "Linnaeus 300 - the future of his Science". International symposium organised by the Royal Netherlands Academy of Arts & Science in collaboration with the Linnean Society of London and the Embassy of Sweden in the Netherlands.

18 October
Meeting at the Linnean Society. Lord (Robert) May speaks on "People, Parasites and Poverty".

31 October -1 November
The Royal Botanic Gardens, Kew. "Orchid evolutionary biology and conservation - from Linnaeus to the 21st century". A celebration of the culmination of the Orchid Classification Project.

22-23 November
Joint meeting of the Linnean Society and the Institution of Mechanical Engineers. "Colour Design and Engineering: Colour in plants and animals - inspiration for design".

For up-to-date information on events, exhibitions and meetings in the tercentenary year, see www.linnean.org and www.linnaeus2007.se.

If you are organising a relevant event, please contact the Linnean Society for it to be included in the list of events.

Please register your contributions to the *International Agenda for Botanic Gardens in Conservation*

International Agenda for Botanic Gardens in Conservation
Registration Form

Name of Institution	

Type of Registration	**Formal**	Board Resolution or other form of approval from relevant governing bodies (e.g. university authorities, local, regional or national government	*Please Tick*
	Informal	E.g. by Director/Senior staff.	

BGCI would welcome copies of any formal resolution, motion or other form of endorsement.

Name of responsible person	
Position	
Address	

Email		**Date of Registration**	

Declaration

This institution welcomes the International Agenda for Botanic Gardens in Conservation as a global framework for the development of institutional policies and programmes in plant conservation for botanic gardens.

Without imposing any obligations or restrictions (legal or otherwise) on the policies or activities of this institution/organisation, we commit ourselves to working to achieve the objectives and targets of the ***International Agenda for Botanic Gardens in Conservation.***

Signed		**Date**	

Please sign and detach this registration form and send it to The Secretary General, Botanic Gardens Conservation International, Descanso House, 199 Kew Road, Richmond, Surrey TW9 3BW, U.K.

Thank you for registering with the ***International Agenda for Botanic Gardens in Conservation***.

Please keep a duplicate copy of this form for your records.

How to join Botanic Gardens Conservation International

The mission of BGCI is to mobilise botanic gardens and engage partners in securing plant diversity for the well-being of people and the planet. It was founded in 1987 and now includes over 525 member institutions in 115 countries.

Institutions can join BGCI for the following benefits:

- Membership of the worldwide plant conservation network
- Botanic Garden Management Resource Pack (upon joining)*
- Regular publications:
  - the regular newsletter, *Cuttings*
  - *BGjournal* – an international journal for botanic gardens (2 per year)
  - *Roots* - environmental education review (2 per year)
  - A wide range of new publications
- Invitations to BGCI congresses and discounts on registration fees
- BGCI technical support and advisory services

	Institution Membership	£ Stlg	US $	€ Euros
A	BGCI Patron Institution	5000	8000	7500
B	Institution member (budget more than US$2,250,000)	600	1000	940
C	Institution member (budget US$ 1,500,000 - 2,250,000)	440	720	660
D	Institution member (budget US$ 750,000 - 1,500,000)	300	500	440
E	Institution member (budget US$ 100,000 - 750,000)	160	250	220
F	Institution member (budget below US$100,000)*	75	120	110
	**Generally applies to institutions in less developed countries*			

Other Membership Categories:

Membership benefits depend on category - see below. These can include:

- Regular publications:
  - the regular newsletter, *Cuttings*
  - *BGjournal* - an international journal for botanic gardens (2 per year)
  - *Roots* - Environmental Education Review (2 per year)
- Invitations to BGCI congress and discounts on registration fees

	Corporate Membership	£ Stlg	US $	€ Euros
G	Corporate Gold Member (*BGjournal*, *Roots* and *Cuttings* plus more)	5000	8000	7500
H	Corporate Silver Member (*BGjournal*, *Roots* and *Cuttings* plus more)	1000	1600	1500

	Individual Membership	£ Stlg	US $	€ Euros
J	Conservation donor (*BGjournal*, *Roots* and *Cuttings* plus more)	250	450	420
K	Associate member (*Cuttings* and *BGjournal*)	35	60	50
L	Associate member (*Cuttings* and *Roots*)	35	60	50
M	Friend (*Cuttings*) available through online subscription only (www.bgci.org)	10	15	15

*Contents of the Botanic Garden Management Resource Pack: *The Darwin Technical Manual for Botanic Gardens, A Handbook for Botanic Gardens on the Reintroduction of Plants to the Wild, BGjournal - an international journal for botanic gardens (2 past issues), Roots - environmental education review (2 past issues), The International Agenda for Botanic Gardens in Conservation, Global Strategy for Plant Conservation, Environmental Education in Botanic Gardens, BG-Recorder (a computer software package for plant records).*

Payment may be made by cheque payable to Botanic Gardens Conservation International,or online at www.bgci.org or by VISA/Mastercard sent to BGCI, Descanso House, 199 Kew Road, Richmond, Surrey, TW9 3BW, U.K or Fax: +44 (0) 20 8332 5956.

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Please clearly state your name (or the name of your institution) on all documentation. Please contact info@bgci.org for further information.

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