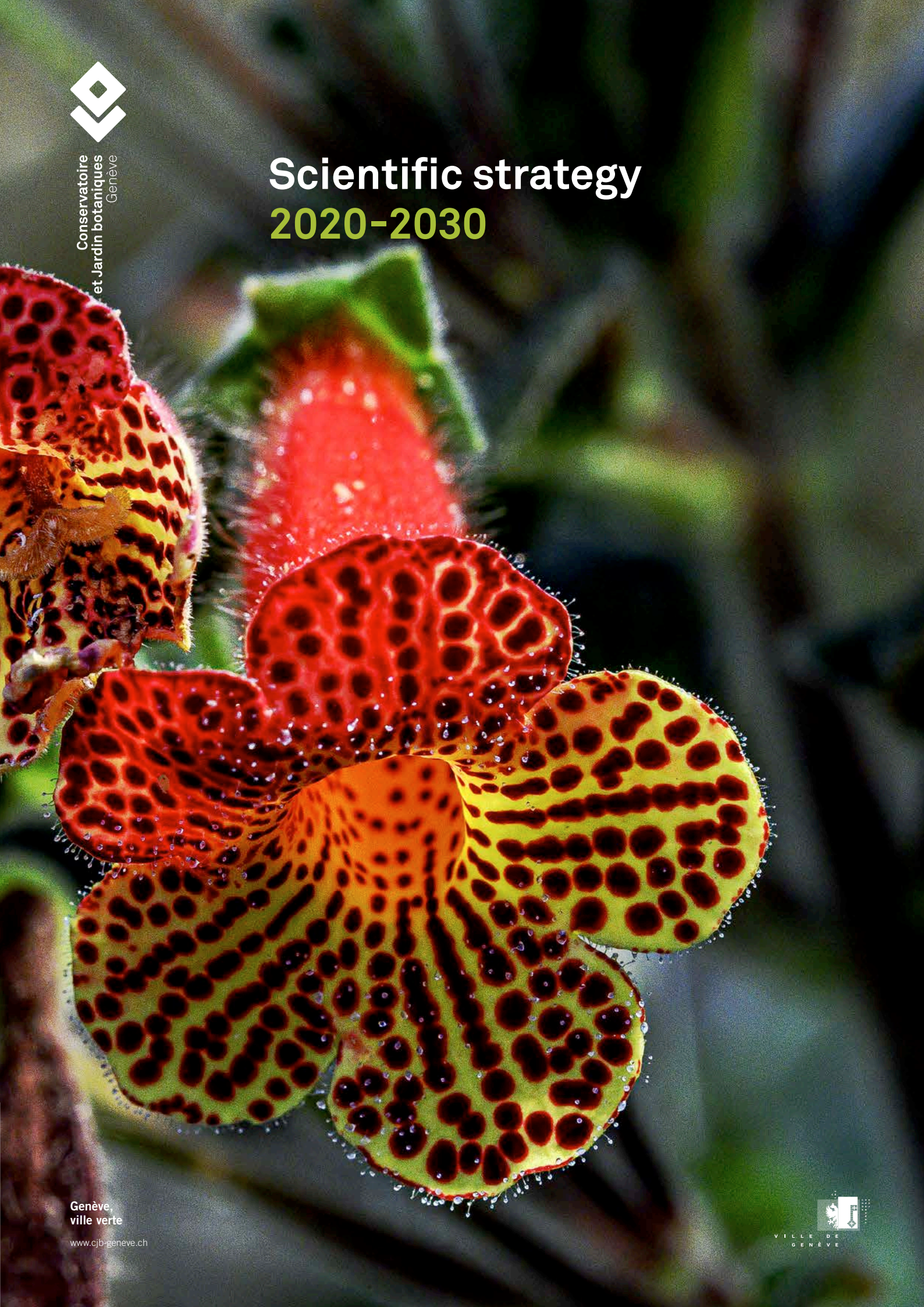

Conservatoire et Jardin botaniques Genève

Scientific strategy
2020-2030

Genève, ville verte

www.cjb-geneve.ch

VILLE DE GENÈVE

Scientific strategy 2020–2030

Conservatory and Botanical Garden of Geneva

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Introduction

The Conservatory and Botanical Garden of Geneva (CJBG) together form a museum. As such, they provide an infrastructure to society for studying and archiving objects – in this case live and dried plants and fungi, as well as botanical works – and information or observations on our environment. The study of these objects and data provides knowledge of the plant and fungal world which is then transmitted to other scientists as well as to the general public. The CJBG make a significant contribution to understanding the major questions posed from our past, our present and for our future. They also participate in the search for solutions, such as *in situ* and *ex situ* conservation programmes for endangered species. As a museum, they communicate with the public in order to provide the most objective information possible on the results of their research and on current knowledge in their fields of competence, while providing a pleasant environment devoted to pleasure and relaxation.

Botanical gardens are effective communication tools. There are more than 3,500 of them across the globe, touching more than 500 million people annually. Not all are invested in fundamental research in botany, but it is increasingly rare to find this scientific activity outside this type of structure, since universities preferentially turn to the study of the mechanisms that guide the development of life at the cellular or genetic levels, to the detriment of knowledge of organisms as a whole. Let us remember, however, that 6 plant species that are new to science are described in the world every day, proof of the need to continue the effort to discover the plant world.

Thus, if the CJBG have an important activity in the diffusion to the public, it is their research activities which are presented in this Scientific Strategy, the foundation for all communication, intended for scientists, politicians or the general public.

The CJBG constitute a centre of excellence in botanical research, both nationally and internationally. They fulfil five main missions (to explore, conserve, research, transmit and protect) which guide the management and development of collections, scientific research, as well as participation its in academic teaching and regional or global conservation actions. They aim to explore, understand and explain plant and fungal biodiversity by contributing to the inventory of species, to the understanding of their biology and their evolution. Their natural history collections and scientific skills are used to conduct basic research on plant and fungal biodiversity, as well as to make the information and tools necessary to better characterise and conserve the biodiversity of our planet available.

Scientific research at the CJBG is under the responsibility of the director. He relies on the advice of the head curator, as well as on a scientific council designated from among the scientific staff for a period of 3 years, to which he delegates part of his responsibilities. The director, as head of an institution that is both university orientated on one hand and museum orientated on the other, respects the academic freedom of each of the scientists. However, it must take place within an institutional scientific framework to which all researchers adhere.

Closed Geneva herbaria with in the foreground the de Candolle herbarium (G-DC) and in the second, Laurent Gautier, curator, putting away piles of the Boissier herbarium (G-BOIS).

This is the reason that this scientific strategy was developed by the scientific council, in concertation with the direction, and in consultation with the scientists between 2016 and 2018 in order to incorporate their contributions and comments. This document is therefore the result of a collaborative process and joint reflection on the development of research within the CJBG. It outlines the scientific strategy of the CJBG for the next ten years (2020–2030).

Context

Natural history collections tell the story of our planet's biodiversity

Natural history collections, such as herbaria, zoological collections, living collections, seed repositories or DNA banks form the core of all natural science museums. These collections, complemented by the libraries linked to them, are the result of a very rich historical, cultural and scientific heritage, and constitute an essential part of our planet's biodiversity inventory. The majority of the activities carried out in institutions housing natural history collections concern the management, enrichment and development of the collections themselves, as well as the dissemination of knowledge resulting from research on specimens. Research is a central activity of these institutions, and collections are better maintained and valorised when they are the subject of scientific studies on the diversity of the living world.

The term "research" – used in relation to natural science institutions – covers a wide range of scientific activities, many of which have no or no longer a place in universities. Within museum institutions with expertise in botany, these include:

- taxonomy and systematics (description of species, classification of plants and fungi and the elucidation of evolutionary relationships between different taxa);
- floristic studies (inventories and field collections, production of checklists and floras);
- molecular phylogeny and population genetics (DNA analysis from species to elucidate their evolution over time, their relationships, the structure of their populations and their modes of speciation);
- vegetation mapping and spatial analysis (analysis of species community assemblages and their changes over time, predictive modelling of changes in natural environments and species distribution);
- ethnobotany (inventory, study and scientific documentation of the relationships between human communities and the flora of a given region at a given time);
- conservation measures (*in situ* or *ex situ* cultivation, seed bank, reintroduction of species, reconstitution of habitats, evaluation of species and habitats, conservation recommendations, Red Lists, etc..).

The role of conservatories and botanical gardens and their collections in society

The definition of a museum, according to the statutes of the International Council of Museums (ICOM, 2007) specifies that a museum is "a non-profit, permanent institution in the service of society and its development, open to the public, which acquires, conserves, researches, communicates and exhibits the tangible and intangible heritage of humanity and its environment for the purposes of education, study and enjoyment". This definition, if it is to correspond to todays reality, needs to be enriched to include concepts such as globalisation, accessibility, data connectivity and

In 2019, as part of his Masters project on the taxonomy, floristics and ethnobotany of palms in Senegal, Matteo Auger-Micou, student at the University of Geneva, collected several male and female specimens of the ron palm (*Borassus aethiopum* Mart.).

sharing, environmental and societal issues, and the dissemination and management of information. Therefore, when approaching the scientific strategy, an innovative and open approach to original concepts must be adopted, while simultaneously using and enhancing the patrimonial collections. Being a fundamental reference, these patrimonial collections gain an inestimable value when up-to-date research approaches are used to study them, enabling the understanding of species evolution, the quantification of biodiversity or the management of natural habitats. The integration of innovative technologies and tools has already opened up new horizons, for example the sharing of information via the Internet is now made easier. This connectivity makes the consultation of specimens in the form of scanned images possible and facilitates the dissemination of information related to these specimens through global biodiversity data aggregators (e.g. GBIF, or Global Plants on JSTOR). The investment of time and funding (internal or external to the institution) in these new tasks of digitising collections has greatly facilitated the development of collaborations, rapid access to source data, as well as the consultation and comparison of information generated in other scientific institutions. This is a task that falls to all institutions and which must complement the definition of 'Museums.'

Natural science institutions thus play an essential role for society by providing both physical and virtual access to their collections and the data they contain, and by disseminating knowledge on biodiversity. By proposing exhibitions based on their history or scientific discoveries, promoting knowledge transfer, and providing educational opportunities, these institutions offer society the indications necessary to understand major contemporary issues and to guarantee the training of future naturalist scientists. They thus cover all facets of the valuable expertise concerning the different aspects of biodiversity and its conservation, as well as the dissemination of knowledge through scientific publications, books and various communications based on research findings.

Biodiversity, which, according to the *Convention on Biological Diversity* (CBD), encompasses genomes, species and ecosystems, is the "cornerstone" of the natural world. It is essential for the balance of our planet and the maintenance of human life on Earth. The conservation and sustainable use of biodiversity, including managing human impacts on it, is an increasingly important global problem. Environmental issues, such as pollution (e.g. carbon dioxide emissions, pesticides), the greenhouse effect and climate change, habitat loss or fragmentation, invasive or pathogenic species, rapid population growth and industrialisation, or the overexploitation of natural resources all affect biodiversity one way or another. The scientific and research activities of the CJBG aim to contribute to the global responses to current environmental challenges.

The museum policy of the City of Geneva

The CJBG adhere to the Museum policy of the City of Geneva (see [2] La Genève des musées, concept et stratégie 2015–2020) that has as its main objectives to:

- bring the local and regional population closer to its museums;
- affirm the role of museums in reflections on contemporary society;
- promote Geneva as a City of Museums.

Their activities fit into the seven strategic actions of Geneva's museums, to:

- affirm the role of museums in the city;
- create a platform for dialogue between museums;
- promote the influence of the Geneva's museums;
- think of the different publics;
- rethink acquisition policies and collection concepts;
- organise scientific research;
- improve infrastructures and visitors reception.

The adoption of a Museum Policy for the museums of the City of Geneva is the result of the General assembly commissioned in 2012 by the magistrate in charge of the Department of Culture and Sport, Sami Kanaan. The aim of the Museum Policy is to enhance the collective potential of Geneva's museums and to affirm their role in the contemporary society. The objective is clearly to provide a tool that responds to society's need for information and to ensure contributions to the major issues of our time.

The present scientific strategy is fully in line with the politically desired vision.

HERBIER DELESSERT
COLLECTION BURMANN

Polypodium spinulosum

Synaphia
cfr. petiolarem
RB.
M. Robert Brown

Synaphea petiolaris Brown prodr. p. 370

Polypodium spinulosum
Burm. ind. p. 233
t. 69
f. 1

Polypodium Indicum, foliis vario modo laciniatis, apicibus spinosis.

HERBIER DELESSERT
COLLECTION BURMANN

KEW NEGATIVE
No. 10577
DATE - 6 JAN 1969
INTLS.

Seen for
Flora of Australia
A.S. George
21 Sept. 1970

= Synaphea spinulosa Merrill
(Proteac.!)
Cf. Christensen Ind. Fil., Suppl. II,
p. 158 (1934)

HOLOTYPE of
Synaphea spinulosa (Burm. f.) Merrill
(Syn: Synaphea polymorpha R.Br.)
Determinavit A.S. George. 3. xii. 1968.

TYPUS

COLL. PRELINNEENNE (G-PREL)
G00818240

1. The Conservatory and Botanical Garden of Geneva then and now

1.1. Historical landmarks: from the first Botanical Garden of the Bastions to the present's Conservatory and Botanical Garden of Geneva

The Botanical Tradition in Geneva

The long history of the practice of botany in Geneva is recognised today as one of the 167 "living Swiss traditions" listed by the Swiss Confederation (www.lebendigetraditionen.ch) within the framework of the safeguarding of UNESCO's Intangible Cultural Heritage (https://ich.unesco.org/ en/en/accueil).

In 1798, Augustin Pyramus de Candolle (1778–1841) left his home town, Geneva, to study natural history in Paris. He benefited from the Parisian scholarly emulation and very quickly became a key member of the circle of the great naturalist scientists of the era, alongside Georges Cuvier (1769–1832) or Jean-Baptiste de Lamarck (1744–1829). In 1808, he was offered the post of Director of the Jardin des plantes de Montpellier and the Chair of botany at the Faculty of Medicine of the same city. Having briefly served as Rector of the University of Montpellier during the 'Cent jours', A. P. de Candolle returned to Geneva in 1816 due to the fall of Napoleon. There he accepted the chair of Professor of Natural History, with the possibility of founding a Botanical Garden in the city. On the 19 November 1817, the authorities planted the first species of the School of Botany in the Botanical Garden, on the site of the present Parc des Bastions. This was the founding act of the institution. The initial articulation of University – Botanical Garden set up by A. P. de Candolle has been maintained throughout the history of the institution, since the teaching of systematic botany at the University is still carried out by CJBG staff.

Within the Botanical Garden of the Bastions, a Botanical conservatory was built in 1824, still under the impetus of A. P. de Candolle. This modest structure accommodated the first botanical collections, such as that of Albrecht von Haller (1758–1823), third son of the famous Bernese botanist Albrecht de Haller (1708–1777). In 1869, the exceptional donation of one of the largest private herbaria of the time, that of the Parisian industrialist of Swiss origin, Benjamin Delessert (1773–1847), definitively positioned Geneva as one of the largest European botanical centres. With its 250,000 specimens, the Delessert Herbarium marked the beginning of the development of the general collection of the Geneva herbarium (G). From 1992 onwards, the herbaria of Johannes Burman (1706–1779), his son Nicolaas Laurens Burman (1734–1793) and Martinus Houttuyn (1720–1798) were separated from the General Herbarium, a process that is still in progress. This collection, acquired by Delessert in 1801 on the advice of Candolle, contains about 30,000 ancient specimens, comprising 17th and 18th century collections from India, Ceylon, the Cape of Good Hope and the West Indies, among others. This pre-Linnaean collection has recently been given a specific acronym (G-PREL). A botanical library exists since the foundation of the Conservatory. It has been gradually enriched, mainly through bequests, and in 1845, some 391 works were listed. Nevertheless, the need to associate the institution with a much larger collection of works linked to the Conservatory's herbarium collections, considerably enriched by the Benjamin Delessert bequest in 1869, took shape in 1874. The then director, John Isaac Briquet (1870–1931) left a lasting mark on the history of the CJBG through his instigation of the move of the Garden and Conservatory to their present site, with the construction of the building *La Console*, inaugurated in 1904, and in 1897 by his by launching of a scientific journal, *Les Annuaires du Conservatoire et du Jardin Botaniques de Genève*, renamed *Candollea* in 1922. Another title linked to the institution, *Boissiera*, was created in 1936. In 1897, Briquet definitively named the institution "Conservatory and Botanical Garden".

Donations from Emile Burnat (1828–1920), the botanists of the de Candolle family and Pierre Edmond Boissier (1810–1885) gave new

Standard sample of *Synaphea spinulosa* (Burm. f.) Merr. (*Proteaceae*) preserved in the closed pre-Linnaean herbarium (G-PREL). This plant was probably collected in 1697 on the west coast of Australia during the expedition of the Dutch East India Company led by Captain Wilhelm Vlaming. It is one of the oldest collections kept in the Geneva herbarium.

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722.

IA – 2

Gesneria quaternaeflora

Deppeana Schl. et Cham. Linnaea 5.

impetus to the collections. Burnat played a discreet but essential role by his financing of more than half of the extension of the building La Console in 1911–1912, to house a new donation of herbaria of nearly 220,000 samples, which he gave, together with his rich library, to the City of Geneva. The Burnat Herbarium (G-BU) constitutes the first historical herbarium of the CJBG. Because of its patrimonial importance, this collection is open for consultation, but its specimens are not sent on loan (termed a closed herbarium). The botanists of the de Candolle family (from four successive generations since Augustin Pyramus) had their own private collections: a herbarium of more than 400,000 samples and an exceptional library. When Augustin, great-grandson of Augustin Pyramus, died, his wife Louise decided to place the collections in public hands: the herbaria were thus donated and the library sold to the City of Geneva on the 20th of May 1921. The de Candolle Herbarium, which had been used for the writing of the work *Prodromus systematis naturalis regni vegetabilis*, became the second closed herbarium of Geneva (G-DC). The rest of the collection joined the General Herbarium, which at the time consisted mainly of the Delessert Herbarium. In October 1924, Augustin de Candolle's wife also handed over to the City of Geneva the botanical correspondence and the archives of the botanists of the de Candolle family, an exceptional collection of more than 9,000 items. On the death of the Geneva botanist Edmond Boissier, student of Augustin Pyramus de Candolle, his rich collections (250,000 herbarium specimens and an important library) were passed on to his son-in-law William Barbey (1842–1914), who actively continued his father-in-law's work. This unique collection reached 500,000 samples and was bequeathed to the University of Geneva in 1918, before being entrusted to the CJBG in 1943 within the framework of an agreement between the two institutions. In contact with all the botanists of his time, Boissier assembled a world class herbarium that formed the basis for his major work, *Flora Orientalis*, published between 1867 and 1888. The closed herbarium of the *Flora Orientalis* (G-BOIS) is the result of a reconstitution undertaken in the 1960s by systematically extracting and reassembling all the samples cited in the *Flora Orientalis*. Throughout the 20th century, the Conservatory's collections (herbarium and library) continued to grow through purchases, exchanges and donations, and La Console soon ran out of space. Between 1962 and 1986, several buildings were constructed and the phanerogamic collections were moved from La Console to a building behind the Villa le Chêne, specially constructed to house them. The herbarium was considerably enlarged in 2012, thanks to a donation from Roger and Françoise Varenne. Two consultation rooms for researchers were added as well as a public reception area. The Console was renovated in 2014 and the Library in 2016, with an enlarged consultation area created. Thanks to this vast renovation programme, the incomparable collections of the CJBG now have a setting befitting their historical and botanical importance.

1.2. The Conservatory and Botanical Garden of Geneva in a few numbers

The CJBG are a dynamic centre for botanical research with an herbarium of more than 6 million specimens, placing it 6th largest in the world, and a library of more than 135,000 volumes and 4,500 periodicals, including 1,500 active ones. In addition to this patrimonial heritage is a rich collection of more than 40,000 living plants. The herbarium grows annually by about 20,000 plant and fungal specimens. Of this collection, more than 344,000 specimens are recorded in our database, including more than 119,000 types specimens, and more than 200,600 images, to date. This information is available in open access on the internet via the *Geneva Herbaria Catalogue* (CHG). Other reference databases are also available online such as the

Original watercolour drawing representing *Moussonia deppeana* (Schltdl. & Cham.) Hanst. (*Gesneriaceae*). Attributed to A. Echeverría and dating from the "Real Expedición Botánica a Nueva España" (1787–1803), it is included in the *Flore des Dames de Genève* (plate 722) and kept in the CJBG library.

African Plants Database (APD), the *Catalogue des lichens de Suisse* and the *Index Hepaticarum*. On average 70 scientific visitors consult the herbarium collections of the CJBG each year. Twenty-seven scientists (equivalent to 23.4 full-time positions, 2018) work on about forty-five different research projects and publish around sixty scientific articles each year. In addition to the herbarium and the library, the scientific research at the CJBG also relies on four laboratories (Anatomy and Micromorphology; Microscopy and Chromatography; Molecular Phylogeny and Genetics; Geographic Information Systems and Remote Sensing). Finally, in 2000, the institution set up the only wild plant seed bank in Switzerland, with more than 30 million seeds stored in it, to date.

1.3. Research and scientific activities at the Conservatory and Botanical Garden of Geneva

The three objectives of the Convention on Biological Diversity

- the conservation of biological diversity;
- the sustainable use of its components;
- the fair and equitable sharing of the benefits arising out of the utilisation of genetic resources.

The Aichi Biodiversity Targets

Strategic Goal A: Address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society.
Strategic Goal B: Reduce the direct pressures on biodiversity and promote sustainable use.
Strategic Goal C: To improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity.
Strategic goal D: Enhance the benefits to all from biodiversity and ecosystem services.
Strategic Goal E: Enhance implementation through participatory planning, knowledge management and capacity building.

The CJBG have a 200-year-old botanical tradition, based on the fundamental need to understand the plant and fungal world, to inventory the species that live on the surface of the globe, to define their distribution and the types of environments they occupy, to understand their relationships, both between species and with their habitats, and their evolutionary trends. The research activities carried out are strongly linked to the richness of the collections and are of a taxonomic, systematic, floristic, ethnobotanical and genetic nature. The CJBG have long specialised in floristics, directing flora projects or contributing with other institutions to the latter thanks to their expertise in taxonomy or to their vegetation analyses at the local, regional (Geneva basin, Alps), national, or international levels (continental Africa and Madagascar, the Mediterranean, Central and South America, South-East Asia and Oceania). These floras require the documentation and study of the species of a given territory and are the basis of the understanding of the functioning of our ecosystems. They allow for the identification of species and their distribution, as well as the quantification of the threats they face. On the basis of these observations, the CJBG propose solutions for their conservation. The research carried out at the CJBG also contributes to the global effort to achieve an in-depth knowledge of the world's biodiversity. Its interdisciplinary research thus plays a key role as a facilitator and trigger for *in situ* conservation processes, particularly in the framework of national and international cooperation projects. In this sense, it meets the expectations of the *Convention on Biological Diversity*, the *Aichi Biodiversity Targets* and the *Global Strategy for Plant Conservation* (2011–2020), see Annex 1, as well as the action plan of the *Swiss Biodiversity Strategy* (2012) and the *Biodiversity Strategy of the Canton of Geneva*, adopted in 2018.

The CJBG have expertise in the following domains:

1. Plant and fungal diversity and evolution

- taxonomy and systematics of plants and fungi with a specialisation in certain target regions (Switzerland, Africa, tropical America, Oceania);
- morphology, anatomy and developmental ontogeny of plants and fungi;
- plant communities and biogeographic distributions;
- molecular evolution, phylogeny and speciation, population genetics;
- museum genomics;
- nomenclature and reference indexes;
- history of botany.

2. Local, national and global flora and vegetation

- floristic research in Geneva and Switzerland, as well as in the Alps, in collaboration with partners from other Alpine countries;
- floristic research in tropical areas;
- biodiversity informatics;
- paper and electronic floras.

3. Conservation of plant and fungal biodiversity

- local and national conservation actions including *in situ* and *ex situ* conservation;
- inventories, mapping, species action plans and Red Lists;
- conservation strategies and action plans;
- seed bank at local and national levels;
- ethnobotany.

1.4. Local, national and international partnerships

The CJBG are involved in many projects and participate in various local, national and international organisations and initiatives. They are represented by the director or a collaborator specialised in a particular field. They also take part in and initiate cooperation projects in their fields of competence and in collaboration with local partners (academic, political or associative), especially in the global South (Africa, South America).

At the local level, the CJBG are active in the following organisations, among others:

The *Société de Physique et d'Histoire Naturelle de Genève* (SPHN), is an organisation founded in 1791 and aimed primarily at the study, advancement and popularisation of science, by organising conferences and debates and regularly awarding prizes and scholarships (Augustin Pyramus de Candolle Prize, Lombard Scholarships for Young Researchers, etc.) in order to encourage university training and research. The CJBG have been linked to the SPHN since their beginnings, since the young Augustin Pyramus de Candolle attended the botany courses given in the society's small botanical garden.

The *Société de Botanique de Genève* (SBG), is an organisation of public utility whose primary goal is to promote the study of botany (floristics, taxonomy, physiology, etc.). The CJBG actively collaborate with the SBG on projects of mapping and/or study of the flora of the canton, and also contribute regularly to the organisation of conferences, workshops and excursions.

The *Commission consultative de la diversité biologique* (CCDB) assists the State of Geneva in the accomplishment of its missions, in particular for projects likely to have an impact on the flora, fauna and sites and biotopes favourable to biological diversity, as well as with issues related to forest. The CJBG are members of the CBD as experts.

In 2010, the City of Geneva and the State of Geneva also signed a convention establishing a framework for collaboration between the *Cantonal Office for Agriculture and Nature* (OCAN) and the CJBG, in the implementation of the Canton's flora conservation programme. This convention sets out the goals to be achieved, the competences, as well as the rights and duties of the parties. Since 2012, a service agreement has been in place to formalise the implementation of this programme, which is co-financed in equal parts by the OCAN and the CJBG. This programme ensures the monitoring of the flora and natural habitats of the Canton of Geneva through actions and products.

At the Swiss level, the CJBG participate in the following initiatives:

The *Global Biodiversity Information Facility Switzerland* (GBIF.ch), the Swiss Node recognised by the *Global Biodiversity Information Facility* (GBIF), is the body officially mandated by the Swiss Confederation to create the optimal conditions for the dissemination of information on biodiversity in Switzerland within the international GBIF network. Its objective is to collect all specimen information from Swiss natural history collections, to aggregate all observations from existing fauna and flora databases and to ensure the availability of national data through a single platform.

InfoFlora is a private foundation of public utility active in the field of information and promotion of wild plants in Switzerland. The founding members are the City of Geneva through the CJBG, Pro Natura, the Swiss Botanical Society (SBS) and the Swiss Academy of Natural Sciences (SCNAT). The head office of the foundation is located at the CJBG. *InfoFlora* is recognised by the Federal Office for the Environment as the national data and information centre for Swiss flora and works in close collaboration with the other national data centres which are grouped together in *InfoSpecies*.

InfoSpecies, the Swiss Species Information Centre, is the umbrella association of Data and Information centres and Coordination centres for species conservation in Switzerland. It encompasses the national databases on vascular plants, bryophytes, fungi and lichens, as well as insects, reptiles, amphibians, mammals and birds.

The *Swiss Barcode of Life* project (SwissBOL), initiated by the Federal Office for the Environment for the centralisation and dissemination of genetic data on the biodiversity hosted in Switzerland, has as its main goals to create a genetic reference catalogue for animals, plants, fungi and microorganisms in Switzerland; to increase knowledge on genetic diversity in Switzerland and to participate in a better monitoring of the global state of biodiversity. The data generated in collaboration with *SwissBOL* are disseminated via GBIF.ch, *Barcoding of Life data system* (BoLD) and *GenBank*.

The *Swiss Systematics Society* (SSS) brings together Swiss institutions and scientists active in all fields of systematics (paleontology, botany, zoology). Its main objective is to ensure that a high level of systematics expertise is maintained in Switzerland. The society represents systematicians from all fields of biology, promotes and supports systematics in academic and political circles, and encourages research and the use of natural history collections in Switzerland.

The CJBG are also active in the Swiss Botanical Gardens Association (*Hortus Botanicus Helveticus*), which brings together Swiss botanical gardens and plant collections with the aim of facilitating the scientific management and conservation of national and international plant collections and promotion of activities in the field of species and habitat protection, in collaboration with regional and national services.

The CJBG are part of the "Collections" group of the *Biology Platform of the Swiss Academy of Sciences* (SCNAT) and participates in the development of an initiative on natural history collections in Swiss institutions – *SwissCollNet* – in order to create a Swiss network for the institutions concerned and to promote the digitisation and scientific use of the national collections.

At the European level, the CJBG and the Natural History Museum of Geneva have formed a 'Geneva group' to join the *Consortium of European Taxonomic Facilities* (CETAF), a European platform for the

One of the oldest trees of the CJBG, a magnificent three-hundred-year-old pedunculate oak (*Quercus robur* L., *Fagaceae*).

promotion of European natural history collections and the research carried out in the institutions hosting these collections. The CETAF prepares position papers and policy documents for the community, while ensuring political visibility and strengthening the position of natural history institutions in Europe. The CJBG have been an active member of the Consortium, having held the presidency (2013–2019) and then the co-presidency of its council (2019–2023).

The CJBG have also been present for many years in the international office of OPTIMA (*Organisation for the Phyto-Taxonomic Investigation of the Mediterranean Area*).

The CJBG actively participate in the association of the Botanical Gardens of France and French-speaking countries (JBF) as well as in the *Botanic Gardens Conservation International* (BGCI). The BGCI is a privileged interlocutor of the Secretariat of the Convention on Biological Diversity (CBD), and is notably at the origin of the Global Strategy for Plant Conservation, adopted by the CBD. One of its objectives is the creation of a World Flora Online (WFO) by 2020. The CJBG are an active member of the WFO Consortium, co-chair its board, and have been selected as the provider of the scientific name management tool from the CJBG Botalista database.

The CJBG have long been involved in botanical nomenclature, since it was that Alphonse de Candolle who proposed the first Code of Botanical Nomenclature in Paris in 1867, the work containing all the rules for giving a scientific name to plants. The Code is reviewed every 6 years on the occasion of the International Botanical Congress. Within this framework, CJBG scientists participate in the council of the *International Association for Plant Taxonomy* (IAPT) and in the various committees of the IAPT that prepare the modifications of this Code, including the editorial committee for the last volume, published in 2018. The dissemination of the latest Code in the French-speaking world has been made possible thanks to the translation of the original document by the nomenclature experts of the CJBG.

The CJBG also host the Swiss-French branch of *ProSpecieRara*, a Swiss non-profit foundation founded in 1982 to preserve breeds of livestock and crop plants threatened with extinction. *ProSpecieRara* works with the Confederation on certain projects and is partly financed by the Federal Office for Agriculture. Over the decades it has developed into an umbrella organisation and today works closely with associations, breeders and growers.

Lectures of the Biology Section of the University of Geneva given by the professor and the lecturers of the CJBG

Compulsory courses:

- Taxonomic and Medicinal Botany (14B015)
- Plant Systematics and Biodiversity (12B018P) Spring Semester

Optional courses:

- Advanced studies in systematics (14B013)
- Biodiversity (14B005)
- Biogeography (14B007)
- Tropical botany (14B016)
- Practical Introduction to botanical collections (14B021)
- Flora and vegetation (14B008)
- Floristics (14B033)
- Scientific writing and communication (14B012)
- Alpine botany and biogeography field course (14B668)
- Tropical botany field course (14B669)
- Flora and vegetation field course (14B009)
- Applied statistics: (14B951)
- Systematics and ecology of lichens and bryophytes (14B070)

1.5 The convention with the University of Geneva

Since their creation, the CJBG have been linked to the University of Geneva. Indeed, it was at the request of the Academy, the forerunner of the University, that Augustin Pyramus de Candolle accepted the Chair of Natural science on the condition that a Botanical Garden would be created to support his teaching. He built it around the School of Botany, as a series of 50 rectangular flowerbeds systematically presenting the species of the different families in the order in which they appeared according to his taxonomic concepts. By 1819, there were already about 3,000 species in this location.

Subsequently, almost all the directors or curators have been in charge of teaching botany at the University. In 1943, this collaboration was formalised and became the subject of a convention between the University and the City of Geneva, thus bringing together the herbarium collections and botanical works within the CJBG. In return, all university teaching related to systematic botany, floristics, vegetation, and plant and fungal biodiversity is given by the scientists of the CJBG, to whom the title of lecturer is awarded by the University. This complementarity has continued to the present day and the convention was updated in June of 2014. The CJBG scientists also provide support to bachelor's, master's and doctoral students in the context of their research projects conducted at the institution. The laboratories of the CJBG, the lecturers and the scientists supervising the students make up the *Laboratory of Plant Systematics and Biodiversity*, one of the eight research groups of the Department of Botany and Plant Biology of the Biology Section of the Faculty of Sciences of the University of Geneva.

Observation of the influence of micro-relief on the distribution of *Ericaceae* heathland with students of the Alpine Botany and Biogeography field course (UniGE course no. 14B668) at La Breya (Valais) in 2019.

2. A scientific strategy for the Conservatory and Botanical Garden of Geneva: a tool for the future

2.1 Why a scientific strategy for the Conservatory and Botanical Garden of Geneva?

This scientific strategy gives a global vision of the institution's scientific activities, highlights its various strengths, underlines the major research themes and positions them in the broader context of the current and future scientific and societal challenges. It provides a framework, respecting the local political guidelines, within which the institution can adequately develop its research themes, and within which its scientists can plan and undertake their research programmes and projects. It also serves as a working tool to define scientific priorities within the institution and to contribute to strategic decision-making on current and future directions.

The strategy documents the institution's main research programme, outlining priority research areas. It also explains how collections, infrastructure, tools and technologies, education and communication activities, scientific expertise and collaborations are used to enhance and achieve the institution's key strategic objectives. The implementation of such a strategy also serves to:

- facilitate the optimisation of resources;
- promote the cohesion of scientific activities and transversality between the herbaria, laboratories, library, popularisation, exhibitions, etc. ;
- promote internal and external collaborations;
- allow the implementation of realistic and feasible projects oriented towards common strategic objectives and coherent scientific communication;
- ensure progress towards institutional objectives and achievements, as well as strengthen the identity of the institution.

The scientific strategy must also serve to develop the institution's profile at different levels (political – public – scientific) and to optimise its communication and scientific mediation activities. Finally, such a strategy aims to improve the visibility of the institution, both internally and externally, by offering a coherent vision of its current and future scientific activities.

This strategy has been developed by all the scientific staff of the institution, based on a SWOT analysis: Strengths, Weaknesses, Opportunities, Threats. This document presents the scientific strategy of the CJBG for the period 2020–2030, in line with the Museum policy developed in Geneva for 2015–2020[1].

2.2 From the evaluation of the existing situation to the elaboration of a scientific strategy for the Conservatory and Botanical Garden of Geneva

The reflection on the scientific strategy covered all the research and scientific activities carried out within the institution. It made it possible to identify the scientific contributions made by the CJBG at local, regional, national and international levels, and to highlight the diversity of scientific skills associated with the research projects and activities. The discussion and exchange also helped to identify new potential synergies between scientists and the different projects, as well as to identify common or cross-cutting research themes or research questions that can be addressed collectively. In the development of the reflections on the scientific future of the institution,

Current and future challenges for the Conservatory and Botanical Garden of Geneva

Collections are essential for research on biodiversity, and a multitude of approaches and concepts are being developed to highlight them, whether by promoting their accessibility (digital or physical) or by facilitating research based on the study of these collections. This also involves the development of digital applications for the consultation of electronic catalogues and projects aimed specifically at valorising the collections, as well as the need to ensure the presence of experts capable of managing scientific collections and the studies derived from them in the long term, by adapting to emerging technologies. These issues encourage us to maintain a high level of expectations in order to meet the challenges of the future. The CJBG therefore aim to:

- ensure the long-term management of their collections;
- perpetuate expertise and skills in collection management, taxonomy and systematics within the institution;
- digitise collections and ensure data sharing in order to make their knowledge available to the community;
- maintain their computer resources (database, digital data storage, bioinformatics support, archiving, electronic data management, access to external computing clusters);
- maintain essential research infrastructures (laboratories, machines, new technologies);
- improve the links between physical collections and digital data;
- disseminate data and knowledge (books, scientific articles, exhibitions, conferences, courses, etc.);
- integrate the principles of FAIR Data and Open Science (e.g. European Open Science Cloud – EOSC, or Open Science – SNSF);
- develop and organize participatory science through projects related to the collections and research projects carried out within the institution;
- organise and facilitate scientifically oriented volunteer work;
- adapt practices to national and international legislative requirements concerning collections and scientific research;
- maintain collaborations with initiatives or organisations, in Switzerland or internationally, in order to promote research, biodiversity conservation and natural history collections.

the following questions were answered: 1) What are the priorities for the collections? 2) What are the priority research themes? 3) What are the botanical competences to be maintained or strengthened as a priority? 4) What are the priorities for scientific communication?

2.3 Research conducted on the collections of the Conservatory and Botanical Garden of Geneva is crucial for the understanding of biodiversity.

Scientific research consists of the systematic investigation and study of objects and original sources in order to establish facts and reach new conclusions. Therefore, the description and interpretation of species, the understanding not only of their past and present distribution patterns, but also of their evolutionary history, occupies a central place in so-called "museum research". The data collected by naturalist scientists from museum collections are a primary source of information for virtually all branches of science aimed at understanding living organisms and their interactions, such as taxonomy, biogeography, ecology, evolution or conservation biology. Such fundamental research is conducted today almost exclusively in natural science institutions, mostly museums, and should, in this time of biodiversity crisis, be considered crucial.

The results of the scientific research conducted on the collections are disseminated through scientific publications, online databases, exhibitions, as well as education, cooperation, training and scientific mediation programmes. Specialists working in natural science institutions are often consulted as experts on biodiversity and conservation issues, as they are considered by politicians and policy makers as the authorities in their fields. Natural history museums, as Centres of excellence in the field of biodiversity sciences, thus contribute to these different activities and provide quality expertise on a wide range of local, regional, national or global issues.

2.4. The infrastructures of the Conservatory and Botanical Garden of Geneva in support of scientific research

The CJBG provide a research infrastructure combining the herbarium and library collections, computer services and databases, cultivation facilities for living collections, the seed bank, the editions and the four research laboratories.

The collections and laboratories are at the disposal of the CJBG researchers and frequently welcome visitors from other institutions, as well as biology students from the Faculty of Sciences of the University of Geneva, either for their own research activities or within the framework of projects carried out in collaboration with CJBG scientists.

The *Herbarium*, with its approximately 6 million specimens, is one of the largest in the world. Heir to a long botanical tradition in Geneva dating back to the 18th century, it brings together plants (algae, bryophytes, ferns, gymnosperms, flowering plants) and fungi from all over the world, but particularly from the Mediterranean region, the Near and Middle East, South America and Europe.

The *Library* is considered one of the most important in the world for botanical science. It contains almost all the scientific books and journals published to date in the fields of plant and fungal taxonomy as well as world floristics, i.e. more than 120,000 volumes and 4,400 scientific journals, 1,500 of which are still active. It also houses a rich

The assets of the Conservatory and Botanical Garden of Geneva

- the herbarium;
- the library and archives;
- the living collections;
- informatics, management databases, and reference databases;
- the editions;
- the laboratories;
- the seed bank;
- mediation and popularization of science;
- university teaching and the links with the University;
- expertise in botany and biodiversity;
- networks of scientific collaborators;
- strategic partnerships.

List of CJBG databases accessible via the Internet

- Geneva Herbaria Catalogue: http://www.ville-ge.ch/musinfo/bd/cjb/chg
- African Plant Database: http://www.ville-ge.ch/musinfo/bd/cjb/africa
- Plant biodiversity in Geneva: http://www.patrimoine-vert-geneve.ch
- Digital flora of the Maghreb: http://www.ville-ge.ch/cjb/flore/html/index.html
- Catalogue of Hedwig Types – Bryophyte Herbarium: hhttp://www.ville-ge.ch/musinfo/bd/cjb/hedwig
- Index Hepaticarum Names Database: http://www.ville-ge.ch/musinfo/bd/cjb/hepatic
- Catalogue of Swiss lichens: http://www.ville-ge.ch/musinfo/bd/cjb/cataloguelichen
- Hyphaene Project: https://www.hyphaene.org
- Auxilium ad botanicorum graphicem: http://www.ville-ge.ch/musinfo/bd/cjb/auxilium
- Database of Brazil in TAPIR (web service): http://www.ville-ge.ch/musinfo/bd/cjb/tapirlink

Field mission to western Thailand in search of *Pandanaceae* on limestone outcrops, conducted by Martin Callmander, curator, and collaborators of the National Park, Wildlife and Plant Conservation Department of the Bangkok Forest Herbarium (BKF).

palette of archival documents (correspondence, manuscripts) from the hands of the greatest botanists.

The Anatomy and micromorphology laboratory carries out histological research on the vegetative and reproductive structures of cryptogamic and phanerogamic plants.

The *Anatomy and micromorphology laboratory* specialises in the detailed study of the anatomical structure of vegetative organs (roots, stems, leaves) or flowers, as well as the floral ontogeny of plants. The research of this laboratory is complemented by observations with the scanning electron microscope (SEM) of the Natural History Museum of Geneva, as well as with a close collaboration with the Plant Imaging Unit of the University of Geneva.

The *Microscopy and chromatography laboratory* is dedicated to the macroscopic, microscopic and chemical study of fungi (lichenised and non-lichenised), myxomycetes, algae, bryophytes and ferns. The means available include binocular microscopes (stereo-microscopes), light-microscopes, a freezing microtome, a thin-layer chromatography installation and two digital cameras for image recording.

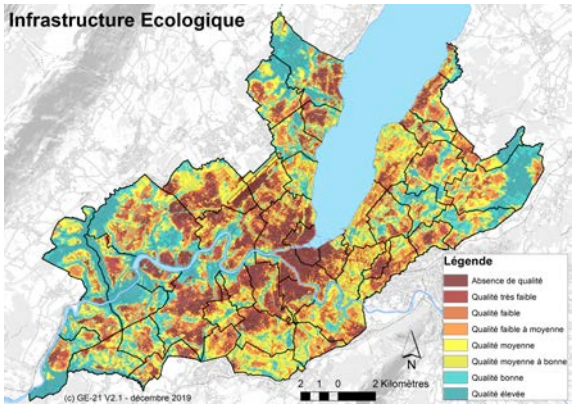
Lichenic substances revealed by thin-layer chromatography carried out in the Microscopy and chromatography laboratory.

The aim of the *Molecular phylogeny and genetics laboratory* is to understand the evolution of biodiversity based on the analysis of genetic and genomic data (Sanger sequencing, Next Generation Sequencing, molecular markers of the SNP or microsatellite type). Research activities are carried out both interspecifically, using phylogenetic approaches, and intraspecifically, using population genetics and phylogeography tools. The analyses carried out make it possible to reconstruct the evolutionary history of plants and fungi (tree of life), to improve their classification and to explain the evolutionary mechanisms behind their diversity.

The Molecular phylogeny and genetics laboratory analyses genetic and genomic data both interspecifically and intraspecifically.

The *Geographic information systems and remote sensing laboratory* brings together the infrastructure necessary for the operation of tools such as Geographic Information Systems (GIS) and Remote Sensing (RS). The GIS are used for the analysis of vegetation and the production of distribution maps of species or habitats. This laboratory is integrated into Territorial Information System of the City of Geneva (SITV) program, a partner of the Information System of the Geneva Territory (SITG), and its results are used on a daily basis within the framework of the “Green Heritage” project, which constitutes the Regional biodiversity information system.

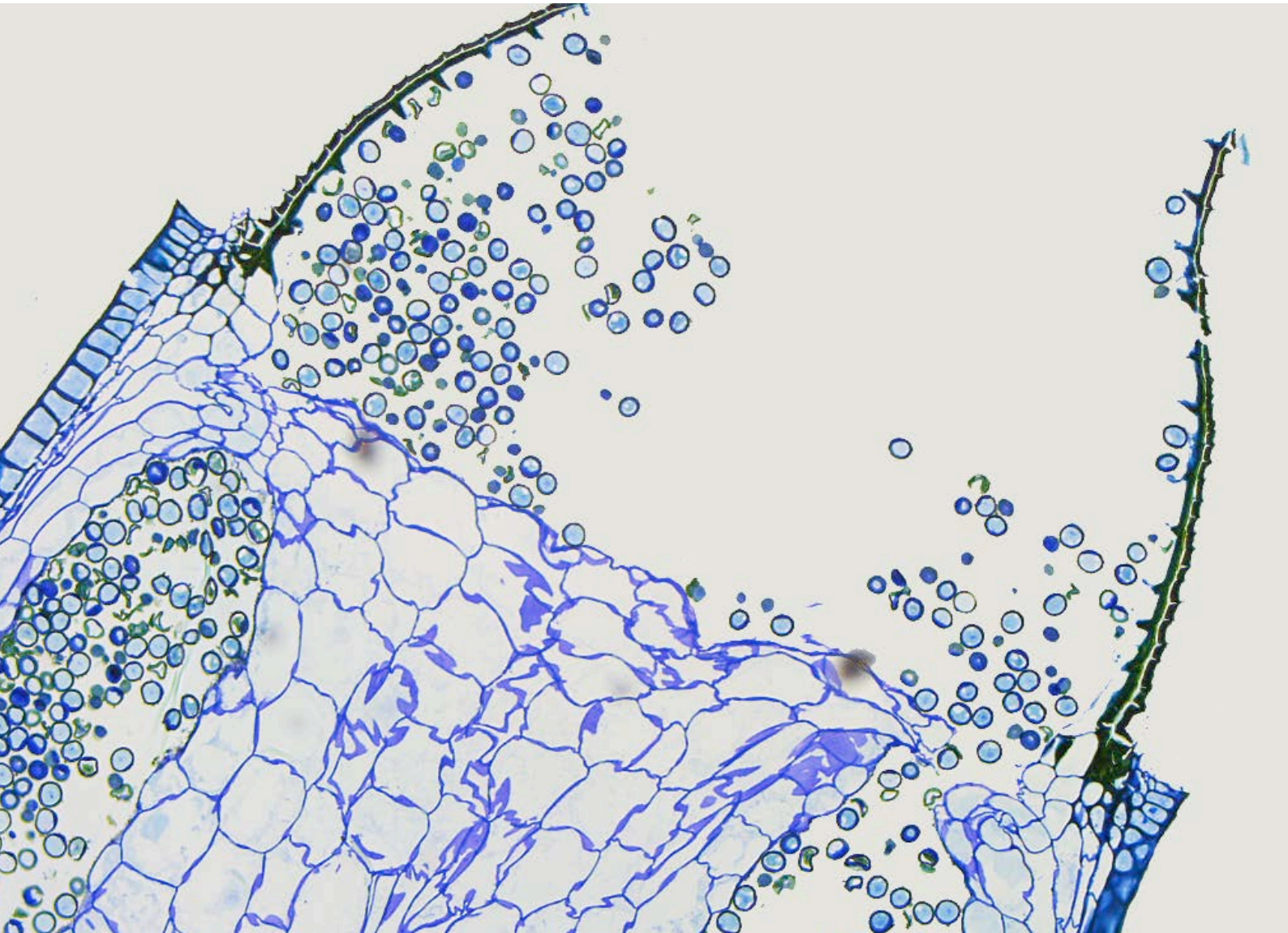
Other infrastructures, such as computer tools and databases like the *Geneva Botanical Information System* (SIBG), the seed bank, the editions and the garden infrastructures are also important in the scientific activities and as tools for the management, analysis and dissemination of results.



The Geographic information systems and remote sensing laboratory works in particular on mapping the network of natural environments.

The *Geneva Botanical Information System* (SIBG) has been integrating different research projects and collection management within the same system for 20 years, in order to share concepts, repositories, data, methods and applications, ensuring the management of the institution’s scientific projects, herbarium collections and living collections at the same time. Most of the information disseminated via online databases is extracted directly from the SIBG, in particular the Geneva Herbaria Catalogue, a virtual catalogue of collections, which gives access to all the herbarium samples recorded electronically, as well as images of the scanned herbarium specimens.

Botalista is the new open source management tool for the non-library collections of the CJBG. It will eventually replace the SIBG, which has become obsolete for various reasons. In order to respect the principles of FAIR data (Findable, Accessible, Interoperable, Reusable) and *Open Science*, the new *Botalista* management tool is based exclusively on *Open Source* software. *Botalista* is proposed as



a collection management tool to other Botanical Gardens, in a spirit of collaboration and data exchange, within the framework of an association bringing together a network of institutions wishing to use it.

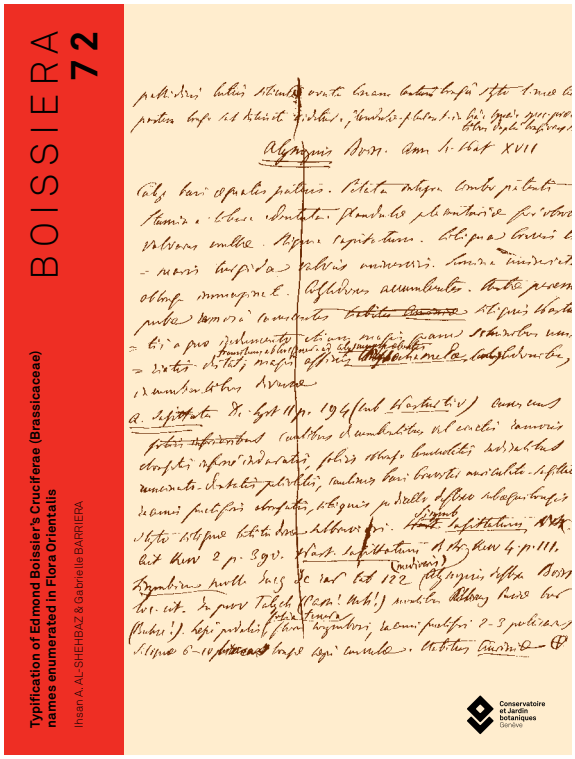
The *Seed Bank*, unique in Switzerland, preserves viable seeds of endangered wild plants in the long term, initially mainly from the canton of Geneva. It is open to other cantons that request it. This seed bank partially meets objective 8 of the Global Strategy for Plant Conservation. A partnership agreement has been signed with the University of Zürich to support the establishment of a second seed bank in German-speaking Switzerland. The collections of the two institutions will eventually be distributed between each in order to increase collection security. This consortium could be recognised as a national seed bank by the Confederation.

Cushion of *Dicranum scoparium* Hedw. (*Dicranaceae*) with numerous sporophytes, observed in the undergrowth of the Jura Vaudois.

Haplolepidous peristome of *Dicranum scoparium* Hedw. observed with a Scanning Electron Microscope.

Longitudinal, coloured 5 µm thick sections of the peristome of *Dicranum scoparium* Hedw. after resin coating and microtome sectionning.

Seeds of *Agrimonia procera* Wallr. stored in the CJBG seed bank.



Cover page of *Boissiera* 72, entitled "Typification of Edmond Boissier's Cruciferae (Brassicaceae) names enumerated in Flora Orientalis" and written by the world specialist on the crucifer family Ihsan A. Al-Shehbaz and Gabrielle Barriera, scientific assistant.

Double page of *Candollea* 74-2 extracted from an article on the description of *Pandanus papateaensis* Butaud, F. Jacq & Callm. (*Pandanaceae*), a threatened species endemic to the raised atoll of Makatea in French Polynesia.

The *Editions* produce publications in botany that are intended both for international scientists and the general public. The Editions publish, among others, the two periodicals *Boissiera* and *Candollea*, perpetuating a scientific tradition initiated in 1897. Other publications, in the form of series or books, sometimes resulting from co-publishing partnerships, target a public of researchers, as well as botany enthusiasts.

Growing facilities for living collections, such as greenhouses, growing rooms and areas, facilitate collaboration between botanist gardeners and scientists. The cultivation of living plants provides important information for some of the institution's research work.

The Winter Garden, the oldest greenhouse of the CJBG, was built in 1911. It was moved to its present location in 1935 to make way for the Avenue de la Paix, leading to the Palace of Nations.

3. The scientific strategy of the Conservatory and Botanical Garden of Geneva

The three pillars of the CJBG are centred on the collections, skills and means of communication. The collections, as explained above, represent the primary source of scientific data and must therefore be considered as the institution's patrimonial reference. Scientific skills, or expertise, are intrinsically linked to the scientists of the CJBG, to their fields of research and to the programmes and projects in which they participate, as well as to the research infrastructures. The skills of the scientists range from those related to the management of the collections to those required for the various fundamental and applied research activities conducted using the collections. These include taxonomy and nomenclature, systematics, cartography, anatomy-morphology and conservation. In order for scientific discoveries to be disseminated and used in different spheres and by our partners, it is important that they are published and made available to scientists and the public. Based on the three core elements that are the collections, skills and communications, three strategic axes have been identified for scientific activities at the CJBG:

A. Document and study biodiversity;
B. Conserve, enrich and make available the collections;
C. Disseminate and popularise scientific knowledge.

For each strategic axis, priority objectives have been defined. Within these priority objectives, several actions have been identified. Axes, objectives and actions constitute the necessary foundations for the elaboration of a future action plan to implement this strategy.

Extract from a fieldwork notebook by Cyrille Chatelain, curator, during a mission to Daraina, Madagascar, in 2006.

Pressing collected plants near a stream in the Ambohitsitondroina forest, as part of research on flora and vegetation conducted in the Loky-Manambato protected area, Madagascar, in 2004.

Field-drier for presses containing plant material from the Antsahabe Forest Massif (Loky-Manambato Protected Area, Madagascar, 2004). A gas cylinder is buried under the dryer. Operating 24 hours a day, it dries the botanical samples in a few days.

3.1. Strategic axis A. Document and study biodiversity

Understanding and documenting the world's biodiversity remains one of the major challenges facing scientists today. The *Convention on Biological Diversity* (CBD) and the *Aichi Biodiversity Targets* form the legal framework for the activities of the CJBG. The fundamental significance of biodiversity, the services it provides and the future well-being of the planet should not be underestimated. They are taken into account in the United Nations *2030 Agenda for Sustainable Development*. Research at the CJBG also contributes to the *Global Taxonomy Initiative* (GTI) and to the implementation of the CBD within the framework of the *Global Strategy for Plant Conservation*. At a time of major biodiversity crisis, it is imperative to intensify research that aims to discover and describe new species, in collaboration with local partners. These tasks remain intrinsically linked to natural history institutions.

Within this strategic axis, four priority objectives are identified:

A1. Identify, describe, name and classify species;
A2. Understand the evolutionary history of species and of biodiversity;
A3. Enrich knowledge of the world's flora through exploration and collection;
A4. Inventory, map, analyse and conserve plant and fungal biodiversity.

Priority objective A1. Identify, describe, name and classify species

The use of a unique scientific name for a taxon is essential to disseminate and share knowledge about that taxon. The scientific name is therefore a central element in the description of biodiversity. Institutions hosting scientific collections usually carry out the task of describing species and disseminating clear, current and consistent associated scientific information. Herbaria archive reference specimens of taxa and increase the knowledge of these taxa with additional specimens. Thus they are the raw material for studies in taxonomy and systematics that aim to understand the perimeters of taxa and their relatives. They also permit the verification, comparison and validation of the identification of species and serve as the reference material for the realisation of monographs and/or floras.

Within this priority objective, seven actions are prioritised:

A1.1. Describe, name and study the plant and fungal world and publish taxonomic and/or systematic revisions and monographs;
A1.2. Develop and disseminate expertise in taxonomy and systematics;
A1.3. Undertake research in taxonomy and systematics with an emphasis on the techniques of integrative taxonomy;
A1.4. Perpetuate expertise in nomenclature;
A1.5. Maintain reference indexes in botany and mycology;
A1.6. Know and qualify biodiversity;
A1.7. Make floras and valorise data from floras.

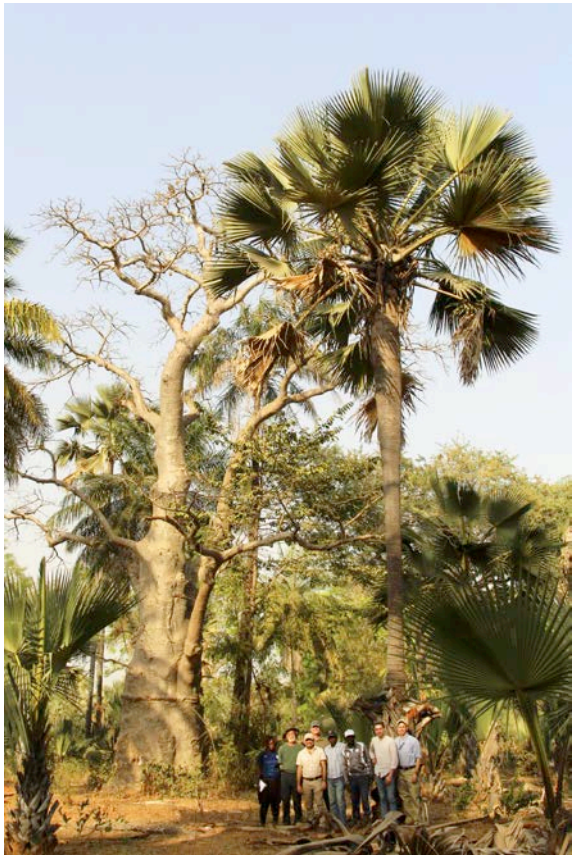
Priority objective A2. Understanding the evolutionary history of species and biodiversity

Effectively protecting biodiversity requires an understanding of the processes that produced it and continue to shape it over time and space. It also requires an ever more precise knowledge of the

species that comprise it, their genetic diversity and their evolutionary relationships.

Within this priority objective, four actions are prioritised:

A2.1. Circumscribe taxa using morphological, anatomical, chemical and molecular techniques;
A2.2. Reconstruct evolutionary relationships between taxa;
A2.3. Understand the diversification of the plant and fungal world in time and space;
A2.4. Describe the processes of speciation and structuring within species.



In 2019 an international team composed of researchers from CJBG, the Montgomery Botanical Center (USA) and the Cheikh Anta Diop University in Dakar conducted the first inventory of palm trees in the Casamance region of southern Senegal.

Priority objective A3. Enrich knowledge of the world's flora through exploration and collection

An estimated 350,000 species of plants are recorded worldwide, as well as about 120,000 species of fungi. Some parts of the world, such as tropical regions, contain a significant part of this plant and fungal diversity, with species that are sometimes very restricted in their distribution ranges. The CJBG contribute to the description and knowledge of the plant world through exploration, in order to respond to the urgent need to conserve and sustainably manage plant and fungal diversity in the context of current threats. These field expeditions also allow for the acquisition of new material, necessary for the enrichment and updating of the herbarium.

Within this priority objective, five actions are prioritised:

A3.1. Organise collection campaigns in teams, within the framework of existing projects at CJBG, or with national and international colleagues;
A3.2. Promote the collection of specimens in the field in collaboration with the foreign institutions concerned;
A3.3. Ensure compliance with national and international regulations applicable to fieldwork and collections;
A3.4. Encourage specimen exchange and acquisition programmes with different partners;
A3.5 Study interactions between human beings and the plant world.

Priority objective A4. Inventory, analyse and conserve plant and fungal biodiversity

In addition to their central role in the knowledge and conservation of species, the CJBG adapt to the various challenges linked to the evolution of society, such as biodiversity loss, species extinction, climate change or population growth and food security. The CJBG participate in the conservation of species and the sustainability of their uses and services, in particular by mapping species distributions, establishing Red Lists, maintaining a seed bank and developing conservation action plans to be carried out in the field. These actions aim to ensure the resilience of ecosystems, with a view to the well-being of present and future generations.

Within this priority objective, five actions are prioritised:

A4.1. Engage in cantonal, national and international strategies concerning biodiversity, as well as participating in their elaboration and implementation;
A4.2. Invest in action plans for *in situ* and *ex situ* plant conservation;
A4.3. Maintain and exploit botanical expertise for nature conservation (flora, habitats, etc.);

A4.4. Analyse the structure, dynamics and functions of communities (vegetation) and species;
A4.5. Carry out inventories, distribution mapping and monitoring, and establish Red Lists and priority lists.

3.2. Strategic axis B. Conserve, enrich and make available the collections

The primary vocation of a museum is the conservation and enhancement of its patrimony. The collections of the CJBG are irreplaceable, as they are the fruit of a centuries-old scientific heritage that is internationally recognised. Ensuring this scientific quality and this representativeness of the plant world requires in part working as Geneva botanists did two centuries ago: collecting specimens in the field, building up collections, mounting or cultivating these plants, storing them over the long-term, and exchanging specimens with colleagues or institutions from around the world. Since the early 2000s, activities related to the digitisation of collections have become increasingly important in tasks of a curator. The digitisation of specimens or documents, which is currently underway, and the publication of the related data in international databases, now make it possible to pool and share knowledge rapidly with the entire scientific community. The CJBG now have the opportunity to make their collections visible and accessible to scientists, wherever they may be. These tools are formidable accelerators of knowledge acquisition, but they also guarantee the sustainability of the collections; thus digitally reproduced, the precious, even unique collections acquire a new life and new uses.

Within this strategic axis, three priority objectives are identified:

B1. Manage and study heritage and scientific collections;
B2. Ensure the development of collection digitisation;
B3. Maintain and develop tools for managing and making collections available.

Priority objective B1. Manage and study heritage and scientific collections

Collections form the foundations of museum activities. For the CJBG, they are divided between the herbaria, the library, the living collections, the genetic material (tissue or DNA) collections and the seed bank. While the origin and heritage value of these different collections are the result of a subtle blend of history, passion, opportunity and self-sacrifice, they have always been driven by the need for botanists to understand the world around them. Naming, comparing, describing or analysing life is the very essence of the natural sciences. This work is based on the observation of material. Collections are and will remain, the main resources used by scientific projects or research endeavours, both internally and by the scientific community in general.

Within this priority objective, five actions are prioritised:

B1.1. Maintain the capacity to study, manage and enrich the patrimonial collections (herbaria, library and archives);
B1.2. Develop collaborative initiatives in the collections (archives, library, herbarium, living collections including *ex situ*) on key themes and/or collections;
B1.3. Manage the genetic heritage of the collections, including links with local, national and international databases;
B1.4. Encourage scientific studies on the collections;
B1.5. Ensure the enrichment of the collections through fieldwork, exchange and purchase of specimens or via donations.

The consultation and working space of the CJBG herbarium.

Priority objective B2. Ensure the development of collection digitisation

Since the early 2000s, the digitisation of collections has created a revolution in the access to and use of the data. "Digitisation", "*big data*", data flow, data interconnectivity, "*open data*" and mobility are all terms that are now part of the daily life of botanists. The digitisation of collections breaks down boundaries be they geographical, social or financial. The scientific community now has continual access to a mass of new data. While this digital shift is a tremendous accelerator for science and the visibility of collections, it requires museums to develop new skills and a new approach to collections management in relation to digital data. Physical collections and their digital counterparts need to evolve together to reinforce their mutual importance.

Within this priority objective, four actions are prioritised:

B2.1. Perpetuate the databasing and digitisation of collections;
B2.2. Make collection data available through digitisation, in particular for historical collections of worldwide reference;
B2.3. Ensure the development and availability of tools for the databasing, scanning and management of digital data (collections, scans of specimens, pictures of organisms);
B2.4. Manage digital collections and maintain information consistency between physical and digital collections.

Priority objective B3. Maintain and develop tools for managing and making collections available

Today, the CJBG have a duty to make their data available in digital form as well. They must ensure that the right tools to create, edit, manage, analyse and disseminate information are available, especially those related to the collections. In addition, the interoperability of information systems must be guaranteed in order to federate and pool digitisation efforts, while optimising resources.

Within this priority objective, six actions are prioritised:

B3.1. Develop and maintain a local and remotely accessible management tool (e.g. *Botalista*);
B3.2. Ensure interoperability with different reference databases (e.g. GBIF, Harvard University Herbaria, International Plant Names Index, African Plants Database, Tropicos, Index Muscorum, Index Hepaticarum, Biodiversity Heritage Library, World Flora Online, InfoFlora, etc.);
B3.3. Regularly disseminate or publish digital data in institutional (CHG) or international databases (e.g. Global Plants – JSTOR, GBIF);
B3.4. Ensure compliance with the Nagoya Protocol for Access and Benefit Sharing;
B3.5. Participate in the development of international standards for biodiversity data and integrate them into databases and dissemination tools;
B3.6. Contribute to local, national and international initiatives that facilitate digital access to biodiversity data.

Pierre Boillat, senior librarian, putting books in the monograph section back on the shelves on the first floor of the Library.


TOP SECRET

3.3. Strategic axis C. Disseminate and popularise scientific knowledge

As a scientific institution, the CJBG have a duty to disseminate knowledge acquired and the results of the research carried out by their scientists to the academic and political world. As an institute financially supported by a municipality, they must also transmit knowledge to the general public and participate in the improvement of the scientific knowledge of the local population. This civic role is all the more important since the CJBG are the bearers of knowledge on biodiversity, which is under serious threat today.

In this strategic axis, four priority objectives are identified.

C1. Publish and edit research results;
C2. Ensure visibility on the internet and in scientific networks;
C3. Popularise scientific knowledge;
C4. Train botanists and biodiversity experts.

Priority objective C1. Publish and edit research results

Botanical literature, or more broadly put all scientific publications, allow for the dissemination of the information produced by researchers. These publications are validated by critical peer review and shared within the scientific community, notably through specialised journals. Since its creation in 1817, the CJBG have always had an editorial activity through scientific publications (e.g. *Prodromus*, *Candollea*, *Boissiera*, the Documentary Series, etc.). New information technologies make it possible to share this knowledge in a free and unrestricted manner (*Open Access*). The CJBG, as a public institution, must ensure the return these results to the public to ensure a wide access to the knowledge produced.

Within this priority objective, six actions are prioritised:

C1.1. Publish and disseminate scientific knowledge and expertise in taxonomy and systematics;
C1.2. Maintain a high-quality scientific editorial activity;
C1.3. Encourage the publication of articles and research results (data) by promoting *Open Access*;
C1.4. Publish digital floras;
C1.5. Use digital archives to make articles available;
C1.6. Produce works on the patrimonial collections of the CJBG and on the associated collectors.

Priority objective C2. Ensure visibility on the Internet and in scientific networks

Botanical gardens are managing a growing amount of digital data, particularly related to the management of their collections (living, herbaria, library, ...) and the research carried out on them. The aim is to make these gold mines accessible, not only to scientists, but also to the non-expert public and public authorities. In view of the multitude of data and information generated by the institution, it is important to find the best channels of dissemination and to diversify them. The internet is currently a vector of choice, making it possible to transmit information in multiple formats. The editorial "rules" must be clarified and explained in order not only to homogenise the transmission, but also to facilitate the reading of the actions. A lively, dynamic and stimulating communication must be created in order to highlight the work carried out by the institution.

As part of the Night of the Museums 2019, Frédéric Bieri, second in charge of the Rockeries & Conservation sector, led a visit on seeds.

Within this priority objective, four actions are prioritised:

C2.1. Improve the editorial process of the institutional website;
C2.2. Define and ensure the scientific content of the website;
C2.3. Valorise the research works on the different local, national and international scientific networks;
C2.4. Publicise the scientific contribution of the living collections.

Priority objective C3. Popularise scientific knowledge

The popularisation of knowledge makes complex issues accessible and intelligible to a non-expert public, and allows for the dissemination of knowledge on subjects on which everyone, as a citizen, can be called upon to express an opinion. Being at the centre of the study of plant biodiversity, at a time when it is under serious threat, the CJBG have a key role to play in helping to alert the public to the major challenges facing our societies.

Within this priority objective, four actions are prioritised:

C3.1. Maintain and develop popularised publications at the local, regional and national levels;
C3.2. Create and provide scientific mediation activities and/or workshops for all audiences;
C3.3. Produce works on the patrimonial collections and associated collectors;
C3.4. Develop joint activities between the Conservatory and the Garden, with a cross-fertilisation of skills, for the benefit of the public.

Priority objective C4. Train botanists and biodiversity experts

The CJBG ensure the perpetuation of knowledge in botany and the training of the next generation. As part of the collaboration with the University, the CJBG are a recognised teaching and research centre for current and future botanists. This training role is essential to sustain research and expertise, and to ensure that biodiversity can continue to be inventoried, studied and conserved in the future. Students, post-docs and other collaborators of CJBG that are non-scientific are an integral part of the institution's research programmes, contributing significantly to publications, conferences and scientific meetings. The training of young researchers thus contributes to the mobility and sharing of expertise among the scientists of the CJBG in Switzerland, and across political borders.

Within this priority objective, five actions are prioritised:

C4.1. Provide training in taxonomy, systematics and conservation;
C4.2. Provide training for students and university teaching at bachelor, master, doctorate and post-doctorate levels;
C4.3. Strengthen links with the University of Geneva and academic integration within the Department of Botany and Plant Biology of the Faculty of Sciences.
C4.4. Promote the introduction of new teaching techniques to ensure the attractiveness of compulsory and optional courses (MOOC, etc.);
C4.5. Develop or participate in e-taxonomy initiatives and regional, national or international taxonomy training courses.

Herbarium specimen of *Passiflora caerulea* L. (*Passifloraceae*) preserved in the closed pre-Linnaean herbarium (G-PREL). This collection comes from the herbarium of the Dutch botanists the Burmans, father and son, acquired by Benjamin Delessert in 1801.


Kohleria amabilis
var. bogotensis (G. Nicholson) L. P. Kvist & L. E. Skog
Gesneriaceae
Colombie

Kohleria amabilis var. *bogotensis* (G. Nicholson) L. P. Kvist & L. E. Skog, a *Gesneriaceae* in culture at the CJBG.

Landscape interpretation with the students of the Alpine Botany and Biogeography field course (UniGE course no. 14B668) on the shores of the Lacs de Fenêtre (Valais) in 2019, with observation of the vegetation on windy calcschists ridges characterised by *Festuca halleri* All. and *Elyna myosuroides* (Vill.) Fritsch.

4. Conclusion

The CJBG hold collections with an invaluable patrimonial heritage. Their studies contribute significantly to the collective efforts to gain an in-depth knowledge of biodiversity. Scientific research forms the basis of their pedagogic activities, educational programmes and public awareness programmes. This scientific strategy outlines the main axes and prioritises the objectives of the institution so that it can respond to the fundamental knowledge needs and to the major issues of society.

On the basis of the strategic axes, priority objectives and actions identified, the CJBG aim to:

- maintain, improve and provide access to their collections;
- provide fundamental taxonomic, systematic, biological, genetic and ecological data on plants and fungi;
- explore the evolutionary processes of plants and fungi to better understand the richness and distribution of biodiversity, past and present;
- contribute to efforts to conserve global plant and fungal biodiversity.

The CJBG will achieve these objectives through the following means:

- focus on the management, development, digitisation and scientific use of collections (herbaria, library, digital and living collections);
- undertake quality research in the fields of biodiversity, evolution and conservation of plants and fungi;
- engage in scientific projects, initiatives and collaborations at local, regional, national and international levels;
- provide dynamic university teaching activities as well as mentoring and training opportunities;
- provide strong communication and biodiversity popularisation programs.

A Siberian elm (*Ulmus pumila* L., *Ulmaceae*) and the temperate greenhouse of the CJBG in the background.

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Links

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Annex 1. Global Strategy for Plant Conservation

The Global Strategy for Plant Conservation (GSPC) is a programme of the United Nations Convention on Biological Diversity (CBD). This programme aimed to slow the rate of extinction of plant species worldwide from 2010 onwards. The GSPC consists of five main objectives and 16 targets.

Objective I: Plant diversity is well understood, documented and recognized

- **Target 1**: An online flora of all known plants.
- **Target 2**: An assessment of the conservation status of all known plant species, as far as possible, to guide conservation action.
- **Target 3**: Information, research and associated outputs, and methods necessary to implement the Strategy developed and shared.

Objective II: Plant diversity is urgently and effectively conserved

- **Target 4**: At least 15 per cent of each ecological region or vegetation type secured through effective management and/or restoration.
- **Target 5**: At least 75 per cent of the most important areas for plant diversity of each ecological region protected with effective management in place for conserving plants and their genetic diversity.
- **Target 6**: At least 75 per cent of production lands in each sector managed sustainably, consistent with the conservation of plant diversity.
- **Target 7**: At least 75 per cent of known threatened plant species conserved in situ.
- **Target 8**: At least 75 per cent of threatened plant species in ex situ collections, preferably in the country of origin, and at least 20 per cent available for recovery and restoration programmes.
- **Target 9**: 70 per cent of the genetic diversity of crops including their wild relatives and other socio-economically valuable plant species conserved, while respecting, preserving and maintaining associated indigenous and local knowledge.
- **Target 10**: Effective management plans in place to prevent new biological invasions and to manage important areas for plant diversity that are invaded.

Objective III: Plant diversity is used in a sustainable and equitable manner

- **Target 11**: No species of wild flora endangered by international trade.
- **Target 12**: All wild harvested plant-based products sourced sustainably.
- **Target 13**: Indigenous and local knowledge innovations and practices associated with plant resources maintained or increased, as appropriate, to support customary use, sustainable livelihoods, local food security and health care.

Objective IV: Education and awareness about plant diversity, its role in sustainable livelihoods and importance to all life on earth is promoted

- **Target 14**: The importance of plant diversity and the need for its conservation incorporated into communication, education and public awareness programmes.

Objective V: The capacities and public engagement necessary to implement the Strategy have been developed

- **Target 15**: The number of trained people working with appropriate facilities sufficient according to national needs, to achieve the targets of this Strategy.
- **Target 16**: Institutions, networks and partnerships for plant conservation established or strengthened at national, regional and international levels to achieve the targets of this Strategy.

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