Cambridge
University
Botanic Garden

Living Collections Strategy

2020-30

Cambridge University
Botanic Garden

Acknowledgements

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Foreword

Cambridge University Botanic Garden (CUBG) maintains a remarkable range of living plant diversity within a nexus of departments and institutions, hosting one of the largest concentrations of plant scientists anywhere in the world. Central to our success is the recognition that our Living Collections support world-class education, learning and research, and in doing so, help to solve some of society's most pressing concerns. In support of these fundamental objectives, we have developed our Living Collections Strategy - a blueprint which will ensure stronger alignment of our garden with Cambridge University's pursuit of education, learning and research at the highest levels of international excellence.

Our Living Collections have their origin in 1762 when the first University Botanic Garden was established in the centre of Cambridge, on about five acres of land, at what is today known as the New Museums Site. The garden was conceived as a typical Renaissance physic garden and grew herbaceous plants used in the teaching of medical students at the University. As the discipline of botany grew at Cambridge under the watchful eye of John Stevens Henlow, the argument was made for a larger botanic garden on its current forty acre site.

The newly designed garden was laid down in 1834 in an innovative and scientific manner. The garden and its landscapes subsequently went on to support seminal work in plant genetics, plant physiology and plant pathology through much of the 20th century. Now in the 21st century, Plant Science at Cambridge continues to grow in strength, through the combined work of the Department of Plant Sciences, the National Institute of Agricultural Botany, the Sainsbury Laboratory at Cambridge University, and the newly founded Cambridge Centre for Crop Science. Within this context, the collections, facilities and expertise at Cambridge University Botanic Garden continue to support a vast array of activities.

Our leading Living Collections are curated to the highest standards and used extensively by colleagues both at Cambridge University and external Higher Education institutions. Our reach is truly global, with projects currently undertaken with partners across the world from Central Asia to South Africa. Research based on our collections forms the basis of fundamental and applied science, supports publications with broad and substantial impact, and underpins international research networks funded by national and regional funding agencies. With over 300,000 visitors each year, we showcase our collections-based research, with our education programme, interpretation strategy and public events enriched by the inclusion of research material.

In this strategy we have sought to bring together information about the Living Collections as a whole and to describe their current composition and condition. We conduct a comprehensive quantitative analysis of the collections, in which we measure their quality according to a number of values. Through this analysis, we address some key questions about the different strengths and weaknesses of our collections, and how these are distributed across the various parts of the collections, and the landscape as a whole. We also explore how our collections are currently used in order to guide our planning for their future use. Finally, this strategy considers the future direction and utilisation of the Living Collections to support our three main objectives: research, education, and conservation. We outline how we will improve the contents of the collections through acquisition of new accessions. But importantly we also consider how to best manage the existing collection to ensure that we are best positioned to support a full range of academic and applied endeavours.

The Living Collections at Cambridge University Botanic Garden are at the heart of our identity, both as a botanic garden, and as a University. We look forward to implementing the aims of our strategy to ensure that we continue to safeguard the world's plant diversity, and drive the pursuit of excellence in all areas of research and teaching where access to plant diversity is essential.

Samuel Brockington
Curator, CUBG

Beverley Glover
Director, CUBG

Executive Summary

The goal of any rational Living Collections Strategy should be to develop a vision which advances the capabilities of the botanic garden; supports its core values and objectives; enhances the relationship between the garden and its stakeholders; and enriches collaboration with its peer collection-based institutions. In pursuit of this goal we have sought to answer four key questions, with respect to our Living Collections:

1) What Living Collections do we currently hold and what is their quality?

2) What aspects of the Living Collections do we need to prioritise in support of our three core objectives: Research, Education and Conservation?

3) How can we best increase the value of our Living Collections through the collection and acquisition of new material?

4) How can we improve and develop our management and procedures to better serve the Living Collections and deliver our core objectives?

This document is composed of six sections:

1) We outline the global context for our Living Collections by summarising our analyses of the global network of botanic gardens. We highlight some of the core strengths and weaknesses of this global network, and emphasise future global challenges which bear on our own Living Collections Strategy.

2) We give an overview of our current collections as currently managed by six horticultural teams. We provide key numbers with respect to the distinctive collections managed by our different teams, and provide a visual display of some of the diversity in these collections, and their contextual landscapes.

3) We define nine key metrics by which we measure the current quality of our Living Collections, and by which we can measure future improvement in their quality. These metrics relate to the key concepts of rarity, diversity, wild-origin, extinction risk, seed-banking, provenance, duplication, longevity and sustainability, and exceptional interest.

4) We examine how our Living Collections are currently used in support of our three main objectives: Research, Education and Conservation. Through quantitative analysis of patterns of use, and through illustrative case studies, we highlight what features and values of our Living Collections are most significant in terms of enhancing our ability to support these three objectives.

5) In the context of our analyses of the global network of botanic gardens, and coupled with an assessment of the strengths and weaknesses of our own Living Collections, we outline eight acquisitions approaches to improve the content of our Living Collections. We propose to focus on collecting and accessioning early-diverging land plants, wild-origin taxa, plant families not currently in cultivation, species linked to our National Collections, plant species threatened with extinction, plant diversity from two Northern and two Southern temperate hotspots, plants of special relevance to Humans and Society, and last but not least, our own native Flora.

6) Finally, we consider how best to improve the management of our Living Collections, and identify seven key qualities of well-managed Living Collections. They should be Open, Accessible, Accurate, Informative, Legal, Secure, and Integrated. In light of these, we define a series of actions which will enhance our Living Collections with respect to these qualities, over the next decade.

Throughout this Strategy, we have sought to enrich the document with case studies and visual insights that narrate the already remarkable value of our collections, but also of our hard-working staff that take care of the Living Collections and give them a voice through an astonishing and creative range of initiatives and activities. We dedicate this Strategy to them!

CUBG Strategic goals

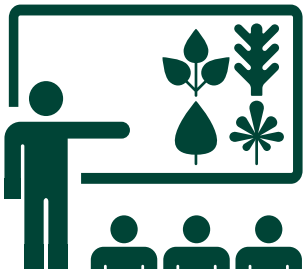
1

Goal 1:
To be recognised internationally as a centre of excellence supporting research in all fields where access to a living collection of diverse plant species is necessary.

2

Goal 2:
To encourage students from a wide range of HE institutions to engage with plant science and plant diversity, and to train future leaders in the field.

3



Goal 3:
To support learning about the natural world, and enjoyment of plants, plant science, and horticulture, by welcoming large numbers of visitors and offering an externally facing life-long education programme.

4

Goal 4:
To develop new opportunities that showcase the research and teaching of the University of Cambridge, and the global network of plant scientists, in a publicly accessible, horticulturally excellent, heritage landscape.

Document sections

This Living Collections strategy document comprises the following sections split into two parts:

The Collections

The Global Context

Through analysis of the global botanic garden network, we outline the global context for our Living Collections.

pages 5–9

Collections Overview

We outline the current content and organisation of our collections with emphasis on the Living Collections as the subject of this strategy.

pages 10–23

Measuring Quality

We define the values by which we measure collection quality and analyse the Living Collections according to these metrics.

pages 24–37

The Strategy

Collection Priorities

We explore the overarching collection priorities imposed by the central objectives of research, education, and conservation.

pages 40–59

Collection Acquisition

We outline eight acquisition approaches designed to improve the quality of the Living Collections.

pages 60–67

Collection Management

We propose seven overarching goals to improve the management of the Living Collections in delivery of our strategic aims.

pages 68–76

The Global Context

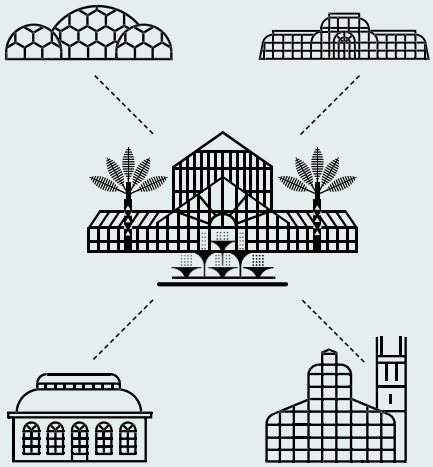
"A botanic garden is an institution holding documented collections of living plants for the purposes of scientific research, education, conservation, and display" (Wyse-Jackson, 1999)

Botanic Gardens have a rich history, which in western culture, dates as far back as the 16th century. Over many years the tradition of botanic gardens has spread across cultural and political boundaries, resulting in the global network of botanic gardens that we know today.

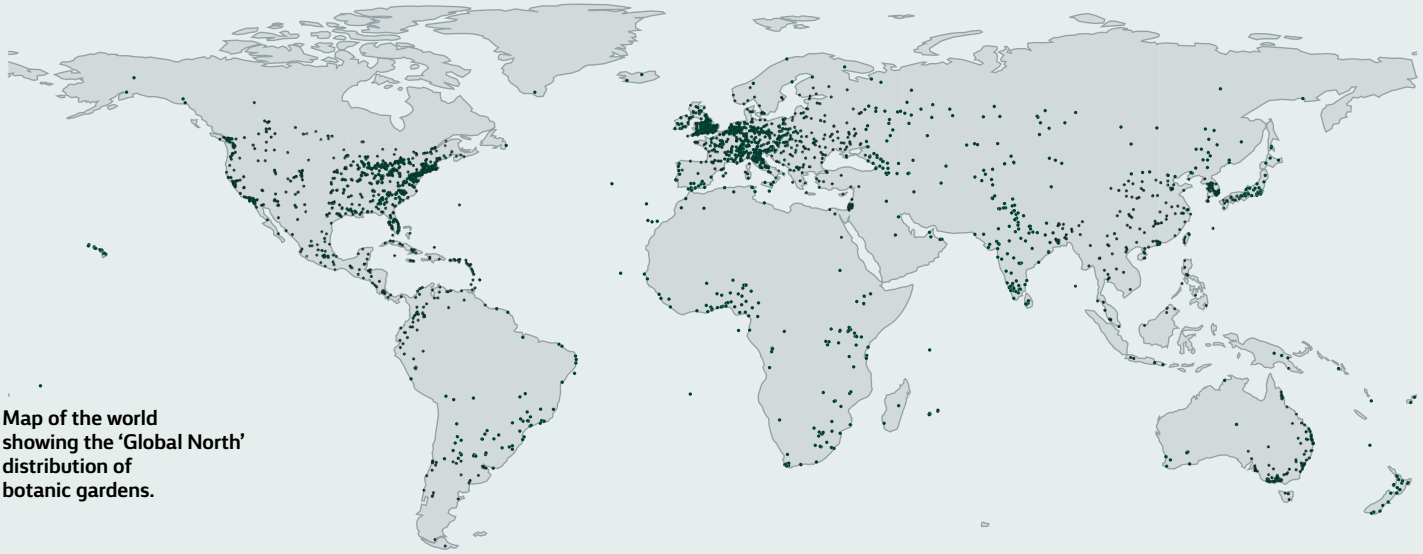
Our approach to understanding the value and significance of the Living Collections at Cambridge University Botanic Garden can only be fully understood with reference to this global network.

In this section, we describe this global context in light of our analysis of the Living Collections across the entire global network of botanic gardens.

Global Botanic Garden Network



What is the geographic extent and distributional bias of the global network of botanic gardens?



Map of the world showing the 'Global North' distribution of botanic gardens.

'Annually over 300 million people visit botanic gardens world-wide'

The global network of botanic gardens is composed of some 3,653 institutions world-wide. Of these institutions Botanic Gardens Conservation International (BGCI) holds collection data for some 1,116 institutions (as of 2017).

The distribution of the botanic garden network can be described as a 'Global North' distribution, with a preponderance of botanic gardens in Europe, North America, Asia and Australasia. Conversely, there are few botanic gardens in Africa, South America, and the Middle-East.

This distribution reflects both economic development and the colonial era which has enriched the economies of the 'Global North' and driven the development of botanic gardens.

However, the areas that harbor the fewest botanic gardens, are also the areas that hold much of the natural wealth of the plant kingdom. This disparity has significant consequences for the current global network of botanic gardens, limiting our ability to serve as a repository the world's flora, and to safeguard threatened tropical diversity.

3,653 **Botanic Gardens world-wide**

1,433,905 **Collection Records**

118 **Countries**

6 **Continents**

Ross Mounce, Paul Smith, **Samuel Brockington*** (2017) Ex-situ conservation of Plant Diversity in the World's Botanic Gardens Nature Plants. 3 (10) 975

Collecting the World's Flora

How many species, genera and families of plants do we hold within our global network of Living Collections?

105,206 Species
9,979 Genera
476 Land Plant Families
423 Vascular Plant Famiies

In 2017, following a two-year research programme, the CUBG in collaboration with BGCI published the first comprehensive analysis of the contents of the Living Collections held across the entire global network. The objectives of the study were to estimate how much of the world's flora is captured in global Living Collections, to understand the geographic and taxonomic biases in representation of the world's flora, and to benchmark the contribution of the global botanic garden network to the *ex-situ* conservation of threatened species.

Analysis of the collections data from 1,116 institutions reveals that the global botanic gardens hold a minimum of 105,206 species or 30% of all known land plant species. This equates to 9,979 genera or 59% of land plant genera, 476 or 75% of land plant families, and 423 or 93% of all vascular plant families.

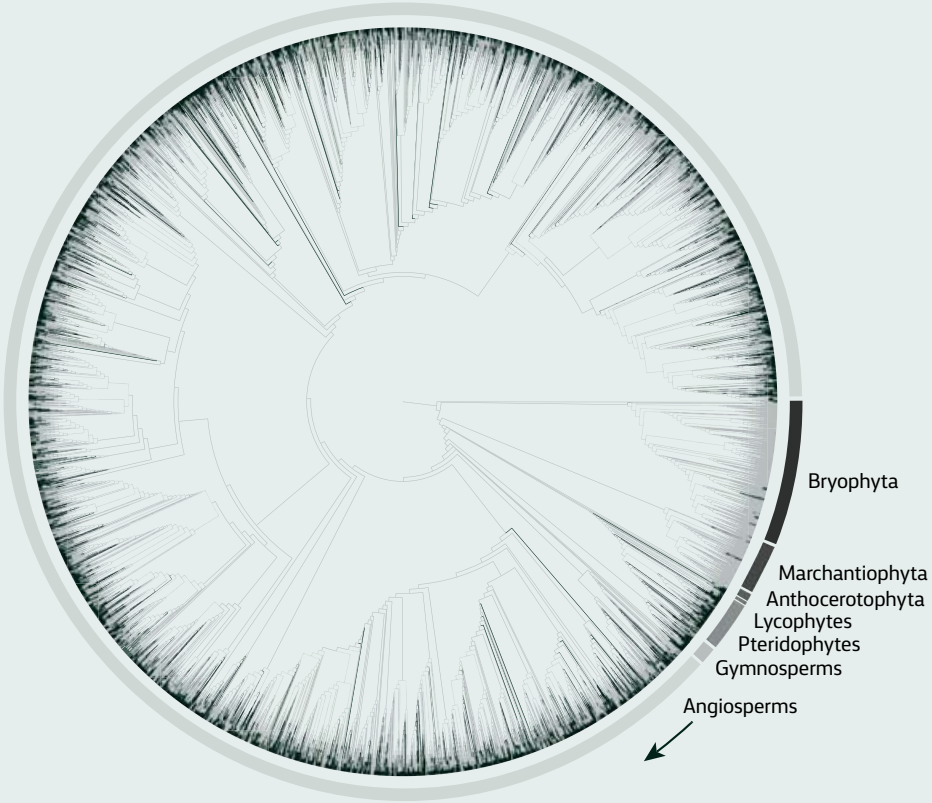
In collating this extraordinary array of plant diversity, the botanic gardens make the World's Flora accessible to researchers, teachers, horticulturalists, and the 300 million people who annually visit botanic gardens world-wide.

Capturing the Plant Tree of Life

'The early-diverging plant lineages, mosses, liverworts and hornworts are poorly represented or documented across the global botanic garden network'

To what extent do we capture the full evolutionary diversity of the Plant Tree of Life within our global network of Living Collections?

The Plant Tree of Life with the lineages represented in Living Collections shaded in black



As shown in the diagram of the plant tree of life above, the global botanic garden network does a remarkable job of capturing the evolutionary diversity of the Pteridophytes, Gymnosperms and Angiosperms. This achievement reflects the traditional horticultural strengths of botanic gardens in the cultivation of ferns, conifers and flowering plants. The phylogenetic breadth of our Living Collections ensure that botanic gardens are uniquely positioned to cater to a diverse set of research interests. Collectively, we are able to support nearly all activities which depend on access to diverse, taxonomically accurate, living material, of known provenance.

Nonetheless, many notable gaps remain. Many lineages of plants do not lend themselves to cultivation in Living Collections. For example, marine aquatic plants, and plants with complex ecological dependencies, such as parasitic plants, will always pose a challenge to cultivation in botanic gardens. But this gap analysis serves to highlight many lineages which are currently absent from Living Collections world-wide, and which could more easily be brought into cultivation.

For example, we collectively do a poor job of collecting, cultivating and documenting early-diverging land plants – the mosses, liverworts, and hornworts. And yet these organisms are a key scientific frontier in our efforts to understand the early evolution of land plants, and their colonisation of terrestrial environments.

By targeting these gaps in the plant Tree of Life, we can ensure that our Living Collections continue to anticpate and support new and emerging fields of research.

Insuring against Extinction

To what extent do we safeguard the world's threatened species within our global network of Living Collections?

Number of threatened species held in *ex-situ* collections

In the face of the current extinction crisis, the Living Collections of the world's botanic gardens can serve as a last-ditch insurance policy to safeguard our most threatened plant species.

Our analyses show that, as of 2017, 41% of the globally threatened plant speies are held *ex-situ* outside of their native habitats. However, only about 10% of our global network capacity is devoted to the cultivation and preservation of endangered species. Clearly, despite the diverse goals and objectives of botanic gardens, there is capacity to conserve a greater proportion of the threatened flora in our collections.

Fundamentally, there is no technical reason why plant species should become extinct, given the array of conservation techniques such as seed banking, cultivation, tissue culture, assisted migration, species recovery and ecological restoration. And as a professional community, botanic gardens possess a unique skill set that encompasses finding, identifying, collecting, conserving and growing plant diversity across the taxonomic spectrum.

% of network capacity devoted to cultivation of threatened species

% of threatened plant species held in *ex-situ* collections

Collections Overview

Cambridge University Botanic Garden is one of the largest University-owned botanic gardens in the world. Here, we look after four types of collections: our library, archives, herbarium, and Living Collections.

Our Cory Library holds 7,827 volumes with many precious books of rare provenance, some annotated by Charles Darwin.

Our Archives include about 1,200 manuscripts and objects, including the original watercolour map of the garden from 1834.

Our Herbarium collection of dried plants, now embedded within the larger University Herbarium totals some 14,000 accessions.

Our Living Collections of cultivated plants comprise some 14,000 accessions and over 8,000 plant species, distributed across a 40-acre landscape.

Opposite page:
The Bee Borders

Horticultural Sections

Our documented Living Collections are managed by six horticultural teams: Glasshouse (GH), Alpine & Woodland (AW), Trees and Shrubs (TS), Demonstration & Display (DD), Systematics (SY) and Experimental (EX). Each team curates a unique collection of plants representing different taxonomic, biogeographic and ecological priorities, and occupying distinct areas of our landscape.

Glasshouse

Description: A collection of plants from tropical, sub-tropical, and warm temperate regions of the world, and generally from warmer climes than our local climate allows.

Location: The Glasshouse Range including Temperate House, Oceanic Islands House, Tropical Wetland House, Arid House, Lower Land Plant House, the Glasshouse Bays, and the Reserve Glasshouses

Accessions: 3,051
Species: 2,194
Families: 235
Genera: 982
Wild Origin: 19.87%
Wild-derived: 6.23%
Garden Origin: 65.05%
Unknown Origin: 8.85%

Cultivars: 226

Red Listed Species: 73

Geographic strengths:
Central America, South America, Tropical Asia and Australasia

Taxonomic strengths:
Orchids, Gesneriaceae, Acanthaceae, Araceae, *Passiflora*, Succulents.

Alpine & Woodland

Description: A collection of plants from the alpine and rocky regions of the world, which generally occur in hilly and mountainous regions below the lower limit of permanent snow.

Location: Alpine Nursery, Mountains House, and Rock Garden

Accessions: 3,870
Species: 2,023
Families: 147
Genera: 676
Wild Origin: 23.29%
Wild-derived: 4.00%
Garden Origin: 63.48%
Unknown Origin: 9.24%

Cultivars: 588

Red Listed Species: 21

Geographic strengths:
Europe and North America

Taxonomic strengths:
Saxifraga, *Fritillaria*, *Tulipa*, *Alchemilla*, Calcicole Alpines.

Trees & Shrubs

Description: A collection of perennial trees and shrubs largely from Temperate Regions, with the core collection as a taxonomic perimeter around the western half of the garden.

Location: Dispersed through the garden but notably concentrated on the boundaries of the garden, Henslow Walk, the Gilbert-Carter area, the Old and New Pinetum, and the Eastern Landscape

Accessions: 2,153
Species: 938
Families: 99
Genera: 313
Wild Origin: 20.06%
Wild-derived: 2.08%
Garden Origin: 56.69%
Unknown Origin: 18.17%

Cultivars: 460

Red Listed Species: 33

Geographic strengths:
Europe, North America, and China

Taxonomic strengths:
Conifers, *Betula, Tilia, Quercus, Lonicera, Ribes, Ruscus.*

Demonstration & Display

Description: A collection of plants which works to enhance the visual appeal of the garden with horticulturally outstanding displays in key areas throughout the garden.

Location: Dispersed through the garden but notably concentrated around the main gates, the Bee Borders, the Mediterranean Beds, the Scented Garden, the New Zealand Garden, the Winter Garden, and the Chronological Beds

Accessions: 2,257
Species: 1,001
Families: 145
Genera: 546
Wild Origin: 10.51%
Wild-derived: 4.74%
Garden Origin: 76.77%
Unknown Origin: 7.98%

Cultivars: 695

Red Listed Species: 4

Geographic strengths:
Europe, North America and New Zealand

Taxonomic strengths:
Boraginaceae, Lamiaceae, Rosaceae, *Acer*, Hammamelidaceae, Poaceae, *Bergenia*.

Systematics

Description: A collection of plants which focuses on displaying the classification of flowering plants with emphasis on representing familial diversity.

Location: The Systematic Beds

Accessions: 687
Species: 610
Families: 235
Genera: 982
Wild Origin: 12.68%
Wild-derived: 2.19%
Garden Origin: 66.76%
Unknown Origin: 18.37%

Cultivars: 60

Red Listed Species: 2

Geographic strengths:
Europe and North America

Taxonomic strengths:
Fabaceae, Poaceae, Asteraceae, Geraniaceae, *Lavandula*, *Rosmarinus*.

Experimental

Description: A section which mainly focuses on growing experimental plants in our reserve houses in support of our researchers, but also has responsibility for native and ecological plant displays.

Location: Fen Display, Chalk Grassland, Ecological Mound and Science Display Garden

Accessions: 699
Species: 412
Families: 85
Genera: 233
Wild Origin: 51.58%
Wild-derived: 6.73%
Garden Origin: 38.40%
Unknown Origin: 3.30%

Cultivars: 145

Red Listed Species: 6

Geographic strengths:
United Kingdom and Europe

Taxonomic strengths:
Rosaceae, Poaceae, Juncaceae, Apiaceae.

Our Landscapes

Our Landscapes

Garden areas:
Temperate Aboretum
Stream Garden
Woodland Garden
Bog Garden
Schools' Garden
Rock Gardens
Main Walk
Systematic Beds
Mediterranean Beds
The Glasshouse Range
The Fern Display
The New Zealand Garden
Life before Flowers
Terrace Garden
Bee Borders
Gilbert Carter Woodland
British Wild Plants
Cory Lawn
Dry Garden
Rose Garden
Winter Garden
Grass Maze
Science Display Garden
Winter Garden
Chronological Bed
Herbaceous Beds
Scented Garden
Autumn Garden

14,000
Accessions

8,000
Plant Taxa

315
Plant Families

139
Threatened Species

40
Acres of landscaped gardens

A Selection of Diversity

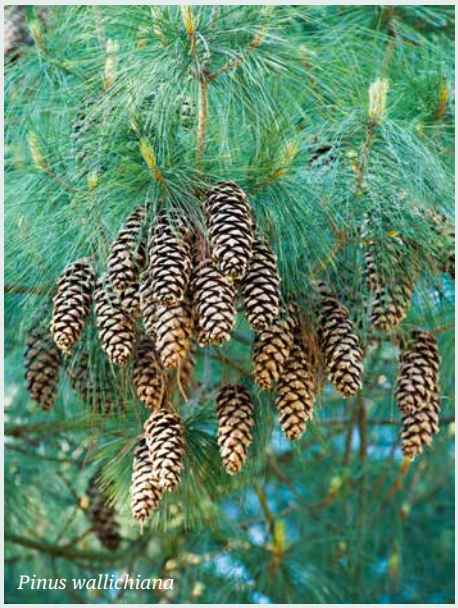

Bulbophyllum lobbii


Strongylodon macrobotrys


Zingiber spectabile


Zamia furfuracea


Passiflora cuneata


Pinus wallichiana


Dicksonia squarrosa


Dionysia tapetodes


Alchemilla plicatula


Clitoria ternatea


Anigozanthos flavidus


Petrea volubilis


Codonopsis rotundiflora


Miscanthus sinensis


Davidia involucrata


Echinopsis atacamensis


Adiantum x mairisii


Coryanthes macrantha

Measuring Quality of the Collections

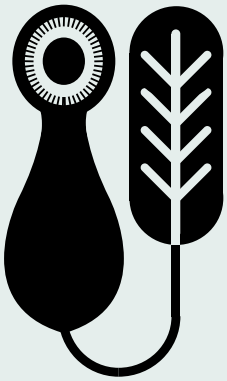
The value of our Living Collections in helping us to meet our goals of research, education and conservation is influenced by a number of key metrics which relate to the following concepts:

- **Rarity**
- **Diversity**
- **Wild Origin**
- **Extinction Risk**
- **Seed Banking**
- **Provenance**
- **Duplication**
- **Longevity & Sustainability**
- **Exceptional Interest.**

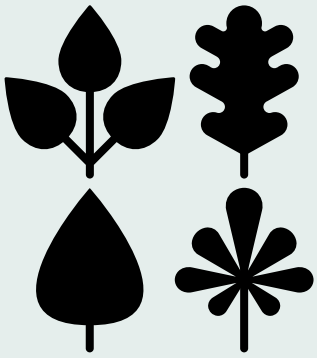
Opposite page:
Nepenthes alata

Quality metrics

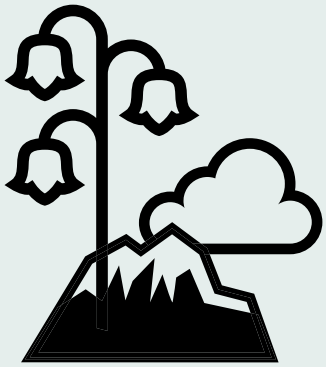
The purpose of the following section is to determine what value our Living Collections hold according to the above metrics, and to explore how that value is distributed among the different parts of the collection, managed by the different horticultural sections: Glasshouse, Alpine & Woodland, Trees & Shrubs, Demonstration & Display, Systematics and Experimental.



Rarity

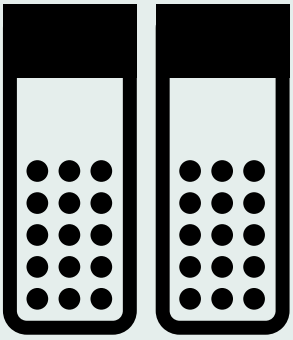


Diversity



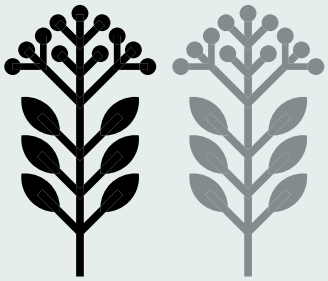
Wild Origin

Extinction Risk

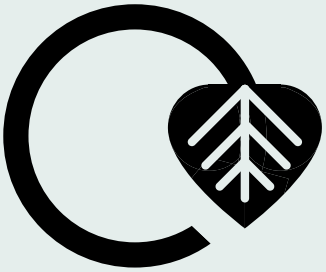


Seed Banking

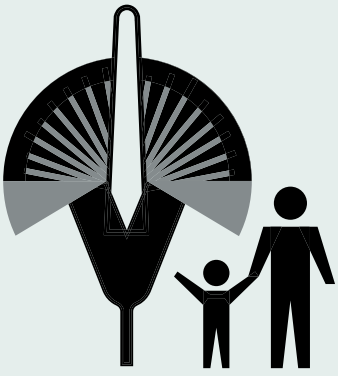
Provenance



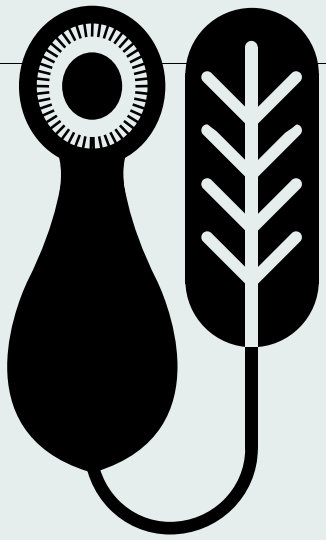
Duplication



Longevity & Sustainability



Exceptional Interest

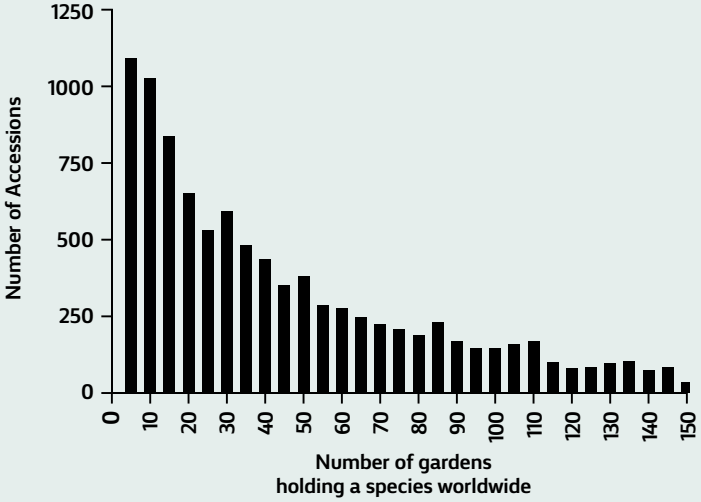


Rarity

The global network of botanic gardens comprises some 3,653 institutions with the collective mission to hold much of the world's plant biodiversity for the purposes of science, education, conservation, and display. In the delivery of those objectives, many species are held in common by individual gardens across the network. However, species that are rare and held in *ex-situ* collections achieve three important goals: 1) enhancing our value as a source of material for other institutions within the botanic garden network; 2) increasing our unique value as a resource to science and conservation practitioners by providing difficult to obtain material; 3) identifying the garden as a visitor attraction providing the opportunity to view the unusual flora of the world.

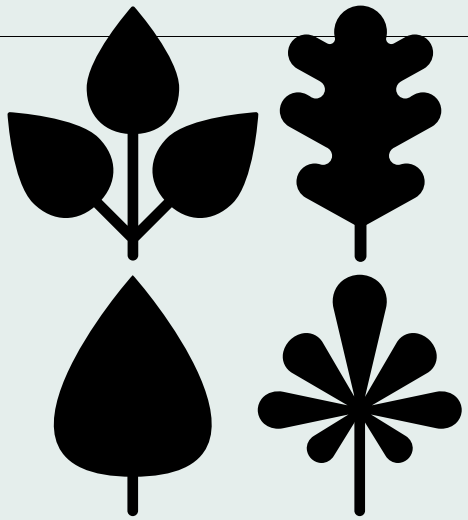
'We hold a unique and distinctive collection with 10% of our species documented in fewer than five gardens world-wide, and 20% of our species occurring in fewer than 10 gardens world-wide'

CUBG: Proportion of Rare Species



Analysing our collections in the context of global datasets of *ex-situ* diversity, allows identification of the rarest accessions across CUBG, and understanding as to how that rarity is distributed amongst the different horticultural sections. These analyses are restricted to accepted biological species only, due to the taxonomic variability in cultivar names. Across the entire garden, our collections exhibit a non-normal distribution with a massive skew towards rarity, emphasising that we hold a unique and distinctive collection of plants. For example, 10% of our species are held in fewer than five gardens worldwide, while 20% of our species are held in fewer than 10 gardens world-wide. However rare accessions are not distributed evenly among the different horticultural sections. For example, 42% of all accessions found in fewer than five botanic gardens around the world are cultivated in our Glasshouses and a further 31% of all equivalently rare accessions are in the Alpine & Woodland Section. Consequently, some horticultural sections have a disproportionate impact on the rarity and uniqueness of the Living Collections relative to others.

Quality Metrics



Diversity: Taxonomic

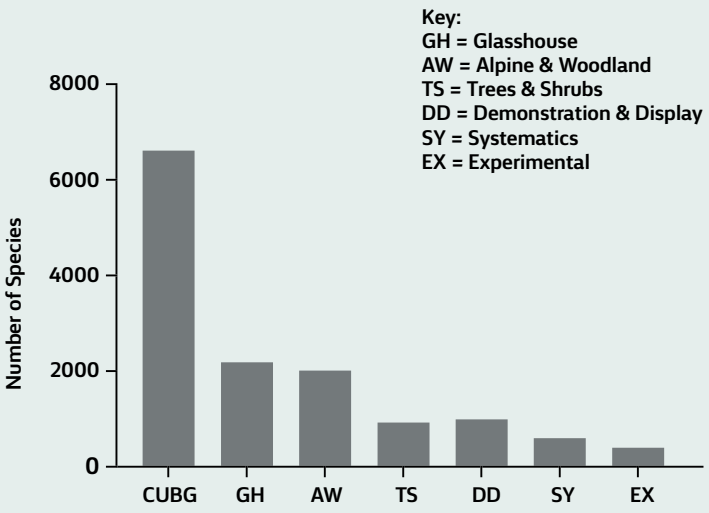
14,209 Accessions
8,215 Taxa
6,624 Species
2,097 Genera
315 Families

The primary determinant of the quality of botanic gardens is the diversity of their collections. Diverse collections enhance all collection dependent activity and underpin the breadth and quality of education courses and the extent to which we can provide research material. Measuring and quantifying diversity is a complex problem and can range from the simplest measures of diversity at different taxonomic hierarchies (e.g. number of species, genera, families) to more complex measures of diversity that include phylogenetic or evolutionary distance criteria. Additional non-taxonomic or non-phylogenetic measures of diversity could include the degree to which different ecological functions are captured, and the degree to which different biogeographic regions are represented in the Living Collections.

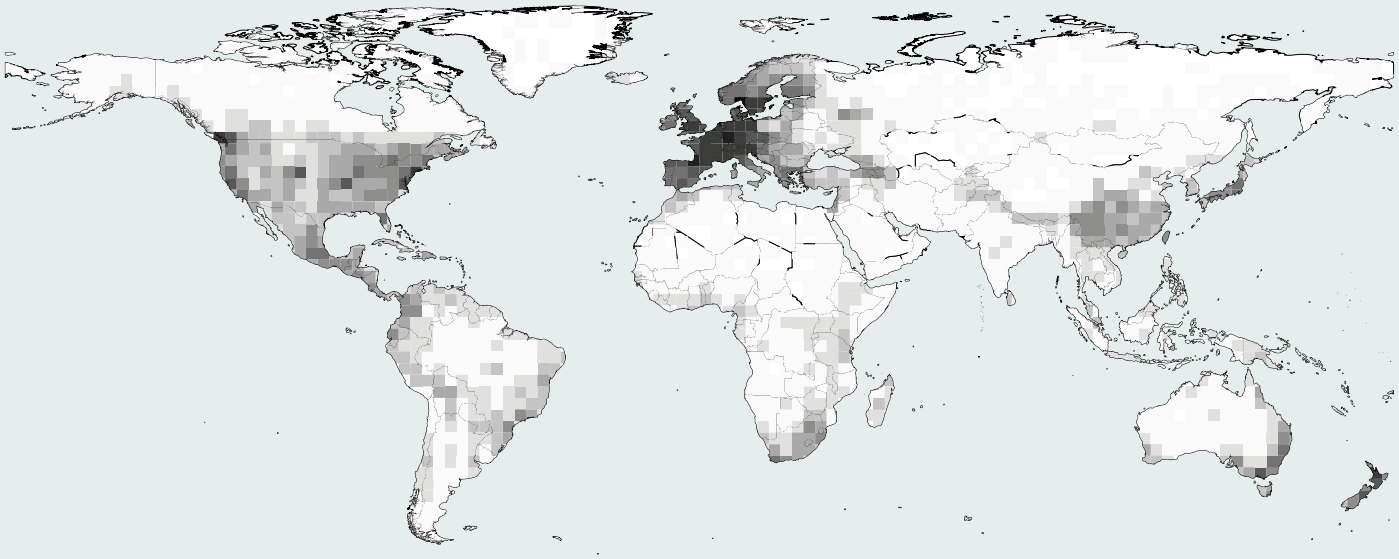
'Diverse collections enhance all activities across the garden and underpin the breadth and quality of education courses and the extent to which we can support a wide range of research'

CUBG: Taxonomic Diversity

Here, the diversity of the Living Collections is assessed with respect to the relative number of species, genera and families in the CUBG as a whole, as well as across the different horticultural sections. Within our entire Living Collections we hold 6,624 species, spread amongst 2,029 genera and 315 families. Such measures differ among the various horticultural sections. For example, Alpine & Woodland cultivate the most accessions, but for all other measures i.e. number of species and number of genera Glasshouse holds the most diversity.



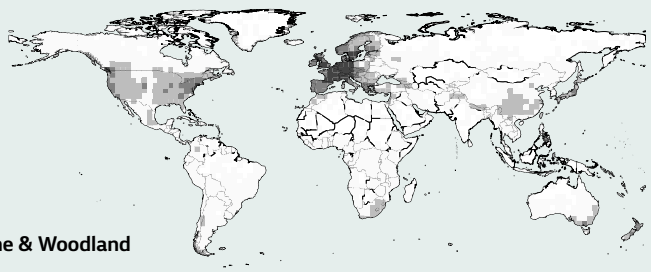
Diversity: Biogeographic



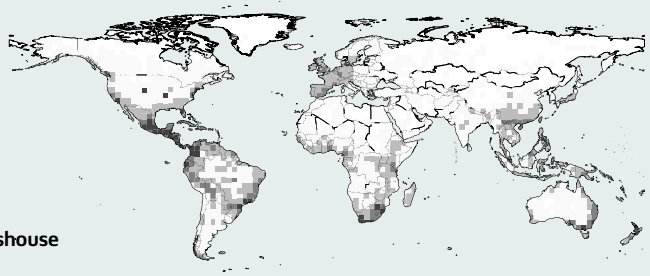
'Our Living Collections are drawn from over 141 countries, primarily from Northern and Southern Temperate regions, but with strong representation from Tropical Central and South America'

CUBG: Biogeographic Diversity

In terms of biogeographic origin, our collections fit the 'Global North' pattern, with our Living Collections composed of Western European species and complemented by accessions from the predominantly temperate North America, China, Japan, South Africa, South Western Australia and New Zealand. The same analyses performed on individual horticultural sections nicely reveal the focus of some of the more specialised sections. Examples include, the heavy sampling from mountainous ranges of North America within the Alpine & Woodland collection, the heavier tropical focus particularly in Central America, within the Glasshouse collection and extensive sampling from Chinese temperate forests within the Trees & Shrubs section.

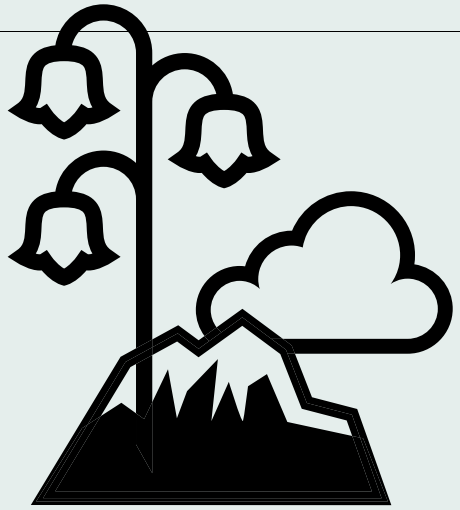


Alpine & Woodland



Glasshouse

Quality Metrics



Wild Origin

In general, the value of our living material declines from point of acquisition from the wild. The declining value of cultivated plants is due to a number of factors. The genetic variability of seeds collected from cultivated individuals will almost certainly represent a fraction of the potential found in natural populations. In general, accuracy of documentation deteriorates over time, leading to accessions of unknown, or at least uncertain, provenance. Cultivated plants, particularly in botanic gardens, are susceptible to hybridisation - which may allow two closely related species that would naturally be geographically isolated to come into contact and hybridise. Cultivated plants are exposed to different selection pressures than those from wild populations, perhaps filtering out genetic characteristics that bestow fitness in their native habitat, and which are the object of research.

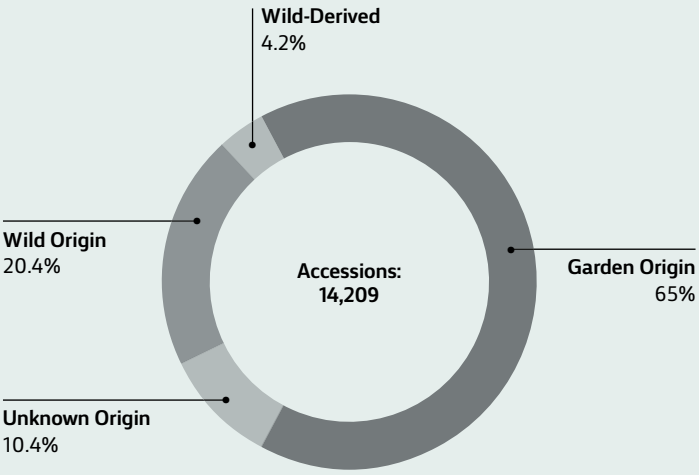
'Just over 20% of our accessions have been sourced directly from the wild, and a further 4% are derived from wild collected species'

CUBG: Proportion of Wild Origin Accessions

Across the entire Living Collections, just over 20% of our accessions are of wild origin, 65% garden origin, 10% unknown origin, and 4% wild-derived.

A similar proportion can be found across most horticultural sections with some notable exceptions. For example Demonstration & Display exhibit just 10.51% accessions of wild origin, with a corresponding increase in accessions of garden origin at 76%, reflecting their primary focus on cultivars and horticultural display rather than biologically accepted species.

The Experimental section that maintains our native species exhibits remarkably high levels of wild collected material at 51.6%, with concomitant decreases to 38% garden origin and 3% unknown origin. This pattern is likely a reflection of the high proportion of UK species in the Experimental collections, where our close proximity to the natural distribution of these species allows for more wild collection and better provenance data. In general, the low proportion of material that is wild-derived (4.15%) emphasises poor sustainability of wild accessions in the living collections.

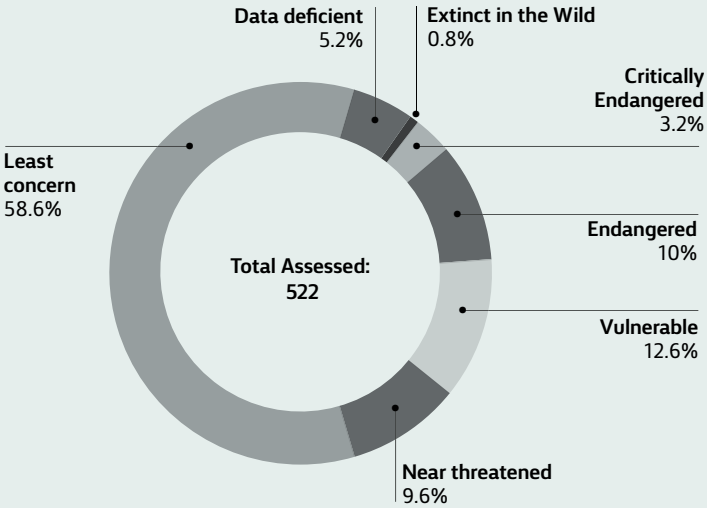


Extinction Risk

For species at risk of extinction, conservation through *ex-situ* cultivation is a necessary intervention. Threatened species refer to three tiers of extinction risk - 'Vulnerable', 'Endangered', and 'Critically Endangered' - reflecting the risk of extinction in their natural habitats. Threatened-species lists are established tools that provide a scaled assessment of extinction risk, which can guide conservation actions. Botanic garden-led action around threatened plants may take several forms: rescuing threatened germplasm, producing material for conservation research, bulking up germplasm for storage, supplying material to reduce pressure from wild collecting, growing species that cannot be maintained in a seed store, producing material for reintroduction and restoration. The number of threatened species held is a measure of the conservation value of the Living Collections, when coupled with appropriate collections management. There is a need to cultivate intraspecific genetic diversity, to maintain that genetic diversity from source, and to ensure the longevity of the diversity within the collections.

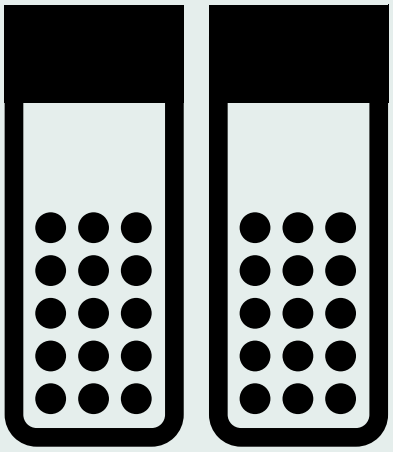
'We hold 139 species that are threatened with extinction, of which 50% have been brought into the collection since 2005. We hold four species that are now extinct in the wild'

CUBG: Proportion of Threatened Species



The total number of IUCN assessed species in the garden is 522, while the total number of IUCN designated threatened accessions held in CUBG is 259, equating to 139 threatened species. Of these, 4 are extinct in the wild, 17 are critically endangered, 52 are endangered, and 66 are vulnerable. Of the remaining assessed species, a further 50 are near threatened, 306 have been designated as least concern, and 27 species are data deficient. Most threatened species are found within Glasshouse. But in many sections, the representation of threatened species is relatively low, particularly in the Trees & Shrubs section, where perennial species should enable conservation longevity. Over 50% of all threatened plant accessions have been brought in since 2005, emphasising recent good quality accessions, but also the poor longevity of threatened species in the garden. The median number of accessions per threatened species is one, indicating both a lack of genetic variability in the threatened plant collections, and lack of specific collections management policy to protect them.

Quality Metrics



Seed Banking

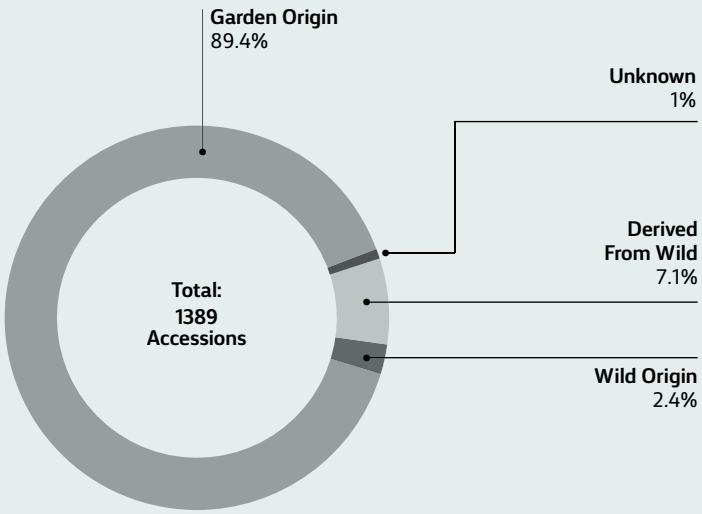
‘Seeds are a convenient means of long-term storage of genetic diversity, as the samples are small in size, are easily handled, require low maintenance and frequently remain viable for long periods’

The banking of seeds has considerable advantages over other methods of *ex-situ* plant conservation such as ease of storage, economy of space, relatively low labour demands and, consequently, the capacity to maintain large samples at an economically viable cost. Seeds are a convenient means of long-term storage of genetic diversity as the samples are small in size, easily handled, require low maintenance and frequently remain viable for long periods. In general, conditions of low temperature and desiccation allow seeds to maintain viability. Seed banks take up little space, but need to be maintained at low temperatures, with a requirement for germination tests, growth trials and regeneration. They are also not suitable for species with recalcitrant seeds. Nonetheless, the proportion of seed held has important implications for the longevity and sustainability of our collection, and can ensure the retention of valuable accessions, while limiting the need for constant influx of common species.

CUBG: Proportion of Collection Held as Seed

The CUBG seed bank holds 1,389 accessions for 762 species divided among 79 families.

The majority of the seed collection has been harvested from Systematics, which rely on annual seed stocks to maintain their displays. The high proportion of garden-origin is simply a reflection of the fact that the seeds are collected within our own garden. More concerning is that the total amount of wild-derived material is low, indicating that we have historically not preferentially collected germplasm for hard-to-obtain wild material.



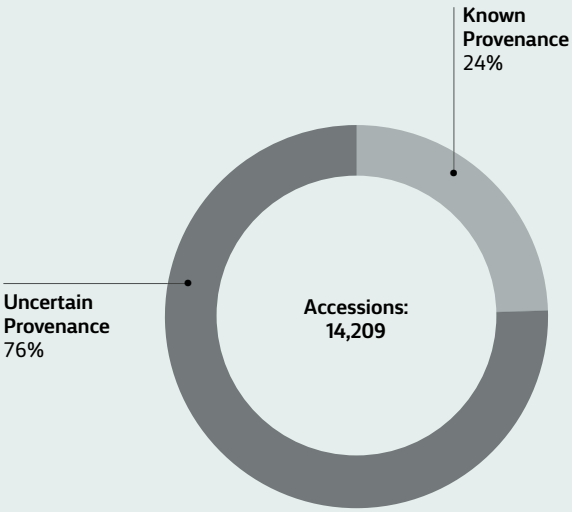
Provenance

Provenance, or the place of origin of a species, is essential information that underpins many potential applications in research and conservation. Known provenance is an essential requirement for all scientific disciplines, but especially branches of systematic research such as taxonomy and biogeography; appropriate use of collections for targeted species recovery and ecological restoration; and the legal use of collections for research and development, especially where the research may lead to access benefit sharing through commercialisation. In general, the accuracy of documentation deteriorates over time, leading to accessions of unknown, or at least uncertain, provenance. Consequently, the availability of provenance data is intimately linked to the immediacy of wild collecting.

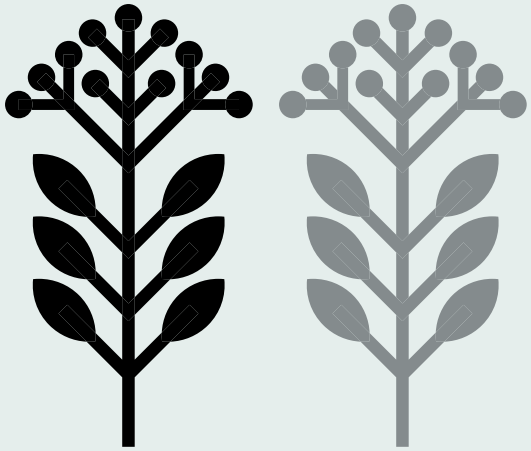
'24% of our collections are associated with provenance data that links them to their country of origin. Most accessions of known provenance are wild-collected'

CUBG: Availability of Provenance Information

The availability of provenance information is very tightly correlated with the proportion of wild origin material in each section. Approximately 98% of all accessions with provenance data are wild in origin. The correlation between wild origin and provenance data is unsurprising, as accurate provenance data is most commonly retained the closer we are to the point of sourcing from the wild. However, the corollary is how poor data sharing is in relation to material of garden origin, and how frequently such material is accessioned into the Living Collections without first obtaining provenance information. Consequently, our collections are lacking for those utilisations where provenance information is essential. Furthermore, under current international legal frameworks, research and development utilisation in the absence of reliable provenance information carries risk and maybe ultimately be illegal. For example, 75% of specimens accessioned since ratification of the Nagoya Protocol in 2014 lack provenance data related to country of origin.



Quality Metrics

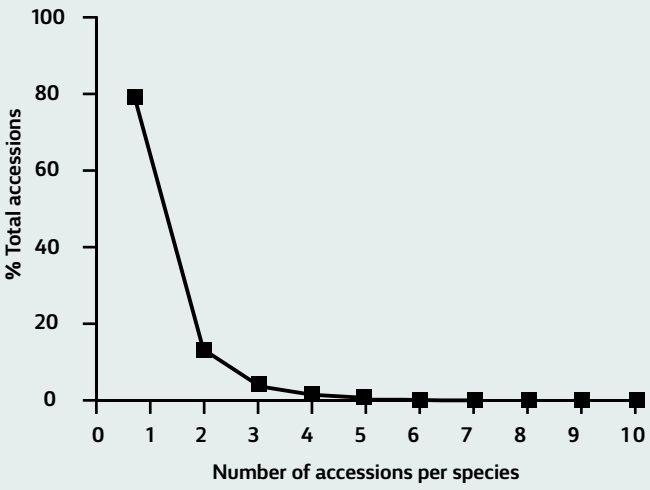


Duplication

Duplication is the maintenance of multiple accessions per species, either within a horticultural section or between horticultural sections. It can be intentional or incidental. Duplication among and within collections is in some instances desirable or essential, for example, conserving genetic diversity of threatened species, installation of large monotypic stands for landscaping, or the frequent cultivation of species that offer exceptional public appeal. However, it is also potentially a waste of resources and collection space, and can result from shortcuts in sourcing, or lack of forward planning in the acquisition of new material, resulting in the recycling of species and accessions within the collections.

'25% of our 14,000 accessions are cultivated in duplicate within our collections. Much of this duplication may be necessary but needs case-by-case evaluation'

CUBG: Degree of Duplication



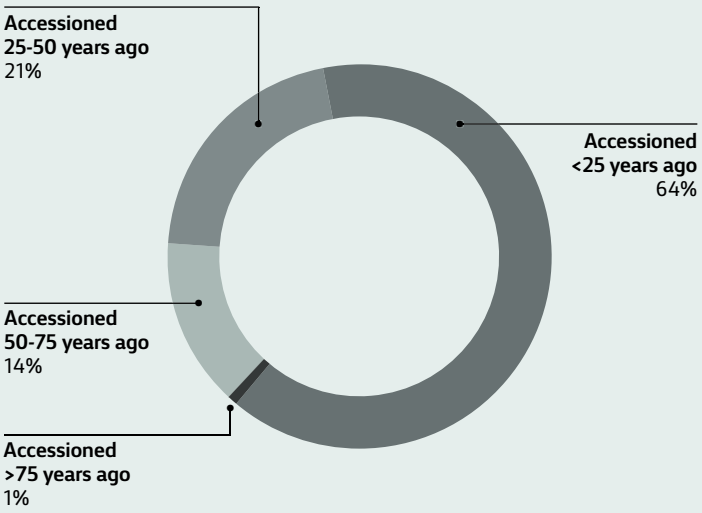
Across the entire garden, 76% of the species in the collections are represented by one accession, while 92% of the species in the collections are represented by two accessions or less. Within the different horticultural sections, there is greatest duplication per species within Trees & Shrubs, Alpine & Woodland and Demonstration & Display, substantially less in Glasshouse, Experimental and Systematics. Among the different horticultural sections, the collections of Glasshouse, Trees & Shrubs and to a lesser extent Alpine & Woodland are highly specialist and exhibit very little duplication of species present in other sections. However close to 50% of the species in Experimental, Demonstration & Display and Systematics are represented in at least one other horticultural section. In effect, over 25% of our 14,000 accessions are cultivated in duplicate or more within our own collections, representing a considerable use of time, space and resources. Much of this duplication may be necessary, but on a species-by-species, accession-by-accession basis, the degree of duplication needs to be evaluated and resolved.

Longevity & Sustainability

The Living Collections of botanic gardens have been described as “rivers of diversity” due the relative impermanence of living collections. Compared with other collections-based institutions, our collections are transient, which is both an opportunity and a threat. As an opportunity it allows Living Collections to shed burdensome historical legacies and change rapidly to meet new demands. But as a threat, it can mean that valuable, rare and important accessions can be unwittingly lost. Longevity of collections is both an important measure of the quality of collections management, but also an essential requirement to support many aspects of our mission. Researchers working on material in our Living Collections need to be confident that material will continue to be available until the end of the research project. Education courses rely on the consistent availability of key material to support planned curricula and course designs. Finally, if botanic gardens are to provide a fundamental insurance policy for the conservation of threatened taxa, it is imperative that endangered species have longevity in our collections.

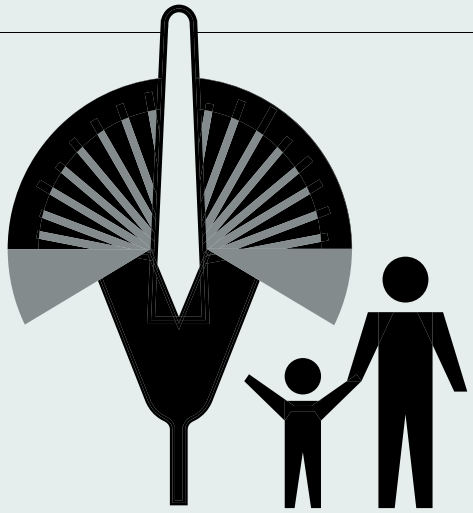
‘64% of all of our specimens were accessioned <25 years ago and only 1% of all of our accessions have been in our collection for more than 75 years’

CUBG: Longevity & Sustainability



Analysing the age structure of the collections allows inferences about longevity and turnover, when assuming more or less constant annual influx of accessions. Across the entire CUBG Living Collections, 64% of all specimens were accessioned <25 years ago, 21% were accessioned between 25-50 years ago, 14% were accessioned 50-75 years ago, and just 1% were accessioned >75 years ago. Some of our collections deviate from the broader pattern. Glasshouse is one of the most speciose horticultural sections, but over 60% of its diversity has been accessioned in the past 10 years, with 80% accessioned <25 years ago, and just 12% accessioned between 25-50 years ago. Such an age profile reveals poor longevity of accessions in this section over longer time periods, where recent accessioning activity has compensated for high rates of turn-over. The woody perennial collections within Trees & Shrubs exhibit far greater longevity, with 65% of accessions over 25 years old, and 25% over 50 years old. The age structure of the Trees & Shrubs collections emphasises their potential value for *ex-situ* conservation due to their longevity in our collections.

Quality Metrics



Exceptional Interest

'*Amorphophallus titanum* or the 'Titan Arum' is one of the most prominent in the plant kingdom due to the fact that it has one of the largest inflorescences of any species'

The previous values are all quantitative, but the value of our collections is also determined by more subjective qualitative aspects, namely their special interest to scientists, educators and the public - i.e. which species hold the most interesting narratives, convey important biological insights, represent scientific advances, or are simply beautiful organisms in some regard. For example, *Nymphaea odorata*, the American white water lily is widely grown but as altogether remarkable and charismatic plants, they offer exceptional interest to the public. Such an approach is akin to the "Big 5" approach of zoological collections, whereby zoos and safari parks seek to hold lion, leopard, rhinoceros, elephant and buffalo, as these five species hold exceptional interest for your typical visitor. An equivalent list for botanic gardens is less formalised but might include: the Giant Redwood (*Sequioadendron giganteum*), the Amazonian water lily (*Victoria amazonica),* Darwin's orchid (*Angraecum sequipedale*), the Jade Vine (*Strongylodon macrobotrys*), and as discussed below, the Titan Arum (*Amorphophallus titanum*).

CUBG: Case study in Exceptional Interest

Amorphophallus titanum or the 'Titan Arum' is one of the most prominent plants in the plant kingdom due to the fact that is has one of the largest inflorescences of any plant species. *Amorphophallus titanum* was discovered in Sumatra in 1878 by Odoardo Beccari who then sent seeds to the botanic gardens in Florence and Kew. It took 11 years before the first plant flowered in 1889 at the Royal Botanic Gardens Kew. Since then there have been only a few hundred flowerings of this plant in cultivation, with most individuals taking 10–15 years to reach flowering.

The infrequency of the flowering, the size and beauty of the inflorescence, and the appalling smell of the flowers ensure that this is always a winning visitor attraction. The 'Titan Arum' has flowered three times in our garden, providing a unique and exciting experience for both our staff and visitors.

In 2015, our 'Titan Arum' flowered at the height of summer. During the 7 day flowering period in July we welcomed 13,443 visitors including late openings to cater for the general excitement and interest. Compared to equivalent time periods in previous years in which the 'Titan Arum' did not flower, this represents a 81% increase in footfall in the garden.

The 'Titan Arum' represents an ideal demonstration of the power of an unusual, rare, and biologically interesting and charismatic plant to excite the imagination of the wider public. The increased footfall provides an opportunity not just for increased revenue but also to engage the public with plant science and the wonder of the natural world.

13,443
Visitors

81%
Increased footfall

60K
Twitter impressions

423
New followers

22
Media/News articles


"As close to a religious experience as a Plant Scientist can get! What a day!"
"I think half of the city has turned up"
"Battled through the rain last night to see the Titan. Amazing plant! Disgusting Smell!"

The Strategy

In this strategy we answer three main questions:

1. What aspects of the Living Collections do we need to prioritise in support of our three core objectives: Research, Education, and Conservation?

2. How can we best increase the value of our Living Collections through the collection and acquisition of new material?

3. How can we improve and develop our management and procedures to better serve the Living Collections and deliver our core objectives?

The strategy comprises three sections:

Collection Priorities

Informed by our analyses, we outline the overarching collection priorities that are needed to fulfil the missions of
- **Research**
- **Education**
- **Conservation.**

Collection Acquisition

We outline eight concurrent material acquisition strategies that will be needed to shape the contents of our Living Collections in order to meet these collection priorities.

Collection Management

We define the major priorities in terms of management of the Living Collections to ensure the collections best support research, education and conservation activities.

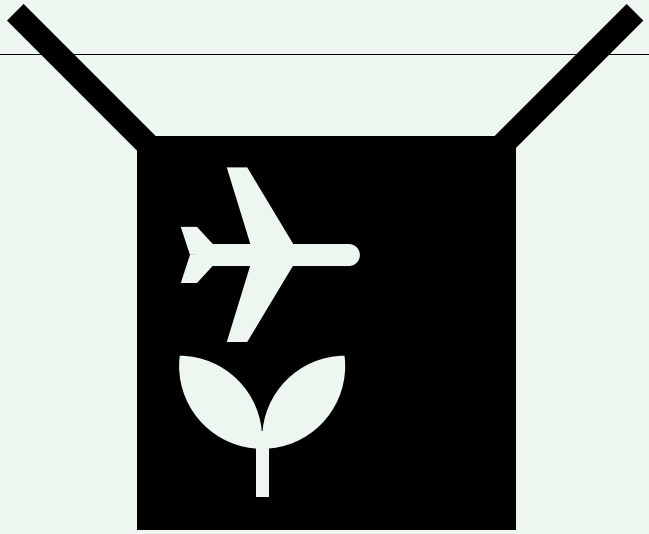
Collection Priorities

In the following section we explore how our Living Collections are used, through analysis of material transfers and with illustrative case studies. In taking this approach we aim to better understand how our various stakeholders can be best served as we develop the content and management of our collections. Informed by these analyses, we outline the overarching collection priorities that are needed to fulfil our mission to support:

- **Research**
- **Education**
- **Conservation.**

Opposite page:
Children enjoying the Systematic Bed displays.

How are our collections used?



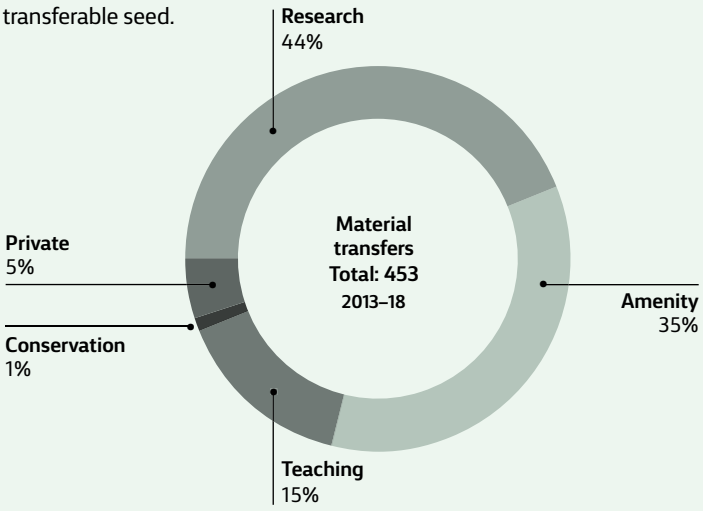
‘In a period of five years we have supplied, for a variety of uses, 1,388 accessions, which equates to about 10% of our entire Living Collections.’

The primary route for the use of our collections is via ‘ material transfers’ which is akin to the concept of the ‘loans’ system of other museums and collecting institutions. The significant difference that our loans are permanent and not returned! Material transfers are categorised into five groups. First and foremost are our Research requests both from within Cambridge and beyond, which receive utmost priority. Our second category is Education which includes all the use of material in our own education programme, as well as the material that we supply to support undergraduate courses at the University of Cambridge and elsewhere. Our Conservation category includes threatened species which we have cultivated in our collection and are then transferred either back to the wild as part of species restoration efforts, or shared with other gardens to ensure a dispersed insurance policy against extinction. We share material for Amenity purposes to help fellow botanic gardens create the horticultural displays that sustain so may of our visitors. Finally, we transfer limited amounts of material to Private specialist collectors and collections.

Analysing Material Transfers

1,388 Transferred Specimens:
Glasshouse: 402
Systematics: 298
Alpine & Woodland: 236
Experimental: 194
Demonstration & Display: 140
Trees & Shrubs 118.

Analyses on collection use are based on 453 material transfers between 2013 and 2018. The 453 material transfers equate to 1,388 individual accessions. It is instructive to consider why some sections contribute more than others. Here, the differences are due to the same characteristics which make collections more valuable to others, namely: diversity (family, genera, species richness), rarity, and proportion of accepted species. The notable exception is Systematics which is one of the least accessed collection in terms of material requests, and the lowest by many metrics of collection quality, yet makes a disproportionate contribution to total number of specimens transferred. This is because the seed bank is largely composed of material derived from Systematics due to their high annual planting regime. This emphasises that material transfers are strongly impacted by the availability of easily transferable seed.

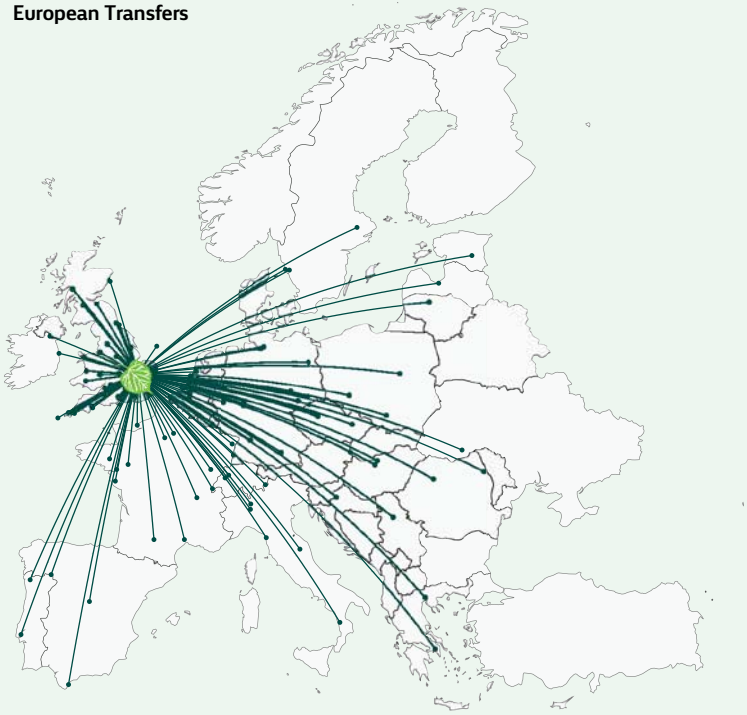


What is the reach of our collections?

Global Transfers

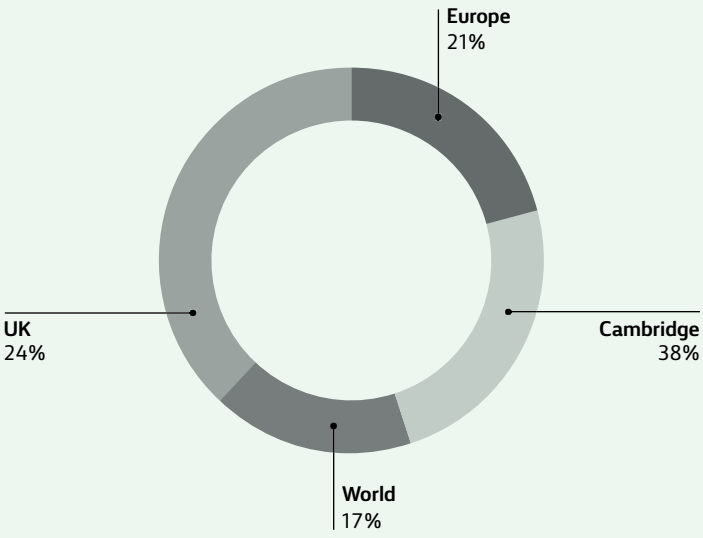
UK Transfers

European Transfers



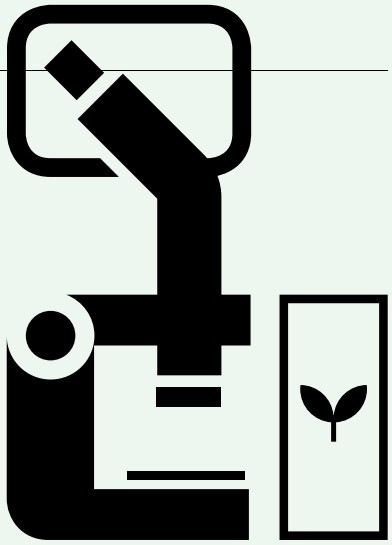
Analysing the Geographic Reach of Research Requests

Analyses of where we send our material in responseto research requests highlight the importance and strength of our immediate research environment with 38% of all our material supporting institutions within Cambridge. A further 24% of our supported research requests cater to requests from the rest of the UK. Further afield, about 21% of all our supported research requests come from institutions across Europe, while a further 17% support research worldwide.



It is instructive to consider what is influencing these statistics. First and foremost is a question of visibility, and the degree to which the quality and extent of our collections are recognised outside our regional and national context. Second, our reach is affected by our ability to cater to international requests, as it is difficult to send live material outside Europe due to phytosannitary regulations. The only way we can send living material outside Europe as opposed to preserved material, is as seed. Catering to international research requests is therefore contingent on a well-stocked seed bank.

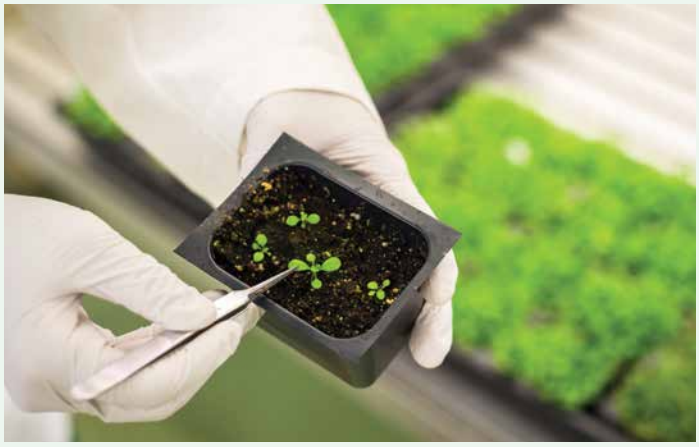
Research



Botanic gardens have been intimately involved with scientific research since their inception. Once devoted to the fields of systematics, taxonomy and economic botany, the expertise and reach of botanic gardens now extends to numerous branches of research both within plant sciences and more broadly. Living collections are utilised to provide essential material for molecular phylogenetics, genomics, and transcriptomics, and are used to screen for high-value chemicals, metabolites, and pharmaceutical compounds. Botanic gardens serve as valuable sources of ecological data including phenological indicators of climate change, plant physiology and plant-animal interactions. Horticultural expertise is employed to develop propagation protocols, to grow unusual research organisms, to manage the bulk cultivation of model organisms, and for the cultivation and breeding of novel and experimental crop species. Living collections also serve as natural laboratories and have provided classic experimental models in the study of the genetics underpinning hybridisation and plant domestication. In the face of the current extinction crisis, botanic gardens are increasingly involved in conservation research, including conservation genetics, and the practice of ecological and species restoration. Finally, the landscapes of botanic gardens support a great range of native flora and fauna, facilitating the study of wildlife, and of the impact of urban environments on native biota.

Cambridge University Botanic Garden is uniquely situated at the heart of a world-class research and teaching university, with an exceptional range of institutions and initiatives that speak to our Living Collections. The Departments of Plant Sciences, Biochemistry and Genetics, the Sainsbury Laboratory at Cambridge University, and the new Cambridge Centre for Crop Science, all engage in fundamental and applied plant science across all frontiers of scientific discovery. Researchers within these institutions and departments benefit from unparalleled access to our diverse collections, while our experimental glasshouse facilities support the cultivation of numerous model species and experimental systems. Outside of the Plant Sciences, the Department of Zoology and the McDonald Institute of Archaeology are especially intensive users of our horticultural expertise, collections and landscape. As part of the consortium of the nine University of Cambridge Museums, our combined collections support exhibitions and research into common narratives that transcend individual institutions' collections, while examination of best practice enhances collections use and their management across the network. The opening of the David Attenborough Building with the Cambridge Conservation Initiative provides many opportunities for collaboration, with the presence of many leading NGO's such as IUCN, WCMC, FFI, Traffic, and the RSPB. Finally, regional and national organisations such as the Sanger Institute, BCN Wildlife Trust, Plant Life, the National Institute of Agricultural Botany, and the John Innes Centre constitute key partners that help to ground the collections, and the garden as a whole, in regional and national science initiatives.

Use of our Living Collections leads to the publication of between twenty and thirty peer-reviewed publications on an annual basis, with many in broad impact journals, and often accompanied by considerable media coverage. The size and diversity of the surrounding research community, relative to the small number of research staff within CUBG, pose an interesting mix of challenge and opportunity with respect to our Living Collections. Despite extensive in-house research programmes from our own researchers, the external demand for access to our collections, landscapes and facilities is generally higher than the internal demands. The varied and ad-hoc nature of our many research requests ensures that it is difficult to anticipate the current and future taxonomic needs of our researchers, but nonetheless the scale of the material requests requires exceptional collection management. Although research requests are difficult to anticipate, generally researchers are seeking material that is rare and may be otherwise hard to come by outside of our collections. Scientists most often require accepted biological species with the highest quality of taxonomic verification, with excellent provenance data and vouchering to support the science, and increasingly, to enable research and development leading to commercialisation.



Case studies

The 1000 Plant Transcriptomes Project

The One Thousand Plant Transcriptomes Initiative (1KP) is a global collaboration to examine the diversification of plant species, genes and genomes across the more than one-billion years of history of the green algae and green plants. The goal of the project was to apply next-generation sequencing technologies to sequence about 20,000 genes from over 1,000 species of plants and algae. The study inspired a community effort to gather diverse plant lineages derived from terrestrial and aquatic habitats on a global scale.

Cambridge University Botanic Garden played a significant role in providing material for gene sequencing, as part of a global network of institutions that hold living collections of plants. High quality living collections are essential for this kind of endeavour, because living plants, as opposed to preserved specimens, are essential for the sequencing approach that was taken by the 1KP consortium. Providing high quality information and certainty about taxonomic identification and provenance is a key strength of botanic garden practice and has been essential in providing the living material used in this sequencing initiative. Research using these data and led by the Department of Plant Sciences in Cambridge is giving insight into C4 photosynthesis, the biosynthesis of high-value plant pigments, and the manipulation of algal metabolism to generate valuable and useful compounds in algae.

The 'Blue Halo'

One of the more popular areas of the Botanic Garden for our visitors is the Bee Borders, in front of the glasshouse range. Here visitors can enjoy a selection of plants brought together to provide the best and most attractive resources for a range of bee species. Recently research from our Director's research group has identified a novel optical property of some bee-pollinated flowers, termed the 'blue halo'.

The study began from an analysis of the petal surfaces of plants growing in our Living Collections. Various species from across the range of angiosperm diversity were shown to produce nanoscale ridges on their petal surface, organised in regular arrays that ran the length of the petal. Analysing the light reflected from these ridged petals revealed that they all produced a peak of reflection in the blue and ultraviolet part of the light spectrum, and that this reflected light was visible over a wide range of angles.

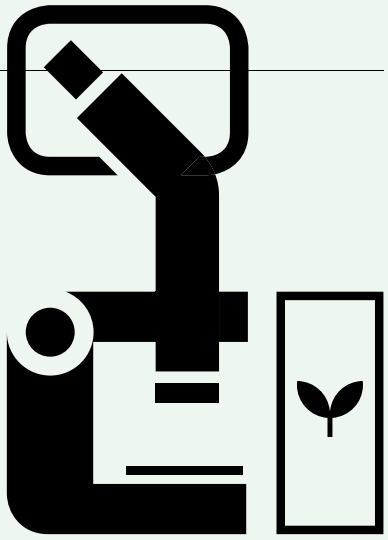
It was this reflection profile that is termed the 'blue halo'. Bees, and many other insects, see much further into the blue and ultraviolet part of the spectrum than humans. The research subsequently showed that foraging bumblebees could not only see the blue halo very clearly and use it to identify a food source, but also that it helped the bees to find flowers more quickly and improved their foraging efficiency.

Discovery of plant-derived Vaterite

Scientists from the Sainsbury Laboratory at Cambridge University working with our Alpine team, recently discovered that the chalky white substance found on the outer leaves of some Saxifraga species is a rare mineral called Vaterite. The team were exploring the inner workings of plants held in our Living Collections using new microscopy technologies. Microscope analysis on one species, *Saxifraga sempervivum*, showed that some plants were exuding Vaterite from glands on the margins of their leaves.

This mineral is more commonly found in outer space than on earth and it is the first time that Vaterite has been found to be associated with plants. The discovery is important as Vaterite has the potential to make medicines more effective due to special properties of the mineral which are useful in enabling sustained and targeted drug release. These properties may be of particular interest for future medical drugs including drugs that combat cancer. Other potential uses include improving the cements used in orthopaedic surgery and for increasing the quality of papers for inkjet printing. The research is an important illustration of how our Living Collections can yield unexpected and fundamental discoveries.

CUBG
Research Priorities



Analysis of our collections use for research reveals several aspects of collection and database content that could be enhanced to improve our ability to support a wide range of research.

Increase diversity

To increase the diversity of our collections particularly at the higher-level hierarchies of family and genera to maximise our ability to respond to ad-hoc research enquiries.

Increase rarity

To increase the rarity of our collections so that what we offer is unique within the global network of botanic gardens.

Increase wild collected species

To increase the proportion of wild-collected species as these provide a more relevant and useful experimental context for many of our research requests.

Increase provenance data

To increase the proportion of the collections for which we hold provenance information, with respect to country of origin, as provenance is increasingly necessary to permit research and development.

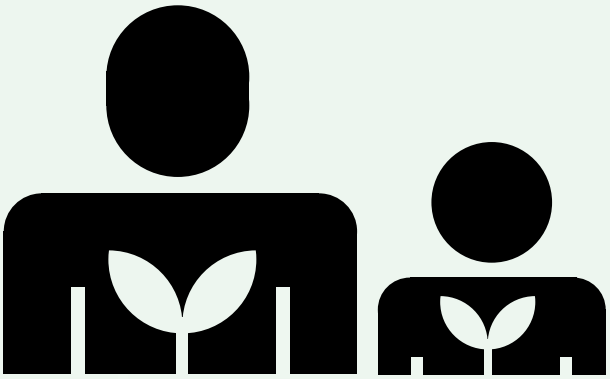
Increase seed banking collections

To increase the proportion of the collections held as seed prioritised for wild-collected, rare material, and accepted species, to enhance our ability to send material internationally.

Increase herbarium vouchering

To increase the proportion of the collections that is vouchered in our herbarium, prioritised for wild-collected, rare material, and accepted species to ensure we have a permanent record to support research publication.

Education



Botanic gardens have a long and well-established relationship with university education and were especially important in the development of medical education within universities, beginning in the 1500s. Gradually the roles of botanic gardens have diversified with respect to education, reaching far greater audiences and covering a greater range of subjects. The educational role of a botanic garden has become increasingly associated with the scientific study of plants, particularly taxonomy, systematics and plant diversity more generally. Associated with this role has been a conspicuous trend towards public education outside the confines of the University, encouraging public learning in the botanical and natural sciences. As concern grows for the conservation of the world's biodiversity, many botanic gardens are demonstrating a shift towards education for plant conservation, with programmes that focus on developing and linking scientific literacy and environmental citizenship. Increasingly important is recognition of the need for engagement with the communities that more immediately surround botanic gardens. Such community programmes may be informed by global policy and cutting-edge science and horticultural advances, but also respond to the needs of the local community and specific, often disadvantaged, groups within that community.

'an inspirational outdoor classroom for all ages; a place to develop knowledge, encourage creativity and bring learning to life'

Cambridge University Botanic Garden is an inspirational outdoor classroom for all ages; a place to develop knowledge, encourage creativity and bring learning to life. Education occurs at many levels from the simple labelling of plants, through interpretation panels, and by the themed organisation of our plants and horticultural displays. More formally, learning programmes deliver activities for schools, colleges, universities, community groups, families and adults. We run a lively programme of adult leisure courses, talks and workshops in subjects ranging from horticulture, science, plant identification, and botanical illustration through to creative arts. For families, there's a great choice of activities and events throughout the year to encourage exploration of the natural world. Our community programme reaches out to local groups and residents through a range of projects and initiatives, including community gardening. We are also committed to training and supporting the next generation of expert horticulturalists and offer seven horticultural trainees places on the 12-month Cambridge Certificate in Practical Horticulture and Plantsmanship. Last but not least, we are heavily involved in the teaching of our own University of Cambridge undergraduates providing a context for training in plant identification and comparative morphology as part of the Natural Sciences Tripos – in particular we contribute material and teaching expertise on courses such as 'Evolution & Behaviour' and 'Plant & Microbial Sciences'. Finally, we offer a flagship week-long course on Flowering Plant Systematics, which brings together learners from both inside and outside the University, and is available for graduate students.

In terms of our Living Collections, education imposes a number of demands. First and foremost, the accessibility of the collection both to independent learners and educators is dependent on high quality labelling. Important also is additional information that we hold about the individual species, as such information can help in the planning of courses and influence the choice of material used in teaching. Finally, in teaching the many facets of plant diversity, human relevance and narrative are extremely important, and there is a growing demand for species which have a compelling story and demonstrable relationship with humans and society.

Education

Case study

The Systematic Beds and the Rising Path

The historical purpose of any set of Systematic Beds has always been as a teaching tool, and their relevance is tightly linked to education. In particular, the unique focus, order, and content of the Systematic Beds specifically lend themselves to the teaching of plant taxonomy and systematics. The beds allow us to use taxonomic hierarchy to educate the public and our students about how the diversity of the plant kingdom has been sorted by botanists into their many families.

Teaching to the level of family provides a useful scope to cover as much of plant diversity as possible, often in relatively limited amounts of teaching time, so that students can better fit their own understanding, particularly of native plant diversity, into broader taxonomic concepts. Furthermore, when you know how to identify a plant to its respective family, it often opens up access to a number of specialised floras and plant keys which will allow you then to further identify the plant to species level.

So, we still use the Systematic Beds in much the same way as they have been used over the past centuries. In many of our courses, and indeed in our flagship course, Flowering Plant Systematics, we will often hold the class outside among the Systematic Beds, so that the students can practice keying out and identifying plant genera and species within particular families. Because each family bed holds a number of representative genera and species, this form of learning really helps students to grasp the essential qualities and characteristics of plants. In essence the family groupings allow one to get a sense of the natural affinities of a plant family, or what the great polymath Goethe referred to as the 'Gestalt'.

In a very practical sense, the Systematic Beds are also enormously helpful to the teacher, as they provide quick and ready access to good amounts of related material which can also be harvested and brought back to the teaching labs for microscopy work, without having to search across our 40 acres of landscape to find them.

In 2015 we were awarded funds by the Monument Trust for the 'Understanding Plant Diversity' project which has been a remarkable opportunity to re-interpret and re-envision the Systematic Beds, and to enhance their utility for our visitors and learners alike.

The new gently elevating Rising Path structure leads up to a platform from which the viewer can look out over the order beds, to better understand this beauty, layout, and structural representation of the plant kingdom. Along the way, the visitor essentially walks through geological time, as our interpretation panels tell the story of the origin and evolution of land plants, culminating in the diversification of the Flowering Plants.

As part of the 'Understanding Plant Diversity' project, we have thought a great deal about the contents of each family bed, so they can better serve their contemporary educational purpose, and we hope to include many more British natives in the beds over coming years, to support that interest for educational courses. But of course, the biggest change is that although we have preserved the heritage layout, the contents of all beds now conform to a 21st century classification system, APGIV, which will allow us to teach the latest and most contemporary understanding of plant diversity. Sometimes this could actually make teaching harder, as some families are only united by cryptic DNA based characters that make it hard for a student to understand the '*Gestalt*' of a particular plant family. However, in this, there are also important lessons about the role of DNA in contemporary classification, and the remarkable diversity and confusing variation that can be held, in groups of plants that we now know to be related.

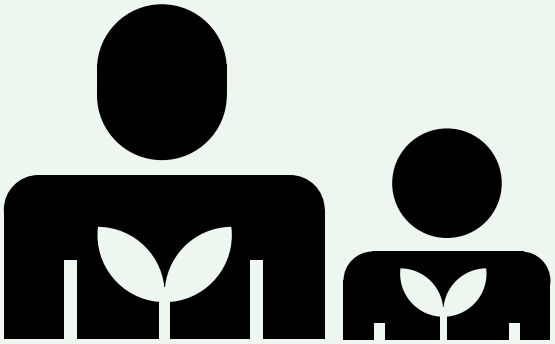
Education


FROM
470
MILLION YEARS AGO
IN THE ORDOVICIAN
TINY MARGINAL
PLANTS BEGIN TO
COLONISE THE LAND
LIVERWORTS - HORNWORTS
MOSSES
FIRST LAND PLANTS


WAYS OF
SORTING
CAMPANULIDS
LAMIIDS
ASTERIDS
FABIDS
MALVIDS
ROSIDS

CUBG Education Priorities

The following priorities have emerged through discussion with our Learning Team and other educators.



Improve and increase labelling

To improve and increase labelling to all accessions (one label/one plant), improve accuracy, and increase use of ancillary information available on labels.

Increase British native plants

Increased representation of British native plants to support identification courses on our native flora.

Increase plants of human use

Increased representation of plants that are of known human use e.g. Animal Foods (e.g. forage, fodder), Bee Plants (honey production), Environmental Use (agroforestry, erosion control, shade), Food Additives (e.g. flavouring, colouring, emulsifier), Fuels (e.g. fuelwood, charcoal, petroleum substitute), Genetic Resources (e.g. crop wild relatives and species with recorded uses in crop breeding), Human Foods (e.g. cereals, fruits, nuts), Materials (e.g. essential oils, fibre, gums), Medicines (e.g. folklore, veterinary), and Socially Relevant (e.g. hallucinogen, religious, stimulant).

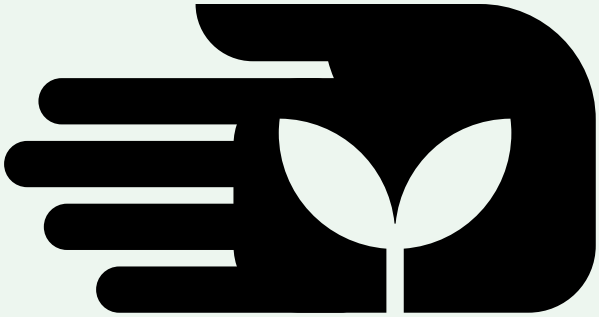
Enrich database information

Enrich information on the database in relation to these categories, so that the collections are easily accessible according to educational and curricula themes.

Opposite page Top:
Geological time chart
Innovative use of anti-slip measures on the walkway doubling up as an interpretation of the diversification of land plants on a geological timescale.

Opposite page Bottom:
Interpretation panels
Underneath the viewing platform, interpretation has been installed to tell the history of our Systematic Beds and introduce the visitor to two essential themes in Systematics, namely: ‘Ways of Looking’ and ‘Ways of Sorting’.

Conservation



An estimated 20% of plant diversity is threatened with extinction. The extinction threat is largely anthropogenic, including habitat degradation, invasive species, resource over-exploitation and climate change. It is estimated that 75% of the planet's land surface is experiencing human pressures such as expansion of built environments, with approximately 40% given to agriculture. Even in wilderness areas, plant populations are vulnerable to invasive species, pests, diseases and a changing climate. For plants with natural distributions within transformed environments, *ex-situ* conservation of plants outside of their natural habitat may be the only way they can survive in the short, medium and even long term. Crucially, threatened plant diversity may also hold the key to solving our major challenges in areas of food security, energy availability, water scarcity, climate change and habitat degradation.

Botanic gardens offer the opportunity to conserve plant diversity *ex-situ* and have a major role in preventing species extinctions through integrated conservation action. Recognizing the unique position of botanic gardens for plant conservation, the first Botanic Gardens Conservation Strategy was published in 1989 and over two decades has evolved into the Global Strategy for Plant Conservation (GSPC), which seeks to halt the loss of plant diversity and to secure a sustainable future where human activities support plant diversity, and where the diversity of plants supports human livelihoods and well-being. The strategy outlines 16 targets encompassing knowledge, conservation, sustainable use, awareness and capacity-building activities. Botanic gardens contribute to meeting all targets, but as the main institutions for *ex-situ* plant conservation, they are key to achieving GSPC Target 8, which calls for 'at least 75% of threatened plant species in *ex-situ* collections, preferably in the country of origin, and at least 20% available for recovery and restoration programmes by 2020.'

Two assertions lie at the core of the central role of botanic gardens in the conservation and management of plant diversity. First, that there is no technical reason why plant species should become extinct, given the array of *ex-situ* and *in-situ* conservation techniques such as seed banking, cultivation, tissue culture, assisted migration, species recovery and ecological restoration. And second, that as a professional community, botanic gardens possess a unique skill set that encompasses finding, identifying, collecting, conserving and growing plant diversity across the taxonomic spectrum. However, the conservation agenda is set to have a considerable influence on botanic garden living collections and their management, which needs careful consideration. Managing collections for conservation influences how we set priorities for species acquisition and space allocation, requires a greater number of accessions to be grown per species to adequately capture genetic diversity, and demands the highest quality collection management to ensure longevity and preservation.

20%
plant diversity threatened

75%
land surface experiencing human pressures

40%
of land given to agriculture

'threatened plant diversity may hold the key to solving our major challenges in areas of food security, energy availability, water scarcity, climate change and habitat degradation.'

Conservation

Fen Orchid
This is the first time the Fen Orchid has been cultivated in the UK

Case studies

Restoring the Fen Orchid

Working with the network of nature reserves and conservation charities across the east of England, we have developed programmes to protect some of our local endangered flora. One such project involves the Fen Orchid (*Liparis loeselii*) - a very rare small orchid with creamy yellow flowers found in only three sites in the UK and rare over most of the rest of its range in Europe and North America.

For the last seven years, we have been working with colleagues at the plant conservation charity Plant Life and the Royal Botanic Gardens, Kew to safeguard and increase the population of the Fen Orchid which is classified in the UK as endangered due to the decreased number of isolated sites remaining and its low population numbers. In the UK, the Fen Orchid is confined to calcareous Norfolk fens where it grows on moss as an epiphyte (a plant that grows on another plant for support). Historic records show that the plant once grew in much of East Anglia, including fens close to Cambridge such as Wicken, Burwell and Cherry Hinton.

The drainage of fens for agriculture and the decline of traditional management on remaining fens have led to a significant decline in populations, with numbers perhaps down to a few hundred individual plants. Working with our partners, we have established an *ex-situ* conservation collection of plants to act as a backup population to the wild population. We will use this collection to re-introduce plants back into some of the sites.

Plans are now underway to re-introduce the species into sites where they once grew. In one winter we carried out a trial relocation within one of the existing sites to demonstrate that the plants can actually be moved in the wild and not just into cultivation, and hopefully the first trial re-introduction will be carried out in coming years using a limited number of plants from the existing sites. We will monitor the plants to establish if the population is sustained or increases. If this is successful, the aim is to increase the number of plants the garden grows to provide sufficient plants for further re-introductions. This is the first time the Fen Orchid has been cultivated in the UK.

We anticipate that it will be another few years before it is known whether any of the trial re-introductions will work. If they do, and we are able to increase the number of sites where the plant is found, it will be wonderful to once again see this rare orchid in all suitable surviving fens in East Anglia and to have played a significant part in reducing the likelihood of this orchid becoming extinct in the UK.

Tulip conservation in Central Asia

In the 17th century, a single tulip bulb could, reportedly, set you back the price of a house. 'Tulip mania' - the supposed period in Dutch history when tulips stirred up a frenzy - may now be long over, but with more than 3,000 varieties to choose from, modern-day buyers are clearly still searching for something special.

The best place to find tulips is in the mountainous landscape of Central Asia where wild tulips carpet mountain slopes. Importantly, these tulips reflect the overall health of the landscape, because when they are present, it is a sign of a well-functioning ecosystem. In populated areas, overgrazing and excessive trampling by livestock prevent tulip regeneration. This decline may be a warning light for surrounding grassland ecosystems: when tulips disappear, it can mean that grasslands are under serious strain. Many graziers understand these threats and are open to exploring solutions to protect tulips and the long-term health of the surrounding life-giving grasslands.

Cambridge University Botanic Garden are holders of the National Collection of tulips, with a focus on wild-collected and accepted species. Thanks to funding from the Darwin Initiative, and in partnership with the Association of Forest Land Users of Kyrgyzstan, Bioreseurs and Fauna & Flora International, we are working to protect Central Asia's tulips.

During this project, we are training a PhD student in essential taxonomic and conservation practices, mapping the tulip species and tulip populations of Central Asia, preserving bulbs and seed in *ex-situ* botanic garden collections, resolving the evolutionary history of the tulip genus, and working with local livestock herders to introduce sustainable grazing regimes in areas of high tulip diversity.

Case studies

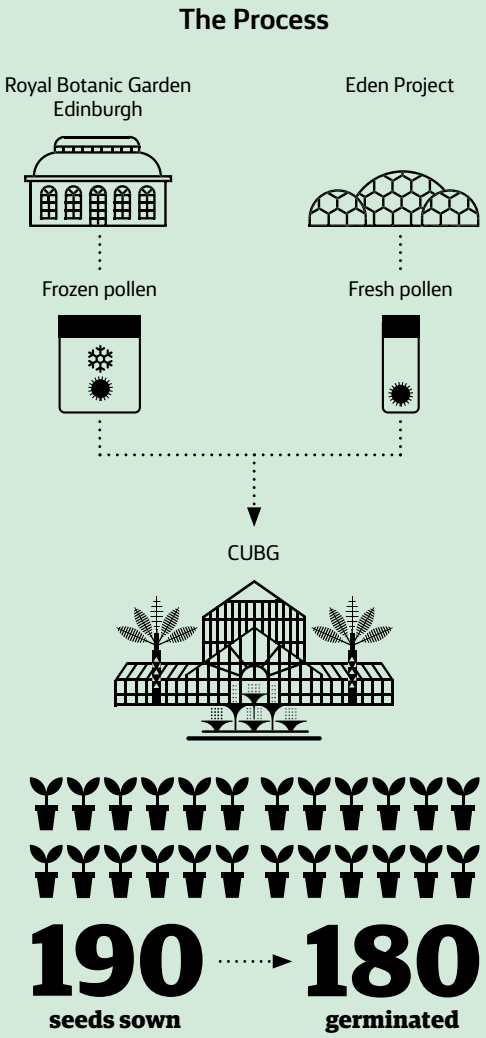
Ex-situ propagation of the Endangered 'Titan Arum'

Amorphophallus titanum (or 'Titan Arum') is now categorised as Endangered by the International Union for Conservation of Nature (IUCN) Red List of Threatened Plants, due to habitat loss. The plant flowers infrequently and when they do, the flower and its pungent smell only last for around two days, as the stench it produces is the plant's mechanism to lure pollinators in the wild. We have successfully raised 160 seedlings from the flowering of our Titan Arum, which is believed to be the first time such a large number of plants have been successfully raised in cultivation in the UK.

Until now, there have only been around 20 fruiting events of these plants in cultivation worldwide. We used the flowering of our Titan Arum to discover more about successfully pollinating the plant by experimenting with two different types of pollen - fresh and frozen - and recorded the results, which we are now sharing with other botanic gardens.

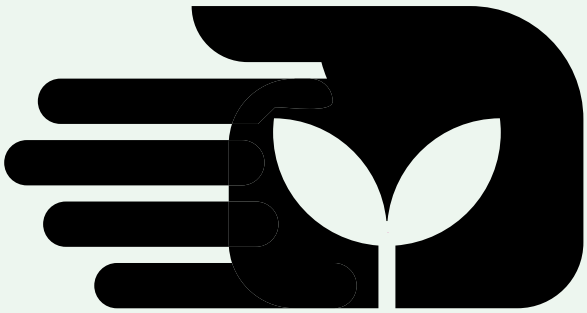
The whole process has taken almost two years from when the specimen flowered in June 2017. On the first night of opening, we received fresh pollen sent from the Eden Project and frozen pollen from the Royal Botanic Garden Edinburgh for pollination. Our specimen set fruit five months after pollination, with each red fruit containing one to two seeds, each of which had to be sown fresh for successful germination. We were fortunate enough to have 190 seeds to sow; of these 180 germinated. However, the most difficult part is successfully getting the seedlings through their first dormancy period. It is common to lose up to 90% of your plants at this stage.

Our work has been important for the *ex-situ* conservation of this species, as we have developed our knowledge and understanding of its requirements, particularly pollination, germination and successful cultivation. By monitoring and recording each stage of cultivation we can fully understand how to grow and increase numbers of this threatened plant to help conserve this species in the future.



CUBG Conservation Priorities

Analysis of our collections and collections management reveals several aspects of the collections that could be enhanced to improve our support of the ex-situ and in-situ conservation of plant diversity.



Increase threatened species

To increase the number of threatened species in our collections, and the genetic diversity of those threatened species for better real conservation value; and to increase the representation of perennial long-lived threatened species.

Increase threatened species in the seed bank

To increase the representation of threatened species in the germplasm collection to safeguard against loss.

Collect and display all extinct-in-the-wild species

To collect and display all currently living extinct-in-the-wild species, to better illlustrate the severity of the issue and the role of botanic gardens.

Annual 'threatened species' audits

To conduct annual audits of all threatened species in our collections to safeguard against loss and deterioration of condition.

Annotate IrisBG™

To annotate IrisBG™ with all regionally and nationally threatened species designations in addition to IUCN designations.

Increase threatened species longevity

To increase the longevity of threatened species through curatorial activity, focus on perennial plants, and through germplasm collection.

Collection Acquisition

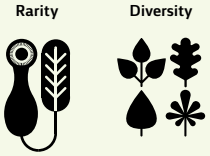
We will adopt eight acquisition strategies which focus on bringing new material into our collections to improve the quality of our Living Collections according to the measures discussed previously. These approaches are described and discussed in relation to the value they will bring to the Living Collections.

- Early Diverging Lineages
- Wild Collected Species
- Missing Families
- Threatened Species
- Species Representation
- Temperate Hotspots
- Plant-Human Interface
- Native Flora.

Opposite page:
Plant Hunting in the Richtersveld, South Africa

Collection Acquisition

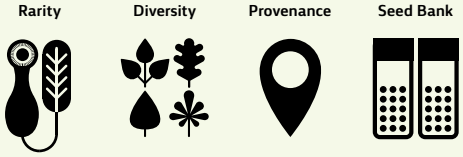
Early Diverging Lineages



Our global analyses have identified that early diverging lineages at many taxonomic hierarchies are under-represented across the global botanic garden network. In particular, Liverworts, Mosses, Hornworts, and Lycophytes are the least represented major plant lineages across a botanic garden network which is more generally focussed on flowering plants and gymnosperms. Less than 4% of bryophyte species are held in *ex-situ* collections world-wide.

Strategy
Acquiring early diverging land plant lineages is an effective approach to greatly enhance the breadth of the Living Collection, whilst enhancing the rarity of our collections in a global context. Here our acquisition strategy will focus at the family and generic level, aiming for at least one species per family, and then one species per genus across these four earliest diverging lineages.

Wild Collected Species



Only 20% of CUBG's Living Collections are wild collected species, despite the fact that wild collected species are essential to deliver research and conservation, due in part to associated provenance data. Acquiring wild-collected species is an effective approach to enhance our offerings to researchers and conservationists, while boosting known provenance data for our collections and enhancing their legality.

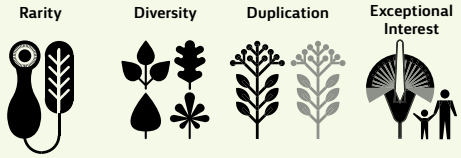
Strategy
Our acquisition strategy will aim to double the proportion of wild collected species in our living collections to 40% through a variety of means, including selective acquisition of material from associated collecting institutions, greater use of institutional seed banks, and focussed collecting expeditions.

'We aim to double the proportion of wild collected species in our Living Collections to 40% through collecting expeditions'

Opposite page:
Collecting expeditions
A selection of images from our collecting expeditions to Vietnam, Namaqualand and Kyrgyzstan

Collection Acquisition

Missing Families



Our Living Collections contain 315 families of plants which equate to 68% of all vascular plant families, and 51% of land plant families. There is consequently ample scope to increase family representation. Increasing the representation of families is an efficient method to comprehensively represent all major lineages of the plant tree of life in our collections, and to capture the resulting macroscopic diversity.

Strategy
We will aim to increase land plant family representation by 25% or the equivalent of about 100 families. Here our acquisition strategy will take two phases. First, we will source material for family-level diversity that is missing in CUBG, but readily present in the wider botanic garden network and institutional seed banks. Second, we will focus on families that are entirely absent from the global botanic garden network, thus requiring dedicated collecting efforts.

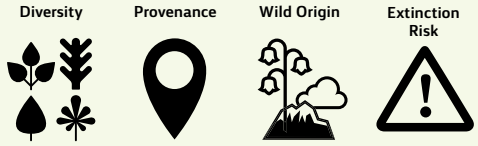
Threatened Species

The representation of threatened species in CUBG is relatively low, given the scale of the current extinction crisis. Over 50% of all threatened plants have been acquired since 2005, emphasising recent good quality accessions, but also the poor longevity of threatened species. The ratio of wild versus garden origin for threatened species indicates a lack of wild sourced genetic diversity. The threatened species we hold suffer from a lack of genetic variability and lack of specific collections management policy to protect them.

Strategy
Here, our acquisition strategy will be to deliberately target all IUCN threatened species, but particularly from temperate regions, with the emphasis on wild sourced material, ideally with multiple accessions per species. We will also seek to collate a collection of all living extinct-in-the-wild species to emphasise the importance of botanic gardens as a refuge for highly threatened species.

‘Our strategy will be to target all IUCN threatened species wherever possible, but particularly from temperate regions’

Species Representation



Where justified by active research, dense species representation should be a top priority. However, it is challenging to justify full species representation within particular genera, in the absence of any identifiable need from an affiliated researcher. Nonetheless, species representation is often a valuable offering for particular avenues of research, and as a general ambition, can result in our holding rarer species. A number of genera are already well represented in the garden and our acquisition strategy will seek to build on these intrinsic strengths.

Strategy
To allow for greater focus and reduce bureaucracy, we will aim to reduce the number of National Collections we hold and to redefine the scope for the remainder. Our National Collections will focus on global diversity rather than European diversity, with emphais on accepted and threatened species. Additional opportunities for complete species representation exist for many genera within the Trees & Shrubs, where there is already high species representation.

Temperate Hotspots

Our Living Collections are mainly European species, complemented by accessions from temperate North America, China, Japan, South Africa, and Australasia. Acquisitions from temperate hot spots of plant diversity such as the Balkans, Central Asia, and South America are notably absent. Our global analyses of *ex-situ* diversity have highlighted the diversity of southern temperate regions, roughly aligned on the 36°S parallel. Little diversity from these same regions are documented anywhere within the global botanic garden network. Collecting within temperate hotspots is therefore an effective approach to acquire suitable material that best fits our climate, and enables the acquisition of taxa that are otherwise rare in cultivation.

Strategy
Here our acquisition strategy will focus on two northern temperate hotspots - the Balkans and Central Asia, as well as temperate hotspots along the 36°S parallel, primarily focussed on temperate South America and South Africa. In southern temperate areas, higher altitude material will be of particular value across the collections in terms of climatic fit.

‘Our geographic focus for targeted collection will be on four temperate hotspots: the Balkans and Central Asia (N. Hemispshere) and temperate South America and South Africa (S. Hemisphere)’

Collection Acquisition

Plant-Human Interface

The extrinsic value of biodiversity has emerged as a key component in the strategy for plant conservation, embedded in concepts such as 'natural capital' and 'ecosystem services'. The utility of plant species for humans also provides a wealth of narratives to emphasise the value of plants to the broader public. In the context of research, useful plant species cater to several research categories including biomedicine, metabolic engineering and crop improvement.

Strategy
Our acquisition strategy will aim to increase representation of plants of known human use. We will focus on the following: Animal Foods (e.g. forage), Bee Plants (e.g. honey production), Environmental Use (e.g. agroforestry), Food Additives (e.g. flavouring), Fuels (e.g. petroleum substitute), Genetic Resources (e.g. crop wild relatives), Human Foods (e.g. cereals), Materials (e.g. essential oils), Medicines (e.g. Folklore) and Socially Relevant (e.g. hallucinogens).

Native Flora

The native flora of the British Isles is not especially rich, and alone certainly cannot sustain the requirements for diversity needed in our Living Collections. However, in the push for global relevance, it is easy to under-represent our own native flora, and to neglect the narratives to be communicated about it. In particular, there is need for native flora to support education courses, where typically learners will be most experienced with our own native plants, and also keen to learn how to identify native plants.

Strategy
Here, our acquisition strategy will focus on acquiring a greater proportion of our native flora and exhibiting the flora in expanded quasi-naturalistic displays including fenland, grasslands, arable meadows, uplands, arable verges and calcareous components of the Breck. Given our alkali soils, a focus on the native calcareous flora across the UK and EU is also desirable.

'We will focus on acquiring a greater proportion of our native flora and exhibiting the flora in naturalistic displays'

Opposite page:
Native Flora
An example of our native flora exhibited in a quasi-naturalistic display on our Ecological Mound


20060350*A
Poaceae
Lagurus
ovatus
Hare's-Tail
G
Mediterranean

Collection Management

Open	Our Living Collections will be freely and openly searchable by the public and our stakeholders.
Accessible	Our Living Collections will be easily accessible to all research, education and conservation practitioners.
Accurate	Our Living Collections will be sufficiently taxonomically accurate for use by our stakeholders.
Informative	Our Living Collections will be fully databased, and enriched with information of value to education, research, and the wider public.
Legal	Our Living Collections will be held to the highest legal standards, consistent with the national and international laws that govern our collections and their use.
Secure	Our Living Collections will be safe and secure, and we will work to mitigate against known and future risks.
Integrated	Our Living Collections will be integrated and networked with our peer collecting institutions, through our curation and collections activities.

Collection Management

Open

Our Living Collections will be freely and openly searchable by the public and our stakeholders.

The key to promoting utilisation of any collection is visibility and the ability to search the contents of the collection. However botanic gardens are traditionally closed in terms of their approach to collections content and associated data. Consistent with this tradition our collections are currently not openly searchable in digital form, by either the public or our stakeholders. In order to ensure our collections are freely and openly searchable we will engage in the following actions:

Data sharing

Our collections data will be shared bi- annually with global collections data repositories such as BGCI PlantSearch™ and Global Biodiversity Information Facility.

Collection portal

Our entire collection will be searchable via CUBG's website with a collections portal embedded within our website architecture.

Digital search stations

We will install digital search stations at key visitor nodes across the Garden to allow the public and our stakeholders to search our collections on-site.

Advertising the collections

We will widely and periodically advertise and market the availability of our searchable collections with our various stakeholders at conferences and through mailing lists.

Accessible

Our Living Collections will be easily accessible to our research, education and conservation practitioners.

Accessibility of our collections to our active users is limited by: available curatorial and horticultural staff time to handle research requests; bureaucratic procedures for processing material requests and recording all utilisation information; our ability to locate material quickly and easily, and the availability of plant material in the right form or condition to enable the material request. In order to ensure that our collections are as accessible as possible, we will engage in the following actions:

Audit material requests

We will periodically analyse the history of our material requests to determine what our major limitations are in delivering.

Maintain a 7 day response time

We will respond to all collection enquiries, either in the positive or negative, within a week of the initial request.

Enhance plant export procedures

We will enhance and diversify our ability to send material internationally by establishing necessary plant export procedures and offering them at cost.

Facilitate digital ordering

We will digitally link the collections portal to material request procedures to enable users to move directly from searching our collections to ordering in a single step.

Enhance the seed bank options

We will increase the proportion of wild origin accessions stored as seed to ensure greater availability of seed to support international research requests.

GPS map all accessions

We will ensure that all accessions are physically mapped within the IrisBG™ database with geographic coordinates to ensure that all plants are easily found.

Collection Management

Accurate

Our Living Collections will be sufficiently taxonomically accurate for use by our stakeholders.

Accuracy of our collections is mainly limited by the following: the challenge of maintaining accurate plant records, which if not done, can lead to missing accessions; acquisition of material from sources with poor standards of taxonomic verification or unverifiable material i.e. cultivars; absence of dedicated staff, staff skills, and verification procedures to update accessions in the face of changing taxonomy. In order to ensure that our collections are as accessible as possible, we will:

Audit our records and seed bank

We will conduct annual audits to ensure that we have up-to-date records, such that all accessions have a plant record within the past four years, and an annual update for the seed bank.

Mobile IrisBG™ devices for staff

We will optimise the use of mobile IrisBG™ devices for all horticulture and curation staff to allow the auditing and updating of plant records in the field.

Verfication of existing material

We will verify 2.5% of our accessions on an annual basis and verify, where possible, all material that is requested for research prior to sending it to researchers.

Resolve synonymy

We will resolve all identified instances of nomenclatural synonymy (~800 species) within our collections and replace out-of-date labels.

Taxonomically accurate sources

Year-on-year we will source an increasing percentage of our new accessions from taxonomically verified or verifiable sources, and reduce reliance on commercial and uncertain sources of material.

Herbarium specimens

We will take reproductive herbarium specimens of all material, where feasible, that is requested for research and education, either prior to, or post utilisation.

Informative

Our Living Collections will be fully databased, and enriched with information of value to education, research, and the wider public.

The IrisBG™ database lies at the core of all collection-related activity undertaken by curation, horticulture and education. In terms of minimum information, the quality of the database is excellent, but there is considerable scope to improve the storage and centralisation of additional information of value for education and research. In order to ensure our database is as informative as possible, we will engage in the following actions:

Enrich the database

We will enhance the value of the database through the addition of additional plant information including but not limited to economic plant categories, native plants, common names, plant explorers.

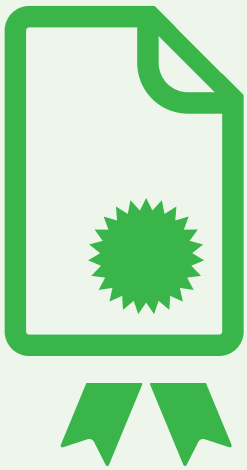
High resolution images

Increase the availability of high resolution images linked to accessions to help with identification and teaching and to supply to researchers.

Digitally link information

We will digitally link all material transfer agreements, prior informed consent, and research description forms at the level of individual accessions.

Legal



Our Living Collections will be held to the highest legal standards, consistent with the national and international laws that govern our collections and their use.

Our collections and procedures must be consistent with the national and international laws that govern their use, including: the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the Convention on Biological Diversity (CBD), the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization to the Convention on Biological Diversity ('Nagoya Protocol'), the International Treaty on Plant Genetic Resources (ITPGR), and the DEFRA Plant Health Controls for Plant Import and Export ('Plant Health'). In order to ensure our collections are legal we will take the following actions:

Collections manual

We will accurately record and publish all our collection procedures in the form of a Collections Policy which will be available for external scrutiny.

Invasive species & pathogen protocols

We will inform and train all staff with respect to their responsibilities under 'Plant Health'.

We will develop protocols to identify, respond to, and communicate the threat of invasive species, highlighting those held by CUBG, and their locations in the Garden.

We will develop protocols to identify, respond to, and communicate the threat of existing and emerging plant pathogens.

Nagoya Protocol

We will stay connected and current with respect to new and rapidly changing legislation e.g. the 'Nagoya Protocol' and 'Plant Health'.

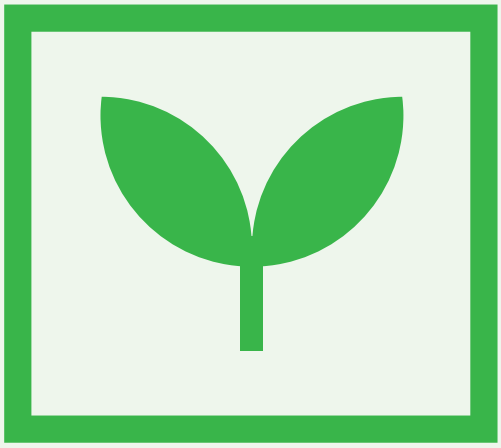
We will inform and train all staff with respect to their responsibility under 'CBD' and the 'Nagoya Protocol'.

We will handle all utilisation of our material for research and development, acquired after 5th October 2014, according to the legal requirements laid down by the 'Nagoya Protocol'.

We will conduct a database audit of all material accessioned after 5th October 2014, and evaluate their status with respect to the 'Nagoya Protocol' and their appropriate utilisation for research and development.

We will conduct an annual database audit at the start of the academic year to evaluate the previous year's intake with respect to their 'Nagoya Protocol' status for utilisation for research and development.

Secure



Our Living Collections will be safe and secure, and we will work to mitigate against known and future risks.

The safety and security of our collections is impacted by several factors including: limited ability to maintain collections as seed beyond the life span of accessions; poor awareness among staff and public as to our most important collections; a lack of curatorial policy to maintain and safeguard our special collections; damage to the collections due to high visitor numbers and inadequate supervision; damage to our Living Collections by newly emerging pathogens and resulting health control measures. To ensure that our collections are safe and secure, we will take the following actions:

Enhanced seed banking

We will increase the proportion of accessions stored as seed to ensure the longevity of accessions in our collections. We will modernise and enhance our short to medium term seed banking facilities, with on-site computer support to facilitate seed bank record keeping.

Highlighting special care

We will highlight in the database all collections which merit special horticultural care including: endangered plants, champion trees, unique accessions, heritage accessions, research collections, and national plant collections.

Labelling special collections

We will highlight all special collections warranting increased awareness to the public, and horticultural attention by staff, with designated labels and interpretation.

Curatorial policies

We will develop specific curatorial policies with respect to our special collections to ensure there is redundancy in case of loss, and collections are maintained through new accessions.

Modelling climate change

We will develop models of the impact of different climate change scenarios on the long term future of our collections and incorporate these findings.

Unknown or risky provenance

We will limit the sourcing of commercial material of unknown and risky provenance particularly from counties and regions which carry a known pathogen risk to our collections.

Integrated

We will ensure, through our curation and collections activities, that the garden is integrated and networked with our peer collecting institutions.

Botanic gardens have a rich history of collaboration and close co-operation through the sharing of plant material and expertise. This network is of ever increasing importance given potential future challenges in acquiring plant material, and our need to work with mutual awareness to deliver on global challenges for plant research and conservation.
In order to ensure that we remain integrated and networked we will engage in the following actions:

Index Seminum

We will deliver a limited but high-quality index seminum annually, to ensure that we feed into this time-honoured process, and share our material with our sister institutions.

Trusted suppliers

We will identify our historically most important suppliers and recipients of plant material and reinforce these relationships with personal visits from the curation team.

Expedition partnering

When conducting collecting expeditions we will seek to do this in partnership with other institutions to improve the quality and safety of the expedition, and to ensure that we are able to support the collection needs of the broader community.

Exchange partnerships

In the context of our collections strategy, we will identify new and emerging partners, and develop the necessary relationships and trust to support the exchange of collection material.

What will success look like?

What will success look like?

Collections Quality

We expect the quality of our Living Collections to increase across all the key metrics which we have outlined.

The diversity of our Living Collections will be enhanced with more families of plants, more species for key genera, and more British Native species.

Our collections will have greater phylogenetic scope, and increased representation for early diverging land plant lineages.

We will expand our global reach with an influx of new material from Temperate South America, South Africa, the Balkans, and Central Asia.

Our proportion of wild-collected species will increase, with an increase in the associated provenance data that we hold.

Our collections will become richer and leaner, as we reduce unnecessary duplication, and increase the value of the collection by focussing on taxa that are rare in cultivation.

Collections Management

Our collection will become increasingly taxonomically accurate, with more up-to-date plant records for all our accessions.

Our collections will be more sustainable with increasing longevity of key species and accessions throughout the collections.

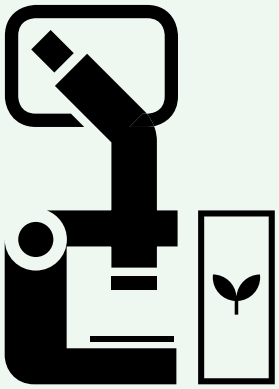
Our collections will be increasingly searched and accessed by our various stakeholders through a new web-based portal.

Our collections will be better labelled and mapped within our landscape, ensuring greater access and use of material by our many stakeholders.

Our underlying database will be a measurably richer resource, with more images, and more supporting information to enhance this use.

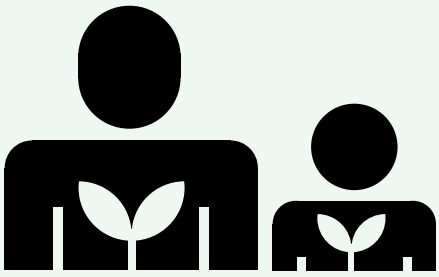
Collections Priorities

Research



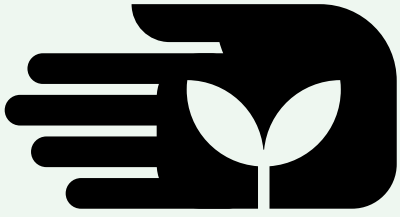
- We will see increasing requests for access to the Living Collections as their quality becomes more widely recognised, and the collections become more visible and accessible.
- Our local and regional community of researchers will increasingly use our collections to support comparative research.
- We will see a boost particularly in international material transfers to Europe and across the world.
- We will see an increase in the number and range of research publications that depend on access to our living collections and landscapes.

Education



- We will see a wider range of material from our collections used to support our own learning programmes and instructors.
- Course curricula will diversify as the education-facing aspects of our acquisition strategy provide more appropriate teaching material and narratives.
- Our teaching materials and pedagogy will be enriched by the increased information that we can provide from our databases.
- We will see a greater level of use of collections in support of Cambridge University courses and the Natural Sciences Tripos.

Conservation



- We will see an increase in the number of threatened and extinct-in-the-wild species that we hold in our collections.
- We will hold an greater amount of genetic variation for newly accessioned threatened species in our collection.
- The longevity of threatened species in our collections will be enhanced by targeted curation, duplication of accessions and seed-banking.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