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Abstract

The Open Scientific Collections Austria (OSCA) consortium consists of 14 museums, universities and scientific institutions in Austria holding outstanding scientific collections. These collections document Earth's biological and geological diversity and serve as essential resources for research on global challenges such as climate change, biodiversity loss, and environmental change. Despite recent advances in digitization, large portions of collection data remain inaccessible due to limited funding and technical capacity. OSCA aims to mobilize, harmonize, and provide Austria's natural science collection data based on FAIR Principles (Findable, Accessible, Interoperable, and Reusable). By building a shared infrastructure, the consortium fosters collaboration among institutions and ensures the long-term preservation and accessibility of valuable scientific data. This paper outlines the structure and objectives of the OSCA consortium, introduces its participating institutions, and presents its cooperative model and data infrastructure. Unlocking Austria's natural science collections and metadata by integrating them into an interconnected virtual information system transforms them into a dynamic and powerful research tool. This approach enhances the visibility and usability of Austria's scientific heritage and enables interdisciplinary research with significant scientific, societal, and economic relevance.

Introduction

Natural history collections provide an essential documentation of the past and current state of bio- and geodiversity and the origin of the Earth system itself. Such scientific infrastructures allow for addressing current global challenges such as climate change, biodiversity loss, sustainable food production, ecosystem conservation, as well as improving human health and security (Meineke et al. 2019; National Academies of Sciences, Engineering, and Medicine 2020). Even though the first two decades of the twenty-first century have seen a rapid increase in the mobilization of digital biodiversity data, much of the information contained in collections housed in natural history museums and other research institutions is still largely inaccessible, despite their enormous potential value to society (Johnson et al. 2023). Digitizing these collections and working toward the goal of internationally catalogued and accessible digitised collections makes data of geological and biological diversity accessible, searchable, retainable, and interactive. However, this digital transformation is constrained by limited fundings, lack of training for personnel, restricting governance structures and limited technical and infrastructural resources (Vollmar et al. 2010; Singun 2025). As a matter of fact, a major part of the natural science collections worldwide is still not digitized.

Digitization of natural science collections entails converting physical specimens and their associated metadata into digital formats that can be stored, accessed, analysed, and shared electronically. This process allows access to museum holdings to those for whom collections have typically been out of reach (Drew et al. 2017). Typically, digitization begins with the recording of metadata, followed by imaging—capturing high-resolution photographs or scans of specimens, labels, and related documentation. While not every specimen is imaged, associated information is entered into digital databases. In most cases data are gathered and distributed under Darwin Core (<https://dwc.tdwg.org/>) and ABCD standards (<https://abcd.tdwg.org/>) (Blum et al. 2019) and can be made publicly accessible through platforms like the Global Biodiversity Information Facility (GBIF, <https://www.gbif.org/>) or institutional databases.

In Austria, museums, universities and other institutions preserve a unique heritage of over 56 million natural history specimens from all over the Earth and even from space. In addition to the major museums and universities, local, often smaller museums and other institutions like monasteries house biological, paleontological, geological-mineralogical, or archaeological collections. While some of the collections have a long history that dates back to the 18th and 19th century, others nowadays include modern specimens. There is a great potential for providing new information to many research questions e.g., in an ecological, socio-economic, or cultural context (Kapun et al., 2025). However, this unique research infrastructure is not yet sufficiently digitally accessible. The vision of seeing natural science collections as one integrated infrastructure—rather than as isolated institutional holdings—opens up transformative opportunities across research, innovation, governance, and the future economy (Schindel and Cook 2018; Arvanitidis et al. 2025). Digitised, standardized,

and interconnected collections enable large-scale, interdisciplinary studies on biodiversity, climate change, ecosystem services, and evolution.

In 2006, a group of Austrian curators of natural history collections initiated efforts to promote the digitization of their holdings, building on their involvement in publishing biodiversity data through GBIF Austria (<https://www.gbif.at/home/>). As an initial step, a nationwide survey of Austrian natural history collections was conducted. This survey gathered information on the number of specimens, the extent of existing digital records, and provided a preliminary cost estimate for the complete digitization of all collections. Based on these results, twelve institutions came together in 2008 to establish the Austrian Digitization Initiative of Natural Science Collections (ODINS). The initiative aimed to coordinate digitization efforts across institutions, apply and further develop internationally recognised standards, and raise awareness among potential funding bodies regarding the scientific and societal relevance of digitised natural history collections. Although the aim of financing such digitization was not achieved, the collaboration between institutions and the exchange of expertise among collection managers continued and intensified.

Due to the involvement of the Natural History Museum Vienna (NHMW) in scientific networks such as the Consortium of European Taxonomic Facilities (CETAF, <https://cetaf.org/>) and as a mini-partner in the Distributed System of Scientific Collections Prepare Project (DiSSCo, <https://www.dissco.eu/>), regular meetings were held to share international developments with the Austrian community. These meetings fostered community building and culminated in the formation of the Open Scientific Collections Austria (OSCA, <https://osca.science/>) consortium in 2021, initially with 12 founding members. Currently, 14 institutions—including museums and universities housing natural scientific collections throughout Austria—are members. OSCA's overarching objective is to compile, integrate and disseminate knowledge about Austria's natural science collections through their systematic digitization. To ensure proper long term conservation and future reuse of the collections, OSCA is developing a standardised infrastructure for natural science collection management. Within a three-year funding period (2022–2024) provided by the Austrian Federal Ministry for Housing, Arts, Culture, Media and Sport (BMWKMS), the consortium has been able to gather and share knowledge regarding the digitization of objects and their associated metadata by establishing workflows and conducting joint pilot studies at participating institutions. The data is available through the OSCA portal (<https://osca.science/portal/>). Additionally, members of the OSCA consortium have made significant progress in expanding and harmonizing collection databases between institutions and have played a leading role in the development of the Herbarium Management System (JACQ, <https://jacq.org/>; Bräuchler et al. 2021).

Consequently, a five-year funding period from the Federal Ministry for Women, Science and Research (BMFWF) started in 2025, enabling the participation of Austria in the European infrastructure DiSSCo (Distributed System of Scientific Collections) and the continuation of OSCA as an Austrian support and coordination structure for DiSSCo. DiSSCo is a world-class research infrastructure for natural science collections, aiming to digitally unify all European natural science assets under a shared framework of access, curation, policies, and practices,

while ensuring compliance with the FAIR principles (Findable, Accessible, Interoperable, and Reusable) (Hardisty et al. 2020; Koureas et al 2024; <https://www.dissco.eu/>). Austria's participation in DiSSCo will increase the findability of the Austrian natural science collections and highlight the available knowledge to the research community, providing the opportunity to align with the European vision of establishing natural science collections as central infrastructure for data-driven scientific excellence and innovation in biodiversity and environmental research.

The consortium

The consortium unites 14 institutions including federal museums, state museums and universities for concerted standards in digitizing their collections (<https://osca.science/partner/>). In 2021, an inventory was carried out among the 12 founding OSCA institutions to assess the current status of digitization and the proportion of existing digital records within their collections. Together, these natural science collections hold over 56 million objects (Fig 1). However, the majority of these objects lack any digital record, making them invisible to both scientists and the public. In 2021 around 15 million objects were digitally inventoried (28%) and images were available for nearly 700,000 objects (1%; Fig.2). It is important to note that several other natural science collections in Austria were not included in the survey, meaning that the total number of specimens is even higher. In 2025, GeoSphere Austria, which holds one of the country's most important paleontological collections, with approximately 160,000 records and an estimated several million fossils, joined OSCA. These numbers are not included in the 2021 survey. The Austrian network of natural science collections committed to digitization and open access continues to grow, with the addition of the BOKU University to OSCA in 2025, alongside GeoSphere Austria.

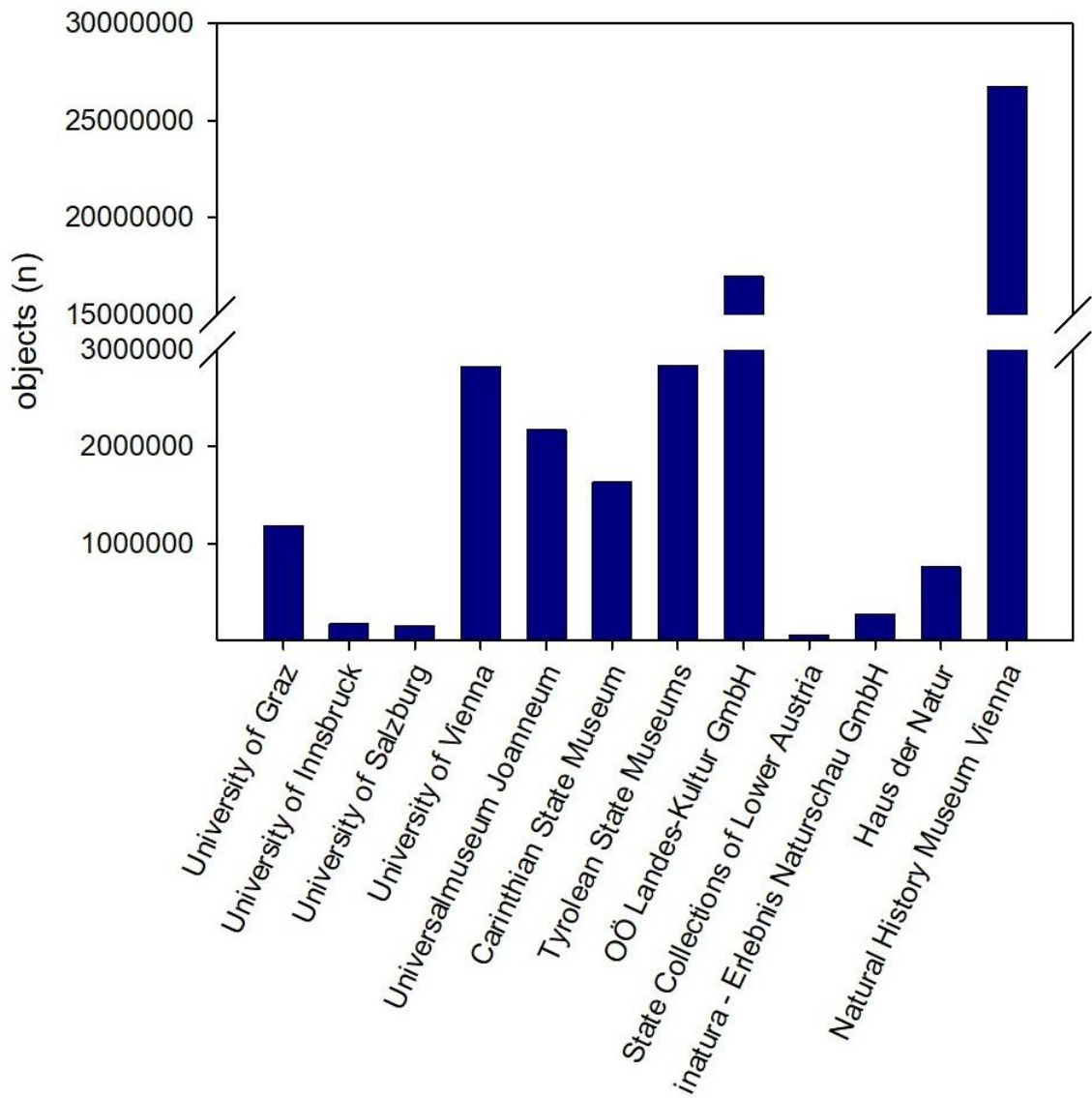


Figure 1: Expert-based estimate of the number of collection objects (2021). Note that at the State Collections of Lower Austria the insect drawers get an inventory number (approx. 3,800 drawers) and not the individual insects (approx. 500,000 insects). In the survey the drawers were counted and not the specimens.

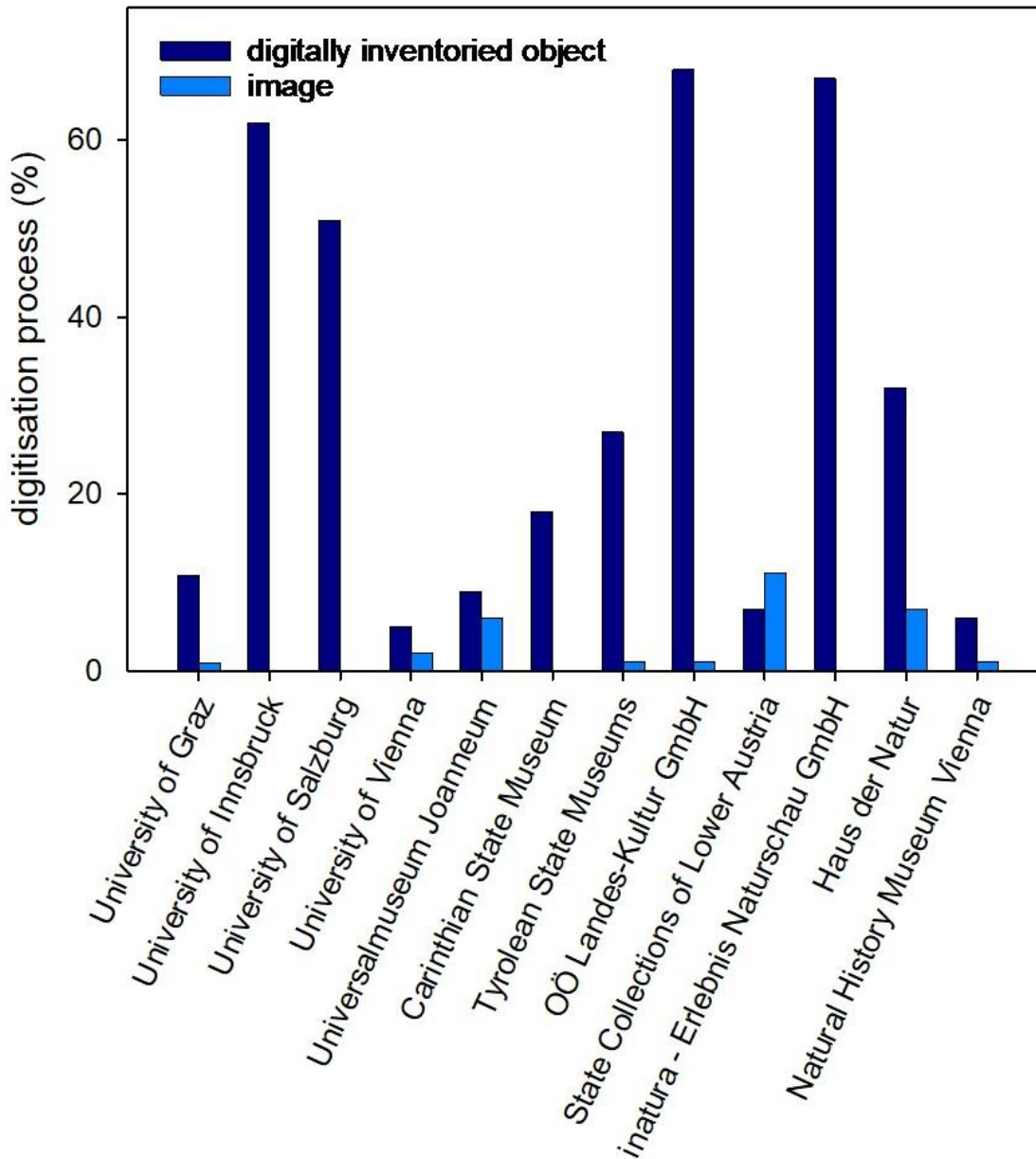


Figure 2: Expert-based estimate of the percentage of digitally cataloged and inventoried objects (dark blue) and percentage of digital copies (image) of the objects (light blue) from 2021.

Participating institutions:

Naturhistorisches Museum Wien (Natural History Museum Vienna (NHMW))

The NHMW in its present form was founded in 1876 and is one of the largest museums and non-university research institutions in Austria and an important center of excellence for all matters relating to natural science. The museum's 39 exhibition rooms cover 8,460 square meters and present more than 100,000 objects. It houses nearly 30 million objects available to more than 60 scientists as well as numerous guest researchers, conducting basic research

across a broad spectrum of topics related to human, earth and life sciences (Jovanovic-Kruspel 2015). It includes objects from anthropology, botany, geology, mineralogy, paleontology, prehistory and zoology (Mikschi et al., 2023). The collections feature objects from all continents and oceans, with a special focus on Austria (Vohland et al., in press.). The different collection database management solutions are becoming replaced by an overarching new system (Vohland, 2025). The NHMW is a member of CETAF (Consortium of European Taxonomic Facilities) and EOSC-SOA (European Science Cloud - Support Office Austria, (<https://eosc-austria.at/>)) and partner in various EU funded projects such as TETTRIs – Transforming European Taxonomy through Training, Research and Innovations (<https://tettris.eu/>), Skills4EOSC (<https://www.skills4eosc.eu/>) and FAIRiCUBE- F.A.I.R. Information Cubes (<https://faircube.nilu.no/>). The NHMW houses the coordination team of the Austrian Barcode of Life (ABOL, <https://www.abol.ac.at/>), a national biodiversity initiative which aims to characterize and study all Austrian species of animals, plants and fungi, especially emphasizing DNA (meta-)barcoding approaches.

inatura - Erlebnis Naturschau Dornbirn

The inatura is the natural history museum of the Austrian federal state of Vorarlberg. Founded as a private collection and museum by the factory owner Siegfried Fussenegger in 1927 (Privatmuseum Fussenegger, from 1939 onwards Schau der Naturgeschichte Vorarlbergs), it became a public museum when purchased by the City of Dornbirn and the State of Vorarlberg in 1958. At this time the natural history collections of the Vorarlberger Landesmuseum in Bregenz (now: vorarlberg museum) were transferred to Dornbirn and united with the Fussenegger collection in the new museum Vorarlberger Naturschau. The museum again changed its name to inatura when it moved into a former foundry in 2003. Its collections include approx. 370,000 objects from botany, geology, mineralogy, mycology, palaeontology, and zoology. Most of these objects originate from Vorarlberg. However, the museum also hosts biological objects from the surrounding regions as well as a formerly private collection of fossils from the Swiss Jura region. Although nearly all the earth science collection and the majority of the biological objects are recorded in a digital inventory database (BioOffice, <https://biooffice.org/>), the level of photographic documentation is still rather low. The collections are open to guest scientists from all over Europe.

Tiroler Landesmuseum (Tyrolean State Museums)

The natural history collections of the „Tiroler Landesmuseen“ are located in the Collection and Research Center (SFZ) in the city of Hall near Innsbruck. An estimate from 2021 indicates that the collections contain approximately 3.5 million specimens, including 337,000 in the botanical collection, around 3.1 million specimens in the zoological collection, 30,000 fossils and 5,500 rocks and minerals. For around 20 years, the main focus has been on inventorying and recording metadata (observations and preserved specimens) in an in-house database (BioOffice). In addition to the permanent staff, the numerous volunteers have done invaluable work, especially in the collection work. As of 2024, the

BioOffice records 3,038,708 zoological, 1,740,153 botanical and 6,447 geological/mineralogical data sets, plus 31,294 literature data sets. Another focus is on the scientific indexing of the collections through revision work, which is particularly important given the extensive material. These scientific revisions include parts of the beetle and bug, butterfly and other insect collections as well as the botanical and mineralogical/geological collections. The data from the natural science collections are used for national (GBIF.at, Biodiversitätsatlas Österreich) and international databases (gbif.org). These comprise a total of 481,150 datasets, 42,436 of which added in 2024. The data from the Tyrolean State Museums are also used for the TIRIS data portal (<https://maps.tirol.gv.at/>, in the protected area) of the Tyrolean Provincial Government. A total of 1,455,344 data from botany, entomology (butterflies and beetles), ornithology and mammals were entered here in 2024.

Haus der Natur - Museum für Natur und Technik

The Haus der Natur is a universal museum of natural sciences with a regional and international focus. It has established itself as a nature competence centre for the city and province of Salzburg.

The physical collections at the Haus der Natur include objects from biology, geology, mineralogy, palaeontology and speleology, a cultural-historical collection and a library. The biological collections include an entomological collection, the herbarium SZB, a malacological as well as a vertebrate collection. The collections and the associated metadata are managed in databases (Salzburg Biodiversity Database, Mineralogical Database of the Hohe Tauern National Park).

In total, there are currently an estimated 900,000 objects in the collections. Of these, 700,000 are biological objects, of which around 260,000 are recorded digitally (at MIDS Level 2, <https://www.tdwg.org/community/cd/mids/>) in the database. Around 80 % of the recorded specimens originate from Austria and 70 % from the province of Salzburg. Observational data without physical evidence is also recorded in the database. A cooperation between the Haus der Natur and the Dutch Observation International Foundation has made it possible to record biological distribution data using smartphones (<https://observation.org/>). After validation, the data is transferred to the biodiversity database, which has led to an enormous increase of data. The Salzburg Biodiversity Database currently comprises 3 million data records on more than 36,000 different taxa. All biological data are transferred to international and national networks GBIF, Biodiversity Atlas Austria (<https://biodiversityatlas.at/>), continuously updated and made publicly available. Data is managed in accordance with the FAIR principles so that the data is findable, accessible, interoperable and reusable (<https://www.go-fair.org/fair-principles/>).

Universität Innsbruck (University of Innsbruck)

The University of Innsbruck is the largest research institution in western Austria. Its holdings also include natural science collections. The approximately 230,000 objects are spread across various faculties and departments and include earth science collections, pharmaceutical, zoological and botanical objects. With more than 10,000 predominantly

botanical objects from all over the world, the ‘Dittrichiana’ pharmaceutical history collection is one of the most extensive collections of its type in the German-speaking area. The 18,000 objects in the earth science collections include palaeontological specimens, minerals and rocks. The botanical collections contain approx. 200,000 objects, including 140,000 herbarium specimens, pollen type collections, collections of plants, macrofossils and seeds. In addition, there are living collections (algae approx. 1,000 isolates) and the botanical garden. The material comes from all parts of the world, but the focus is on Austria and the Alps. The current degree of digitization varies greatly. The earth science and pharmaceutical collections are largely digitised (internal files and mostly photos). About 75% of the herbarium collection has been digitised (metadata, internal database). The objects are made available for scientific research.

Universität Salzburg (University of Salzburg - Herbarium SZU)

The University of Salzburg Herbarium (SZU) is the active botanical research collection for the Department of Environment and Biodiversity, situated within the Botany division and serving as both a repository and resource for faculty and students of Evolution and Systematics of Plants. It cares for more than 100,000 vouchers collected by and for our researchers, the majority of which were collected since the modernization of the university in the mid-20th century. Holdings include a sizable vascular plant collection (c. 70,000), lichen collection (c. 15,000), bryophyte collection (c. 15,000), and carpological collection (c. 5,000). The Herbarium SZU is primarily concerned with the flora of the European Alps, but also of other European and Asian mountains, with collections including high alpine lichens, orchids, and steppe plants. SZU also stewards an expanding silica (dried plant tissue) collection and a DNA bank (c. 4,000) as part of the Austrian Barcode of Life (ABOL) initiative, leveraged to record the genetic diversity of the flora of Austria. SZU gives special attention to montane-alpine plant species, including endemic and threatened taxa of the European Alps. As a research herbarium with access to molecular laboratories of the University of Salzburg, the Herbarium SZU is part of multiple national and European consortia of natural history collections providing biodiversity data to numerous infrastructure programs, such as GBIF (Global Biodiversity Information Facility), BOLD (Barcode of Life Data Systems) and JACQ Virtual Herbaria. As members of OSCA and now DiSSCo (Distributed System of Scientific Collections), Herbarium SZU provides frameworks for generating curated molecular sequence data directly linked to collection data in online and accessible formats to further biodiversity research.

Oberösterreichische Landes-Kultur GmbH

The Oberösterreichische Landes-Kultur GmbH (OÖLKG, formerly known as Oberösterreichisches Landesmuseum) includes all formerly public museums in Upper Austria. Consequently, its collections and research cover a broad range both with respect to geographic focus and research field – from regional to global, from modern arts to history, biology and geology.

At the Biodiversity Center Upper Austria (BCUA), the OÖLKG houses the second largest natural history collections in Austria. 13 scientists curate the ca. 17 million objects and Natural History exhibitions are presented at the Schlossmuseum Linz. The 1,300 m² permanent exhibition for Nature in Upper Austria will soon receive another 1,000 m² to present the collections and the research of scientific staff to the public. Being the go-to for any issues related to biodiversity at the regional level, the BCUA also is an important hub for biodiversity data aggregation and publication at all levels. While being strongly connected to conservation biology practitioners in the region, BCUA scientists and collections also contribute to addressing the urgent issue of biodiversity loss at the European and global level.

Landessammlungen Niederösterreich (State Collections of Lower Austria)

The State Collections of Lower Austria are responsible for a unique collection of more than six million museum objects pertaining to the cultural and natural history of Lower Austria, acting on behalf of the Department of Arts and Culture of the Office of the Lower Austria Federal Government.

Comprising twelve departments, the State Collections include the fields of cultural history, archeology, art, and nature. The collections' main focus is the Federal Province of Lower Austria, its culture and nature.

The nature collection comprises around 600,000 objects and combines the fields of earth sciences, zoology and botany as well as specialised collections.

The history of the State Collections of Lower Austria is closely linked with the more than 110-year-old history of the Landesmuseum Niederösterreich. Various exhibition locations throughout Lower Austria, such as the Museum Niederösterreich, the Landesgalerie Niederösterreich, the Karikaturmuseum Krems, the MAMUZ and the Römerstadt Carnuntum display a selection of their comprehensive collection holdings.

Universalmuseum Joanneum (State Museum of Styria)

The Universalmuseum Joanneum was founded in 1811 by Archduke Johann of Styria as a multidisciplinary museum with the mission of collecting, researching, and documenting the nature, art, and culture of the province, in order to actively promote the intellectual and technological development of Styria. Today, it holds a wide range of collections from various fields of natural history, history, and art. Comprising 14 locations, the Universalmuseum Joanneum is the oldest federal state museum and currently the second-largest museum in Austria.

The Natural History Museum is one of the 21 museums of the Joanneum. Its permanent exhibition offers an earth science and a biological sciences tour. In addition, various topics are explored in greater depth in temporary exhibitions.

The natural history collections consist of 2.1 million objects from the fields of botany, geology, mineralogy, mycology, palaeontology, and zoology. The objects originate mainly from Europe, with a particular focus on Austria and the State of Styria; nevertheless, a significant number also come from the Balkan Peninsula. The extent of digitization varies greatly across the collections. While more than 90% of the estimated 270,000 earth science objects are recorded in local databases, only around 10% of the approximately 1.1 million zoological objects have been digitised. Of the 750,000 botanical and mycological specimens, 20% have been digitised so far.

Universität Graz (University of Graz)

The university of Graz was founded in 1585 and is the second-largest and second-oldest university in Austria. It is divided into six faculties, with the Faculty of Natural Sciences consisting of eight institutes (Biology, Physics, Chemistry, Molecular Biosciences, Earth Sciences, Mathematics and Scientific Computing, Psychology, and Pharmaceutical Sciences). The Institute of Biology focuses on the topics of biological complexity and biological systems in environmental change. The university herbarium at the Institute of Biology (official abbreviation: GZU) is one of the most important botanical collections in Europe with approximately 1,200,000 specimens from all over the world. The herbarium material includes vascular plants, bryophytes, fungi, lichenized fungi and myxomycetes as well as algae and cyanobacteria. Approximately 10,000 type specimens are currently stored in GZU. The lichen collection, founded by Prof. Dr Josef Poelt, with at least 220,000 specimens is of particular importance worldwide. Herbarium digitization has been underway since 2003, with about 10% of the collections currently digitized.

Landesmuseum für Kärnten (Carinthian State Museum)

The Carinthian State Museum is a multidisciplinary museum with eight departments and twelve museum locations. It is Carinthia's leading natural and cultural science and art history institution with a pioneering role and international standards in the areas of research, communication and preservation of objects. It has collections in many subject areas including objects from archaeology, art, botany, folk culture, geology, history, mineralogy, numismatics, paleontology and zoology. The museum has its origin in the activities of the Historical Society for Carinthia (1844), the Natural Science Society for Carinthia (1848) and the Kärntner Landsmannschaft. Since 1884, their collections have been housed together in the kärnten.museum in Klagenfurt.

Universität Wien (University of Vienna)

The University of Vienna is the oldest university in the German-speaking world and among the largest universities in Europe. It also houses numerous scientific collections of international importance, amongst others, for botany and zoology: Approximately 200,000 zoological samples are housed in the zoological collection of the Department of Evolutionary Biology, University of Vienna. The collection coverage is worldwide, but with a strong focus on European marine and non-marine species. Specimens are accessible to the scientific community via loan or visit. In the last five years approximately 3 % of the collection have

been digitized. The herbarium of the University of Vienna houses ca 1.5 million botanical objects from all plant and fungal groups world-wide, with a focus on Central Europe. It is fully accessible to scientists and guest researchers via loans as well as guest visits. It is an important research infrastructure for the Department of Botany and Biodiversity Research of the University of Vienna as well as the international scientific community. About 10 % of the collection has been databased, and 6 % with digital images. There are also plans to promote digitization in other important collections, such as the Palaeontological Collection or the Geological Collection, and to integrate them into OSCA.

Universität für Bodenkultur Wien (BOKU University – University of Natural Resources and Life Sciences, Vienna)

BOKU positions itself as a pioneer in the green economy, aiming to integrate sustainability into all areas of society. Among others, it is actively involved in numerous international collaborations, including membership in the Euroleague for Life Sciences (ELLS), the United Nations Academic Impact (UNAI), the European University Initiative (EPICUR), and the Austrian-African Research Network (Africa UniNet). Currently, BOKU is home to over 10,000 students from more than 100 countries. As part of its Open Innovation Strategy, BOKU is currently developing the online platform BOKU MATERIALS, with the goal to create a publicly accessible collection of valuable BOKU resources and making them available to research institutions worldwide. At present, the platform features 16 materials including plasmids and host cells from the field of biotechnology and aims to complete the collection by the end of 2026. The collection will also include items such as garden designs for landscape planning, seed samples, self-developed wood adhesives and a variety of other unique materials developed across BOKU's diverse fields of research. Through BOKU MATERIALS, these materials can be used for a variety of applications, thereby fostering scientific progress around the world.

GeoSphere Austria

GeoSphere Austria is Austria's national service for geology, geophysics, climatology, and meteorology and custodian of one of the country's most significant geological and palaeontological collections. Originating in 1835 with the founding of the Montanistische Museum (Mining Museum) and formally established as the Geologische Reichsanstalt (Imperial Geological Survey) in 1849, the collection has grown over nearly two centuries through dedicated geological mapping and expeditions. Today, it comprises approximately 160,000 datasets and an estimated one million individual fossils, spanning geological periods from the Cambrian to the Quaternary. The collection includes around 26,000 type specimens, reflecting its high scientific value. It features a wide diversity of taxa, from protists and microfossils such as Foraminifera to plants and vertebrate and invertebrate animals. In addition, GeoSphere Austria houses extensive mineralogical and geological material, including 7,500 mineral samples, 25,000 rock samples, and currently 441 drill cores representing 16 kilometres of core material. A significant part of the samples were collected

and described by prominent Austrian geologists and palaeontologists, including Franz von Hauer, Rudolph Hoernes, Melchior Neumayr, Edmund von Mojsisovics, Constantin von Ettingshausen, Dionys Stur, Franz Unger. Specimens originate from key geological sites throughout Austria and worldwide locations. Together, these factors make the collection an essential reference for national and international research and a valuable resource for supporting geological and palaeontological knowledge.

The collection faced serious challenges during World War II, when bombing damaged parts of it and buried some specimens. Thanks to the efforts of volunteers and soldiers, much of the collection was saved, although some items were lost permanently. This history underscores the critical importance of digitalizing collections to preserve and safeguard scientific knowledge against potential future risks.

The model of cooperation

In 2022, all 12 founding institutions signed a joint Memorandum of Understanding (MoU) with the aim of opening, connecting and making Austria's natural science collections more accessible, while implementing FAIR data principles.

This MoU set out the following objectives:

- Establishment of a digital inventory and creation of a catalogue of the Austrian natural science collections, including, where possible, all botanical, zoological, geological (paleontological, mineralogical, extraterrestrial) and anthropological objects.
- Development and use of Austria's natural science collections as research infrastructure, respecting the legal ownership.
- Enhancing global visibility of Austria's natural science collections for various stakeholders across research, politics and the public.
- Development, adaptation and – within the framework of institutional possibilities – implementation of standards to improve interoperability and inter- as well as transdisciplinary use of collection data.
- Creation of 2D and 3D digital images of parts of the collections.
- Linking the specimen data with metadata, automated backbones (taxonomy, geography) and research data (e.g. genetic data, distribution data, functional data).

In 2024, the MoU was extended, with the participating institutions expressing their interest in OSCA as a national support structure for the digital opening of Austrian scientific collections and their participation in DiSSCo as a corresponding European research

infrastructure. Through the Austrian participation and the integration of the Austrian natural science collections into the European research infrastructure DiSSCo, along with its services and standards, the usability of the collections for a wide range of scientific and societal applications will be increased.

National Data Infrastructure

PIDs (Persistent Identifiers)

Digitization of past and future collections of the OSCA institutions is a process that has been ongoing for years and is constantly being adapted to standards. The standardized assignment of clear and unique identifiers is one of the most important steps making the data findable according to the FAIR principles (Wilkinson et al. 2016; Mons et al. 2017). In the course of various international projects, such as the EOSC (European Science Cloud), DiSSCo and SYNTHESIS+, the importance of a persistent identification of the objects was emphasized (Hadistry et al. 2021). The NHMW follows the evaluation of the DiSSCo team and will use the DOI system (Digital Object Identifier) to identify digital collection objects in their currently developed collection database DIVINA (<https://divina.nhm.at/home>; Vohland, 2025).

Storage

OSCA provides participating institutions access to a shared storage facility for hosting and publishing its digital copies supporting efficient collaboration, sustainable data management, and reliable access to digital assets. Moreover, the infrastructure is supposed for long-term use, ensuring that institutions can continue to benefit from shared hosting and storage services.

Data Aggregation

In the course of the participation in the European research infrastructure DiSSCo, an Austrian Data Cache will be set up. The primary objective is to establish a centralized data pipeline that efficiently aggregates specimen data and associated imagery from Austrian institutions, validates them against the established standard Darwin Core (DwC, <https://dwc.tdwg.org/>). At its core, the system implements a sophisticated process flow beginning with data submission through a user-friendly interface that accepts both specimen data in Excel format (conforming to Darwin Core standards) and associated image files. This initial submission undergoes rigorous processing and validation, where the raw data is parsed, validated against schema requirements, and subjected to quality assurance protocols. Concurrently, uploaded images are processed through an IIIF (International Image Interoperability Framework, <https://iiif.io/>) server, which extracts valuable metadata to be integrated with the specimen records. Validated data are stored in the central OSCA Data Cache, a PostgreSQL database serving as the authoritative repository for all aggregated biodiversity information. Each record is assigned a PID to ensure long-term discoverability

and citation. The system exposes a flexible Application Programming Interface (API) supporting both REST (Representational State Transfer) and GraphQL protocols, enabling efficient data distribution to multiple endpoints, including the OSCA Portal, DiSSCo, and Kulturpool (<https://kulturpool.at/>) each with specialized connectors that transform the data into the required format specifications (Darwin Core Archives (DwC-A), Open Digital Specimen, (openDS, <https://terms.dissco.tech/>) and Europeana data model, (EDM, <https://pro.europeana.eu/page/edm-documentation>) respectively).

As the designated data hub for all OSCA institutions, this aggregation system will play a central role in enhancing data accessibility, interoperability, and scientific utility across the biodiversity research landscape. This hub functionality transcends mere technical aggregation to encompass semantic harmonization, quality enhancement, and distribution optimization. The system's architecture explicitly acknowledges this pivotal position by implementing robust validation protocols that ensure data quality and consistency across institutional boundaries, sophisticated identifier management that enhances long-term discoverability and citation capability, and flexible distribution mechanisms that maximize data utility across diverse platforms and use cases. By centralizing these processes, the system reduces technical burdens on individual institutions, eliminating the need to maintain multiple, independent pipelines and improving overall data quality.

Data Flow

The OSCA institutions constitute the DiSSCo node for Austria. To enable publication on national and international portals, digitized data—comprising digital records of preserved specimens and associated media—are provided independently by each participating institution (Fig. 3). These data are stored across multiple servers and databases, each operated and secured locally by the respective institutions. The consortium has agreed to adopt the Darwin Core (DwC) data standard for the publication workflow. Participating institutions supply their data in DwC format to the OSCA Cache, a centralized data repository currently under development. The OSCA Cache facilitates the regular distribution of data to both the OSCA Portal and DiSSCo; however, only records related to preserved specimens are transmitted to DiSSCo. In parallel, institutions also publish their data directly to GBIF. Additionally, data is provided via an existing aggregator—located at the Oberösterreichische Landes-Kultur GmbH (LINZ)—to GBIF Austria and the Biodiversity Atlas Austria (Fig. 3).

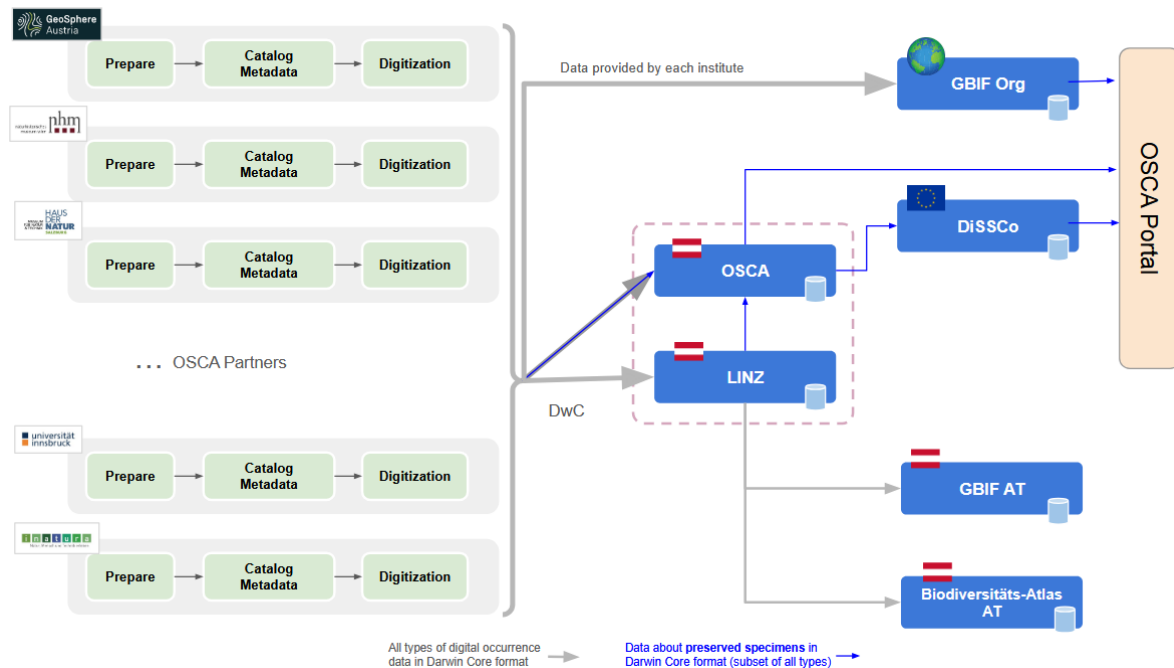


Figure 3: Overview of the OSCA data flow. The diagram illustrates the process by which data from Austrian institutions—undergoing digitization of their natural history collections—are made publicly available through national platforms (GBIF AT, Biodiversitätsatlas AT, and the OSCA Portal) and European infrastructures (DiSSCo). In addition, individual institutions provide their data directly to GBIF. Blue lines represent the data flows established through OSCA, while grey lines indicate existing data flows managed by individual institutions and the data aggregator at the Oberösterreichische Landes-Kultur GmbH (LINZ).

Beyond making Austrian natural science collections permanently accessible, the digitized data enable automated systems to generate novel scientific insights. The use of Artificial Intelligence (AI) methods can accelerate digitization processes, particularly in the identification and classification of objects. A standout application is Handwritten Text Recognition (HTR), enabling AI to transcribe handwritten historical notes into searchable digital text, making previously inaccessible information available to researchers and the public (e.g., using tools like Transkribus (<https://www.transkribus.org/en>)). AI can also facilitate enhanced content organization and linkage by detecting relationships between archival materials, supporting cross-referencing and discovery through automated pattern recognition and analysis.

Portal

The OSCA portal (<https://osca.science/portal/>) is already increasing the proportion of digitally accessible object information in Austria by consolidating data in a central, publicly available platform. The scope of the portal is to organize the data available and enable researchers to search for data published in Austria, as well as in European and International databases (Fig. 4). Currently, the portal enables integrated searches across OSCA data as

well as through DiSSCo (<https://discover.dissco.eu>), Europeana (<https://www.europeana.eu>), GBIF (<https://www.gbif.org>), and GeoCase (<https://geocase.eu>), thereby incorporating data from outside Austria into its search results.

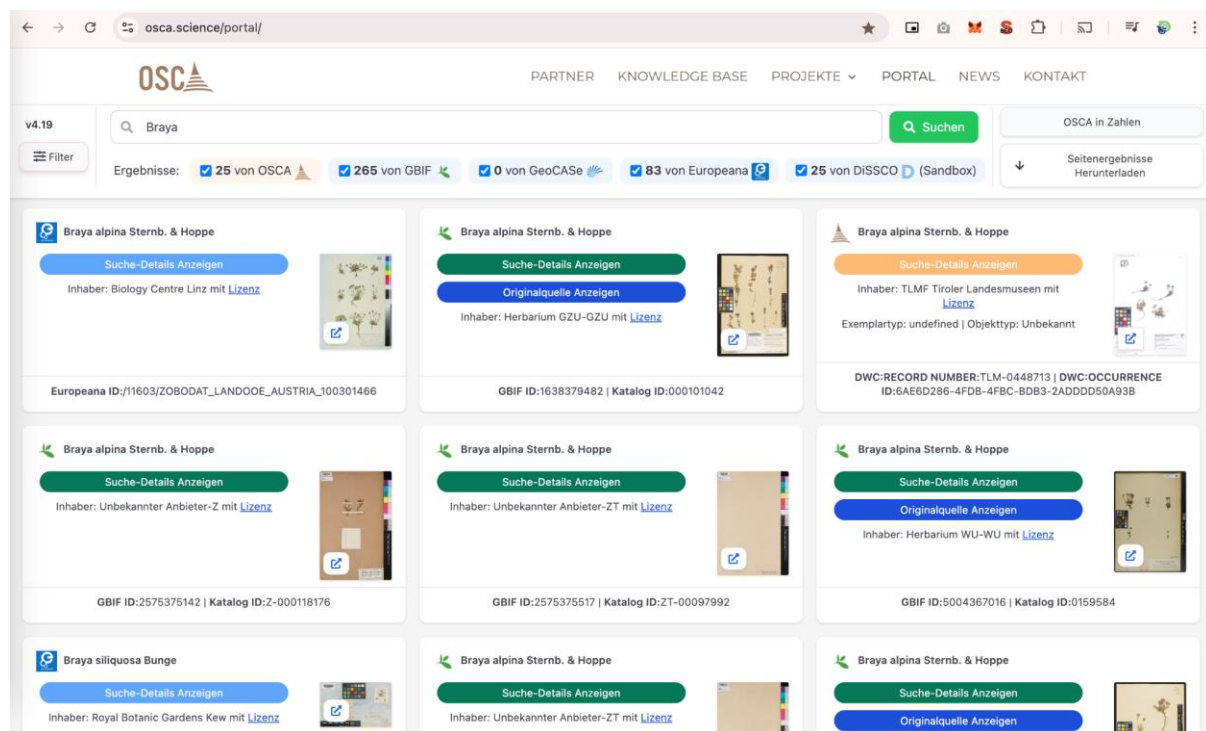


Figure 4: A screenshot of the OSCA portal displaying unified search results for 'Braya'. The search sources can be enabled/disabled according to the user's wishes. The search results display a minimum of cataloging information and essential links to original references. The OSCA data (depicted in orange) displays the available data in DarwinCore format.

Capacity building

Within the framework of OSCA, weekly scheduled meetings take place to exchange information, workflows and training material and to conduct workshops on various digitalization topics. In addition, the consortium meets in person once a year to exchange ideas and share experiences and lessons learned. Complementing access to international resources such as the DiSSCo Digitisation Guides (<https://dissco.github.io/>), OSCA is developing a set of nationally tailored guidelines to support the digitization of Austria's natural science collections and their integration into the OSCA data aggregation infrastructure. These materials will range from basic checklists to detailed technical documentation, all of which will be made available via the OSCA website (<https://osca.science/>). Collaboration with national and European projects and initiatives such as the European Open Science Cloud (EOSC), the Consortium of European Taxonomic Facilities (CETAF), and DiSSCo remains a key strategic priority. The NHMW in the Austrian support structure EOSC Support Office Austria and, through Skills4EOSC, is already a project partner in the area of capacity building for collections.

Conclusion

Over the last 25 years, natural science collections have increasingly been recognized as a vast, distributed infrastructure for research and discovery, essential for advancing our understanding of the evolution of life and providing a source of baseline data for research, from human and animal health to environmental and climate change (Bakker et al. 2020). This global recognition has led to a vast and growing demand for the Austrian natural science collections to mobilize their data. However, the majority of objects still lack any digital record, making them invisible to scientists and the public. Therefore, a central objective of OSCA is to advance the digitization of Austria's scientific collections. The digitization of the Austrian natural science collections is a process that has been ongoing for years. Achieving this requires an enormous digitization effort, and prioritization criteria are necessary to manage this effort (Krishtalka et al. 2016; Bakker et al. 2018). Sustained progress will depend on securing long-term funding from national, European, and international funding bodies. By bringing the institutions together, sharing knowledge on topics related to the digital transformation of Austria's natural science collections in the consortium and building a common infrastructure, Austria is advancing towards its goal to digitally open their collections and make them visible, accessible and usable. Even though there is still a long way to go until the Austrian natural science collections are completely digitized and accessible, the readiness of the OSCA institutions has increased over the past few years by sharing knowledge regarding digitization and starting to build a centralized data pipeline that efficiently aggregates specimen data from Austrian institutions.

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