Rue Vautier, 29
1000 Bruxelles

natural
sciences
.be

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RESEARCH STRATEGY

Institute of Natural Sciences

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Preface

The Institute of Natural Sciences was created in 1846, more than 175 years ago, at a time when the emphasis was on exploring nature and broadening our knowledge of an endless, exciting, and dangerous planet.

Its purpose was as broad as the natural world on Earth. This brought in a great deal of natural diversity as study material, building up a vast collection of specimens from across Belgium and the world. The challenge now is to make these collections relevant for the modern world around us, and for our future.

In our modern times, an organisation like our Institute of Natural Sciences needs a research strategy which focuses on fields in which it excels and in which knowledge needs to be enhanced and further developed. The six research themes of this Research Strategy show which research fields are prioritised, how this work is relevant to society at large, why the Institute of Natural Sciences is the place for lines of this research and what infrastructure is in place to make this happen.

Our research themes cover fundamental research, looking at the building blocks of the world and of natural sciences. They also cover applied research, which addresses societal challenges. The two are closely linked and crucial for the other two pillars of our mission: to engage the public about the natural world and to preserve our collections for future generations. The collection-based nature of our work further distinguishes it from that of more academically oriented organisations.

Fourteen of the societal challenges summarised by the United Nations' 17 Sustainable Development Goals (SDGs) are addressed by our institute's six research themes, with a special focus on nature and biodiversity conservation, management of marine environments and sustainable use of geological resources. Our research always strives to ensure nature-based solutions to contribute to these SDGs.

This Research Strategy, developed collectively with our scientists, guides the research groups at the Institute of Natural Sciences, demonstrating the shared vision of its unique strengths and lines of work that should be maintained and developed. By publicly clarifying its Research Strategy, our institute strengthens its identity and opens itself up to new partnerships, showing our strengths that could match others' concerns.

Michel Van Camp
General Director

Our profile

The Institute of Natural Sciences is devoted to nature's conservation, the study of its long history and its sustainable management.

Our institute is respected by the academic world and public authorities for its research activities and the services we provide in terms of advice, expertise and studies. It is much loved by the general public for its museum and its rich programme of activities

The Institute of Natural Sciences also conserves, enriches and manages immense natural history collections of specimens, samples, archives and databases. For several decades, the institute has been engaged in citizen science through the participation of volunteers in the sampling, monitoring and study of specimens. The Institute of Natural Sciences manages the Belgian oceanographic vessel, the RV Belgica, on behalf of the Belgian Science Policy Office (Belspo). The Institute of Natural Sciences is one of the ten federal scientific establishments governed by Belspo.

Research

One in three people employed at our institute is a scientist. The scientific personnel comprises mainly biologists, palaeontologists and geologists, but also oceanographers, anthropologists, prehistorians and archaeologists, as well as geographers, physicists, bioengineers and mathematicians, which facilitates multidisciplinary research.

Services

Policymakers, administrations and citizens count on our institute for evidence from research to shape their decisions. The Institute of Natural Sciences provides scientific expertise under Belgium's international commitments in relation to environmental protection. We develop tools, databases and methods for monitoring natural land, freshwater or marine environments.
The Institute of Natural Sciences also offers evidence-based advice for the development of national and European policies that protect and conserve biotopes and biodiversity, and ensure the sustainable use of natural resources.

Collections

With 38 million specimens, our collections are among the five largest of Europe. As well as being among the largest in the world, they represent Belgian heritage of global significance. The collections of the Institute of Natural Sciences are both a reference and a research facility and as such, will be part of Europe's major natural science collections digitally unified under the Distributed System of Scientific Collections (DiSSCo) Research Infrastructure. They are visited and studied by researchers from around the world. For several years now, the Institute of Natural Sciences has been committed to an ambitious programme to digitise its collections. Our open source software, DaRWIN, allows us to encode all the data on any collection of specimens. Our institute also manages large databases, resulting from monitoring and other research activities, as well as an ever-growing collection of frozen tissues and molecules.

Museum

For the general public, the museum is the best-known part of the Institute of Natural Sciences. Within our walls are 16,000 m^2 of permanent galleries, temporary exhibition rooms and educational workshops, welcoming roughly 350,000 visitors each year, approximately 30% of whom are school groups. Our Dinosaur Gallery is world famous and the largest in Europe. The museum highlights the collections by opening part of them up to the public, and actively disseminates scientific knowledge on nature, promoting a respectful approach. It aims to engage audiences as widely as possible, within its walls, but also beyond its walls, through travelling exhibitions and events. Our citizen science projects also allow the public to participate actively in research. Ambitious efforts are still underway to renovate the premises, making the museum more welcoming to meet and exceed visitors' expectations.

Vision

> **BRINGING NATURE INTO EVERYONE'S LIVES**

Mission

To provide the scientific world, public authorities and civil society with high-level and relevant science, appropriate advice, opening up avenues of discovery in nature, its long history and its sustainable management.

The research at the Institute of Natural Sciences aims to:

- inform citizens, in particular on three challenges: biodiversity loss, sustainable use of geo-resources and climate change;
- produce state of the art knowledge;
- link our research to policy and societal challenges, providing expert advice;

and is using the following approaches to achieve this:

- maintaining and expanding our research infrastructure;
- managing and enriching our collections, databases and models;
- providing certified long-term monitoring and reference data in a variety of fields.

Structure of the Research Strategy

Research themes

Our research activities are grouped into six research themes. These cover research on evolution, both today and in the past, on biodiversity across the three biotic realms (marine, freshwater and terrestrial), on palaeo-ecosystems, on archaeology and anthropology, in support of marine management and on geological research for a sustainable society. Together, they provide an overview of our scientists' strategic research activities.
Most research themes run across the Operational Directorates (ODs) of our institute.

Focus topics

To narrow down the broad fields of the six research themes, each has a set of focus topics. They give direction to the research activities and highlight the research topics in which we excel and where our institute's work should continue to make an impact.

Five-year targets

Each research theme is also accompanied by a five-year target, in which we state where we would like to stand in 2027, at the end of the five-year period of this Research Strategy. Each year, an action plan will be formulated for the research themes and especially for the five-year targets, for which milestones will be identified which should be reached on the way to 2027.

Transversal themes

Two general issues return in most or all of the research themes, namely **Climate change** and **Science-policy interface**, and these are considered transversal themes. They are recurrent in the descriptions of each research theme and receive a special description.

Overarching concerns

Research infrastructure and collections

The Institute of Natural Sciences has a broad set of research infrastructures to support both its own scientists and external researchers. These include first and foremost our collections of 38 million physical objects, but also molecular and tissue collection in deep frozen condition, as well as datasets and databases. We are also proud of our mobile units, such as the new oceanographic vessel, RV Belgica, and the surveillance aeroplane, as well as our COHERENS modelling system and our well-equipped laboratories (molecular, chemical, zoological, archaeological and geological) with their wide variety of analytical tools, including a scanning electron microscope.

Sustainable Development Goals

In 2015, the United Nations adopted the Sustainable Development Goals (SDGs), also known as the Global Goals, as a universal call to action to end poverty, protect the planet, and ensure that by 2030 all people enjoy peace and prosperity. The Institute of Natural Sciences adopted these SDGs and a special section explains which of the 17 SDGs are addressed by the six research themes of our research strategy.

Driver teams

To each of the six research themes and two cross-cutting themes, a group of insitute's scientists (a 'driver team') is attached. Their tasks are to monitor the activity and output of the research in that theme by a series of KPIs and other metrics, to draft an annual action plan to follow-up on the five-year target and to report to the Board of Directors – Science (BoDsci) and to the Scientific Council of the institute. They also interact with the Institute of Natural Sciences Research Office (ResO) regarding funding opportunities and with the Belgian Biodiversity Policy Support Group (BIOPOLS) regarding the Science-policy interface Transversal Theme. One representative of each driver team is also a member of the driver team of the Climate Change cross-cutting theme.

RESEARCH THEME 1

Evolution and the web of life

Evolutionary processes have driven the diversity of life over different time scales: from a few generations to billions of years. This research theme investigates the evolutionary processes that have shaped biodiversity at various levels, from genes and genomes, over species to ecosystems, in the present and in the past.

OPERATIONAL DIRECTORATES INVOLVED: OD TAXONOMY AND PHYLOGENY, OD EARTH AND HISTORY OF LIFE, OD NATURE

Five-year target: Building bridges between deep time and recent evolutionary research

Biologists study the living world and its components to investigate how individual genomes and bodies as well as large-scale communities and ecosystems function in the present day. Palaeontologists work with fossils and fossil assemblages, and as such have an astonishing window on life in the past, ranging from a few hundreds of years to many millions and even billions of years. Nevertheless, biologists and palaeontologists intrinsically study the same thing: the patterns and processes of evolution leading to past and present biodiversity. Yet, scientific interactions between researchers of past and present evolution are scarce. We wish to promote collaboration between evolutionary biologists and palaeontologists, both within and outside the Institute of Natural Sciences. One obvious way of collaborating is to construct integrative phylogenetic trees using molecular, morphological and fossil data. Our vast collections can play a major role in this endeavour.

> **BY 2027, WE WANT TO HAVE AN INCREASED SCIENTIFIC OUTPUT IN WHICH PALAEONTOLOGICAL AND RECENT BIOLOGICAL RESEARCH IS INTEGRATED, PREFERABLY THROUGH INTERDISCIPLINARY COLLABORATIVE EFFORTS.**

Focus topics

Major events in the evolution of life

Signatures of life are visible in the fossil record up to about 3.5 billion years ago. Since then, life has continuously evolved and adapted to changing circumstances. Major events in evolution have been recognised, such as the origins of eukaryotic cells, multicellularity, sex, and the different body plans in plants and animals. Under this focus topic, the institute studies major adaptations to large environmental changes in the past, for example on the origin and rise of major vertebrate lineages, including the transition from feathered dinosaurs to birds.

From adaptation to speciation

Organisms are continuously exposed to important changes in their environments. Populations and species respond to such challenges through adaptations: morphological, physiological and behavioural. Such adaptations are often the result of natural and sexual selection, but also other processes can lead to genotypic and phenotypic changes. Adaptations can also lead to new species. Our institute studies these processes at various levels, from very fast (intraspecific) adaptations to large species radiations such as in the Galapagos archipelago, in ancient lakes such as the Siberian Lake Baikal and in the East African Great Lakes such as Tanganyika.

Genome evolution in non-model organisms

Several genomic processes are known to be directly related to phenotypic diversity, i.e. the variations in the way genotypes manifest themselves in morphology and behaviour. Mutation, genetic drift, gene flow, recombination and natural selection are among the processes thought to be the main drivers of evolution in animals. Recently, however, several other mechanisms have been described that may underlie remarkable phenotypic changes, such as gene transfer between species, transposable elements (so-called 'jumping genes'), genomic reorganisations and others. At the Institute of Natural Sciences, lesser-known non-model organisms like beetles, molluscs and ostracods are the main targets of this research.

Parrot's feather (Myriophyllum aquaticum).

Reproductive strategies

Most multicellular organisms reproduce sexually at least once during their life cycle. Besides sex, however, there are myriad other reproductive strategies in organisms, including ancient asexuality, feminising effects of endosymbiotic bacteria, mixed (sexual and asexual) reproduction, hermaphroditism, brooding, hybridisation leading to asexuality, the caste systems of social insects and many more. These reproductive strategies strongly influence how species have originated and how they adapt to present and future environmental changes. In short, these inherent biological characteristics contribute to the identity of the species.

Transversal themes

Climate change

Climate change is, and has been, a major driver of adaptations and extinctions. Our scientists have a great deal of experience in studying the consequences of climate change on evolutionary processes and their impacts on phenotypic variation, and as such can contribute significantly to studies on the consequences of present-day climate change. For example, the rate of climate change might exceed the adaptation rate of large numbers of species, which will either go extinct or might need to cope with these increased rates by means of lesser-known mechanisms (e.g. epigenetic

processes), that allow organisms to respond much faster to change. Also, the biological impacts of climate change on life are not well understood. The deep-time vision of our palaeontologists could be most useful there, for example by comparing past to present extinction rates linked to climate change. Our collections provide an important source of study material for investigating phenotypic variation in relation to global change impacts over time.

Science-policy interface

The results of the focus topics and the related climate change issues can be translated into clear recommendations for policy support. For example, our work on climate change events leading to mass extinctions in deep time, billions of years ago, can inform models predicting the future impact of current climate change. Also, our research into the effects of climate change on the genetic structure of populations and the adaptability of organisms could contribute to recommendations on conservation measures to mitigate global change.

Lanternfly Pyrops spinolae (Westwood, 1842) (Hemiptera: Fulgoridae).

Perucetus colossus' specimen being transported from the site of origin (Ica Province, southern Peru) to the Museo de Historia Natural, Universidad Nacional Mayor San Marcos (Lima).

RESEARCH THEME 2

Biodiversity in a changing world

Biodiversity comprises the variety of life in all of its forms, from the past to the present, across animals, plants and a variety of microorganisms. Our institute's scientists study the three main levels of biodiversity: genes and genomes; populations and species; and communities and ecosystems. Their work covers the three major habitat realms (terrestrial, freshwater and marine). This research theme highlights the tools used to study these features to characterise and identify organisms and their relationships through a discipline called taxonomy, a core strength of all institutions of natural history. Taxonomy provides the common language in all biological fields. This research theme deals with fauna from around the planet, but biodiversity studies receive particular attention in the polar, tropical and subtropical regions, and of course, in Belgium.

OPERATIONAL DIRECTORATES INVOLVED: OD TAXONOMY AND PHYLOGENY, OD NATURE

Five-year target: To intensify data mining the Institute of Natural Sciences' collections and datasets, revealing patterns and processes of present and past biodiversity with new techniques.

To realise this vision, a strong emphasis shall be placed on the institute's historical physical collections, DNA and tissue collections and large databases. The collections in natural history institutions have become places where new discoveries are made. This way, we can add value to these collections by providing answers to contemporary questions. In addition, a large variety of datasets exist at the Institute of Natural Sciences about animal species (including vertebrates, invertebrates and their associated microorganisms) and a wide array of environmental measurements (e.g. seawater characteristics).

> **BY 2027, WE AIM TO HAVE PRODUCED SIGNIFICANT SCIENTIFIC OUTPUT BASED ON THE HISTORICAL COLLECTIONS, INCLUDING DATABASES, OF THE INSTITUTE USING NEW TECHNIQUES SUCH AS MOLECULAR TECHNIQUES.**

Focus topics

Taxonomy and its tools: species and higher systematic groups

Taxonomy underpins most biological research domains and human activities that deal with the living world. It does so in two ways. The first is by describing morphological and genetic (including genomic) variation of organisms. This provides the basic questions and data to study evolution and interactions between organisms and their environments. The second is by inventorying and classifying variation at organism level. Taxonomically relevant information is extracted using a range of methodologies, including morphological and anatomical studies, DNA sequencing, scanning electron microscopy, micro-Computer Tomography (CT) scanning and 3D imaging technique using X-rays to see inside an object. This is also done through direct research on behaviour such as communication between organisms. The institute's research not only uses these techniques, but also aims to improve their applicability, such as in enhancing digitisation processes, or by optimising high-throughput DNA analyses of historical museum specimens (known as museomics).

Ecosystem dynamics

Ecosystem functioning is determined by looking at how an ecosystem's living (biotic) and non-living (abiotic) components interact. An improved understanding of such interactions allows for more focused research on ecosystem health, by identifying potential threats. The worlds' ecosystems suffer from immense human ecological footprints. Human activities, such as agriculture, urbanisation and deforestation, alter the temperature and nutrient load of the environment. Humans also affect species interactions by introducing alien species and depleting vulnerable populations, and have an effect on spatial processes by increasing rates of fragmentation and habitat turnover. The institute hosts several active databases resulting from sampling schemes and long-term data series on large spatial scales: nationwide, continental and even global.

Species on the move

Biological migration, or dispersal, is pervasive in the living world. It manifests itself in various ways: as cyclical events (e.g. seasonal bird migrations), as one-way mass events (e.g. some butterflies and dragonflies), as occasional, stepping-stone events, or as more or less continuous exchanges of individuals or propagules (such as eggs or seeds) between populations and regions. Dispersal can lead to a simple expansion of the area in which a species lives, but when it is a fast and forceful expansion, the species becomes invasive. Climatic change and anthropogenic effects can facilitate invasions of alien species. Furthermore, invasive species can act as vectors of parasites and pathogens. The institute investigates bird migrations, but also distributional changes of invasive alien species, vectors of diseases and parasites, agricultural pest species, and many more. Our historical collections enable researchers to determine the timing of the arrival of currently widespread invasive species.

Biodiversity patterns and processes: tropics, sub-tropics and polar regions

Documenting and measuring biodiversity is a core mission of natural history institutions. The Institute of Natural Sciences conducts biotic surveys and impact assessment studies in terrestrial, freshwater and marine habitats. These surveys cover multiple scales and ecosystems. They generate large quantities of material (physical specimens and measurements) for further taxonomic, ecological or phylogenetic work, allowing a better understanding of how biodiversity is distributed in space and time. A case in point is the tropics, sub-tropics and the polar regions, which are among

the most fragile ecosystems on Earth, given their extreme environments and the special adaptations of their organisms. They are also under increasing pressure from human activities and global warming. These regions serve as sentinels and models to assess the effects of climate change for the entire planet, because of the amplification of global trends.

Services

BopCo

BopCo (The Barcoding Facility for Organisms and Tissues of Policy Concern) is jointly run by the Institute of Natural Sciences and the Royal Museum for Central Africa (RMCA), and is financed by Belspo. It aims to provide identifications of organisms of policy concern and their derived products. It relies on morphology and DNA barcoding, but it is constantly expanding its service offer to include additional methodologies (e.g. environmental DNA, ancient DNA, next-generation DNA sequencing) and taxonomic expertise (by involving a growing number of specialist taxonomists across relevant animal groups). BopCo's services are solicited by a broad scope of national and foreign stakeholders, including public authorities (such as customs) and agencies, private companies and NGOs. BopCo positions the Institute of Natural Sciences and RMCA as European key players in applied taxonomy.

Centre of polar data management

Our institute has a great deal of experience in the management of large marine databases, especially those of the North Sea through its Biodiversity and Ecosystems Data and Information Centre (BEDIC), which also houses the Belgian Marine Data Centre (BMDC). At the same time, the Institute of Natural Sciences has hosted the Antarctic Biodiversity Portal on behalf of the Scientific Committee on Antarctic Research (SCAR). Finally, the Princess Elisabeth base in Antarctica accommodates Belgian and international scientists who generate a large volume of data annually. Our institute is therefore ideally placed to become the centre of Antarctic data management. By extension, because of its expertise gained in managing these Antarctic databases, the Institute of Natural Sciences has the ambition to become an international centre of polar data management, including databases from both Antarctica and the Arctic regions.

Transversal themes

Climate change

This research theme is highly involved in documenting the consequences of climate change, and by extension of all human induced global change, on global biodiversity. We have observed the impact of climate change on the timing of bird migrations, so that inversely, observations on bird migrations can be used as sentinels of climate change. There are clear effects of climate change on expanding ranges of species, particularly alien invasive species and disease and parasite vectors. Through studies of our historical collections, the timing of these events can be documented.

Science-policy interface

Research on the consequences of climate change on biodiversity loss provides scientifically underpinned recommendations to policy makers. It must assist the Belgian governments to respond to international commitments regarding the protection of marine mammals, pollinators and general ecosystem health (see also research theme 5). The Institute of Natural Sciences can also advise the federal government on Belgium's political position in the polar regions.

Organisms of policy concern include, but are not limited to, endangered species protected under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), Alien Invasive Species (AIS) of which our institute hosts the national scientific secretariat, agricultural pest species, human and veterinary parasites and pathogens and their vectors, organisms of the food chain, and many others. The expertise of BopCo regarding the identification of CITES and other classified species, greatly assists the authorities in meeting international regulations. The Institute of Natural Sciences hosts the CEBioS programme, which builds capacities for the conservation and sustainable use of biological diversities in partner countries of the Belgian Development Cooperation, including through the Global Taxonomic Initiative (GTI).

Bird ringing

RESEARCH THEME 3

Ecosystems over time

How an ecosystem functions, both on land, in freshwater and in marine environments, is influenced by the way its living and non-living components interact. Understanding these processes allows more targeted research on the effects of global changes, such as climate change, on ecosystems and their constituent communities. Using fossil evidence from the deep past, we learn how natural changes in the climate and various other physical variables triggered biotic events such as extinctions, recoveries and radiations. We see how this happened billions of years ago and in more recent settings, and on different geographical scales.

OPERATIONAL DIRECTORATES INVOLVED: OD EARTH AND HISTORY OF LIFE

Five-year target: To highlight the importance of the Institute of Natural Sciences' collections and Belgian geosites in understanding past major environmental and climatic changes and their impact on the ecosystems.

We have four main objectives with this vision. First, to reinforce field activities and monitor high-potential fossil localities in Belgium, e.g. Devonian localities of Lompret and Warmifontaine, and Neogene marine fossil sites in the area of Antwerp. Second, to valorise promising collections in Institute of Natural Sciences and other public collections: Ordovician-Silurian collections of the Institute of Natural Sciences, Carboniferous collections of the 'National Centre for Coal, Measure Geology' (at the Institute of Natural Sciences), Paleozoic collections of the Centre Grégoire Fournier at Maredsous and others. Third, to refine the lithostratigraphy of key stratigraphic intervals in Belgium (e.g. the Devonian Carboniferous boundary). And fourth, to develop and apply new tools on collections and during fieldwork activities: synchrotron-based micro X-ray fluorescence, laser-scanning surfaces of large vertebrate skeletons (e.g. the Bernissart Iguanodons), ancient DNA, or stable isotope analyses.

> **BY 2027, WE WANT TO FOCUS OUR RESEARCH ON KEY STRATIGRAPHIC INTERVALS, WELL-DOCUMENTED IN THE BELGIAN GEOLOGICAL CONTEXT AND IN THE INSTITUTE OF NATURAL SCIENCES COLLECTIONS, DURING WHICH IMPORTANT FAUNISTIC AND FLORISTIC TURNOVERS AND MAJOR ENVIRONMENTAL CRISES CAN BE OBSERVED.**

Focus topics

Mid and late Palaeozoic biodiversification and extinction events

This research focuses on the complex interactions between biodiversity and the environment throughout the major Ordovician–Carboniferous interval in the mid and late Palaeozoic (around 500 to 300 million years ago). This period is characterised by the greening of emerged lands that led to the biggest ever biodiversity boom on continents. It induced a long period of systemic instability, with alternations of greenhouse and icehouse climates reflected by major changes in sea level or by mass extinctions of various magnitudes in marine ecosystems, linked to profound geochemical marine changes. This focused research theme aims at reconstructing biodiversity and sedimentary dynamics to clarify many fundamental questions related to mass extinctions. What caused them? What followed them? How did ecosystems recover? It also gives insight into climate change, evolutionary patterns and other decisive questions on the history of life on Earth.

Cretaceous terrestrial revolution and Cretaceous/Paleogene mass extinction

Terrestrial ecosystems acquired their modern structure during the Early Cretaceous, about 145-100 million years ago, with the diversification and progressive distribution of organisms in the continental niches that they now occupy. The patterns of these modern-like ecosystems did settle along with significant global warming that started at that time, and the apparition of most orders of flowering plants, together with the radiation of key families of pollinators. From this period, referred to as the Cretaceous Terrestrial Revolution, some important modern vertebrate groups arose, including most freshwater ray-finned fish lineages, squamate reptiles (such as lizards and snakes), dinosaurs (including birds) and mammals.

This Early Cretaceous opening onto our modern world was first adequately documented by palaeontologists thanks to the discovery, in 1878, of the iguanodons in the Bernissart locality in Belgium, now part of our collection. The fossils found at this fabulous site seem to be an endless source of information for palaeontologists, who are also exploring sites of similar age in other parts of the world, such as China, Spain and Lebanon. At the end of the Cretaceous period, 66 million years ago, a meteorite hit the Earth, causing the most recent mass extinction, before the current one (known as the sixth extinction) caused by human activities. Our researchers are exploring several sites surrounding the crisis in Belgium, France, Romania, Algeria, Russia and China, in order to better understand the evolution of biodiversity in Cretaceous ecosystems, just before and just after this catastrophe which completely reshuffled the cards of life on Earth.

Effects of abiotic changes on associated faunas and ecosystems during the Cenozoic

We study the changing climatic conditions during the Cenozoic, which represents the last 66 million years of Earth's history. During the early Cenozoic, particularly during the Paleocene–Eocene Thermal Maximum, the climate was much warmer than today. This period corresponds to the peak of diversification of modern mammal groups. During the Eocene to Oligocene transition and the most recent Quaternary, recurrent glaciations dried and cooled the Earth. We reconstruct the evolution of abiotic and biotic environments in Belgium and selected sedimentary basins abroad (including India, Peru, DR Congo and China) across the entire Cenozoic. By monitoring the evolutionary changes of fossils, researchers can confirm the standard biozonations or develop new, more refined biostratigraphic frameworks. These temporal frameworks are crucial for reconstruction of the sea levels and the tectonic history of fossil basins. Special attention is also given to the palaeo-environmental evolution of important fossil localities the use of several proxies, such as groups of organic microfossils and stable isotopes, in association with taphonomic reconstructions (relating to the conditions affecting fossilisation) and descriptions of fossils.

Transversal themes

Climate change

Understanding how past climatic changes influenced palaeo-ecosystems and how ecosystems recovered after major extinction events in the past is of primary importance to better understand the causes and effects of the current climate change and biodiversity crisis. Amongst the most relevant research questions in this domain are the investigations of the synchronicity between past climatic events and biological crises. What is the tempo and rate of extinction and recovery/radiation following a major climatic event? Also, how do climatic crises produce new ecological niches and what are the signals recovered from the fossil record that testify for the subsequent filling of these niches?

Science-policy interface

The knowledge on past events can be useful to act upon the present climate change. This research will allow us to assess the impact of projected climate changes on biodiversity and ecosystems, identifying their vulnerabilities, their resilience capacities and how such ecosystems recovered in the short-, mid- and longer terms as well as the limits of ecosystems and their services to adapt to climate change, informing policies for smart climate adaptation.

Fossilized leaves from Gelinden (Belgium). They date from the Early Paleocene, the periode right after the extinction of non-avian dinosaurs.

The last mile weighs the most: the pelvis of Morris

RESEARCH THEME 4

Past interactions between humans and nature

Humankind is part of nature and the biological and cultural evolution of our species has always been strongly influenced by the natural environment. However, the relationships between human societies and their environment have changed dramatically from the early periods of human evolution to the present. Humans gradually increased their influence on nature, by controlling and exploiting animal and plant populations, domesticating several species, and developing complex human societies. The impacts of human actions on global biodiversity and climate have recently become so widespread that many observers now speak of human-dominated ecosystems and argue that we have entered a new planetary epoch, the 'anthropocene'.

OPERATIONAL DIRECTORATES INVOLVED: OD EARTH AND HISTORY OF LIFE, OD TAXONOMY AND PHYLOGENY

Five-year target: To develop and structure research around past human activities and their contribution to global change together with other federal institutes, and/or other related bodies.

The aim is to increase our capacity to make the most of research results, including on our collections through improved communication and exchange of expertise with other institutes. This will improve our research and allow us to develop best practices for the study of human remains. We want to do so in collaboration with other scientific institutes in Belgium, at federal level and beyond.

> **BY 2027, WE WANT TO ESTABLISH A CENTRE OF EXPERTISE ON PAST HUMAN ACTIVITIES THROUGH A STRUCTURAL COLLABORATION WITH OTHER FEDERAL SCIENTIFIC INSTITUTES IN BELGIUM**

Focus topics

The rise and life of human populations throughout the Quaternary

Belgium has a central place in research on the history of paleo-anthropology and the acceptance of human evolution by the scientific community. The Institute of Natural Sciences has a large collection of human fossils, including Neanderthals and anatomically modern humans from Belgium, as well as the largest prehistoric archaeology collection from Belgium. This collection plays a key role in recent international studies on the disappearance of the Neanderthals from Europe and the early presence of modern humans in Europe, both as subject and as reference material. The exceptional preservation of DNA and proteins in these specimens offers great potential for genetic and isotopic studies. Diet, health, cultural and funerary practices inform us about the way of life of these past human populations.

Human exploitation of natural resources

Humans have been exploiting various natural resources since the beginning of their existence until the present day, including plant, animal and mineralogical materials. Zoologists, botanists and anthropologists at the Institute of Natural Sciences investigate the domestication of animals, explore fishing and hunting practices, document the use of wood and wild plants and reconstruct human dispersals and land use strategies in past societies. Geologists and archaeologists work together to unravel the geographical provenance and mobility of raw materials used by humans.

Skeleton of an adult cave bear next to a cub in a former exhibition at the Museum of Natural Sciences in Brussels.

Wing of a male mallard, showing the iridescent and colourful blue speculum in the secondary remiges.

Human-induced environmental changes: lessons from the past

Human activities have shaped the environment and have had significant impacts on climate. The introduction of agriculture was particularly significant as land cover influences the exchange of humidity, energy and greenhouse gases with the atmosphere. Geoarchaeological and bioarchaeological analyses allow the researchers at the Institute of Natural Sciences to document deforestation, overgrazing, overhunting, overfishing, extinctions, invasions and pollution. This adds a historic dimension to studies on human impacts on biodiversity, allowing more precise reference conditions to be defined which are of relevance to policy makers dealing with conservation issues. Detailed knowledge on the human-nature interactions from a mid to long-term perspective provides the scientific base to apply nature-based solutions, which are key to addressing today's challenges.

Services

The Institute of Natural Sciences has contracts with the Walloon and Brussels regions to assist them in the analysis and interpretation of archaeological finds. Archaeozoological and anthropological studies of skeletal remains, as well as botanical (pollen, phytoliths and starch grains), carpological (seeds and fruits) and anthracological (charcoal) studies are carried out, based on samples and materials collected during archaeological excavations in both regions. There are also occasional ad hoc contracts on the same research themes with the Flemish region.

Transversal themes

Climate change

Climate change has driven the evolution of humans. Scientific research has revealed that past environmental changes had strong effects on our ancestors, and vice versa. We can learn many lessons from the past which can help us better understand present and future challenges, mitigate related risks for society and improve resilience against extreme environmental conditions.

Science-policy interface

The Institute of Natural Sciences has a great deal of expertise on the mutual impacts between human evolution, societal evolution and environmental changes. This makes our scientists particularly well-placed to assist government agencies in drafting best practices for working with and managing human remains. In addition to this, we will continue to develop expertise in forensic anthropology in support of the Belgian Federal Police Disaster Victim Identification (DVI).

RESEARCH THEME 5

Science for sustainable marine management

Seas and oceans have played a pivotal role over the last millennia of human history. Traditionally, their importance was limited to fisheries and transport, but since the Second World War, offshore industries, including aquaculture, windmill farms and even tourism, have started playing an ever-increasing role. Gone is the idea that oceans are boundless sources of riches for our use – we know now that these environments are stressed and have become fragile. The North Sea is one of the marine areas most heavily impacted by human activity. Sustainable management of the North Sea is thus a perfect example of the Blue Growth approach: how can we maintain the balance between developing marine and maritime economic activities, while preserving as much of the marine ecosystems as possible? The knowledge obtained by studying this particular marine area can be readily applied to other marine environments around the globe, including the polar seas.

OPERATIONAL DIRECTORATES INVOLVED: OD NATURE, OD TAXONOMY AND PHYLOGENY, OD EARTH AND HISTORY OF LIFE

Five-year target: To establish the knowledge base and tools for the next level of marine management

Currently, marine management is based on a set of observations or indicators (physical, chemical, biological), mostly derived from point sampling activities spread in space and time over the area under consideration. These single point observations are then extrapolated, through modelling for example, to draw conclusions about the health of the marine system. We aim to improve our monitoring processes and to develop the tools and techniques to observe the marine ecosystem in a holistic fashion. Crucial to this endeavour is the availability of a continuously measured set of relevant variables at sea with a dedicated autonomous platform or augmented observatory. For that purpose, we use satellite remote sensing techniques and develop other methods to continuously observe the marine ecosystem. This generates considerable data that must be stored to provide easy access. We will thus develop a consolidated modelling platform, including several validated modules (hydrodynamics, sediments, biogeochemical, chemical pollutants, larval transport of fish and other marine organisms) ready to be used to test hypotheses, to assess the impact of anthropogenic pressures and to test management options and nature-based solutions in the North Sea.

> **BY 2027, WE ARE GOING TO SET THE BASIS FOR AN AUGMENTED OBSERVATORY FOR THE BELGIAN PART OF THE NORTH SEA, THAT WILL INTEGRATE THE LATEST OBSERVATION AND MODELLING.**

Focus topics

Research in support of sustainable blue growth

Seas and oceans represent a vast potential for innovation and economic growth, but are greatly understudied. Blue Growth is Europe's long-term strategy for sustainable economic activities in the marine and maritime sectors, such as wind farms, maritime transport, floating solar farms, aquaculture and passive fisheries, and at the same time taking into account the sustained ecological health of the marine ecosystems. This requires an environmental knowledge base embedded in a legal and regulatory framework. Examples of these challenges include recent renewable energy initiatives such as wind farms and the potential exploitation of deep-sea mineral resources.

Towards an integrated and holistic assessment of the North Sea.

The Institute of Natural Sciences invests in research in support of marine restoration and nature-based solutions to conserve, restore and create biotic and abiotic marine natural values. Human and global impacts increasingly pose a threat to marine environments. The capacity to predict marine ecosystem resilience needs a holistic approach, integrating physical and biological research. There are three main lines in this work.
The first is the study of the interaction between biological and the physical environment of these habitats, looking at natural marine hard substrates that seem to degrade while artificial marine hard substrates proliferate.
The second studies aquatic ecosystems. These integrate data from a variety of mapping and measuring events: 3D coupled hydrodynamic-biogeochemical models support eutrophication management; jellyfish drift models assess the origin and fate of jellyfish blooms; and larval (fish) transport models coupled to individual-based models measure larval dispersal patterns and connectivity.
Lastly, we also conduct research on mineral and organic suspended particulate matter which crucially influences benthic and pelagic ecosystems, biogeochemical cycles, human activities like harbour siltation and the fate of pollutants and nutrients adsorbed to it.

Marine forecasting as an essential tool in marine management

This work supports the management and mitigation of natural and man-made hazards such as storm surges, floods and pollution. For that purpose, the institute monitors marine environment and ecosystem health, and supports the shipping industry and other offshore activities. The main mathematical model used for marine forecasting in the North Sea is the

model we developed, COHERENS, which has proved to be an indispensable tool for all kinds of studies: physical, biological and more recently, sediment transport.

New tools for new substances: advanced chemical pollution detection

Research on marine pollution comprises a wide range of activities. This includes oil and chemical spill detection and characterisation; modelling the way spills move and change over time; environmental sensitivity mapping as well as in-situ spill and impact monitoring. It also covers the application and validation of innovative surveillance sensors and tools such as those in the field of marine pollution enforcement as well as exploitation of their results. The Institute of Natural Sciences also performs trend and risk analyses on marine pollution.

Developing marine subsoil analysis as a tool in marine management

This is an integral part of the first focus topic in RT6 which develops a multiscale geological framework of Belgium that will include a comprehensive metadata catalogue, conceptual framework and scientific vocabulary of the existing Belgian geological maps, data sets and 2D/3D subsurface models, useful for decision and policy support.

Satellite remote sensing in support of aquatic ecosystem management

The scattering and absorption of light in water can be measured by satellites as spectral reflectance (water colour). Satellite remote sensing can thus be used to map the concentration of chlorophyll (a proxy for phytoplankton biomass) and suspended particulate matter and related parameters. This provides information on eutrophication, optimisation of dredging activities, environmental impact of constructions at sea (changes in light availability and bottom sediments), aquaculture, etc. Satellite data also support other disciplines such as aquatic biology and sediment transport. The Institute of Natural Sciences carries out research to improve methods for satellite remote sensing, to ensure the quality control of satellite data products and to exploit satellite data in support of aquatic ecosystem management and science.

Services

Legal mandates

The Institute of Natural Sciences, through the Marine Forecasting Centre, has a set of mandates for research and monitoring from the federal government. These mandates include monitoring the environmental status of the Belgian part of the European Economic Zone in relation to the obligations of the Convention for the Protection of the Marine Environment of the North-East Atlantic (the OSPAR Convention), the European Marine Strategy Framework Directive (MSFD) and the Water Framework Directive (WFD). These activities include studying the ecological impact of dredging and relocation works and of the sand and gravel extraction; monitoring the ecological impact of wind farms (such as presence of sediment plumes around wind turbines); monitoring the ecological impact of the Sea Farm CODEVCO of the Colruyt Group, as well as the advanced observations in relation to the Bonn Agreement and the International Convention for the Prevention of Pollution from Ships (MARPOL). In addition, our Marine Forecasting Centre issues five-day forecasts of the marine conditions in the North Sea, twice a day. These forecasts are used to support the missions and activities of the Belgian and foreign public sector. The successful forecast of December 6th 2013, the so-called Sinterklaas storm, is a case in point.

Marine data management

In support of the mandates of MFC mentioned above, the Belgian Marine Data Centre provides tools for data dissemination, reporting and publication, taking into account the ongoing data regulations (eg. INSPIRE Directive 2007/2/EC), Open Data Directive (EU) 2019/1024), following FAIR principles (Findability, Accessibility, Interoperability, and Reuse of digital assets). It develops and maintains databases and reporting procedures in the required formats, and provides open access to the marine datasets via its metadata platform, at the same time ensuring further dissemination and interoperability with international data infrastructures. Furthermore, tools are developed for data visualisation and automatisation of dataflows, from sampling onboard the RV Belgica, for example. Research theme 5 contributes to the increased visibility and data mining of our institute's datasets and collections.

Other services

Various other services include the development of improved satellite data processing techniques, specialised chemical analyses, such as oil fingerprinting, detection of explosives in sea water and sediments, as well as measuring eutrophication parameters and organic determinants. We also perform scientific evaluation of environmental impact assessments at the request of Belgian governments and conduct aerial surveys to monitor marine mammals and perform sniffer observations for exhaust gas of large vessels.

Transversal themes

Climate change

This research theme contributes considerably to the observed and predicted consequences and to potential mitigation of climate change. We investigate and monitor the impacts of maritime transport, wind farms, floating solar farms, aquaculture, or fisheries on climate, and the way climate change may impact those activities. The Institute of Natural Sciences's expertise and datasets are used by the Belgian Marine Climate Service. Our infrastructure thus also allows estimates of the effects of changing climate to sea level rise and impact on amplitude of tides, currents and waves.

Science-policy interface

Most, if not all, of the service-directed research in this research theme is either aimed at federal or regional policy-support or towards support required, directly or indirectly, by industry. Science provides the information needed to make the best, and often most difficult, decisions. Research Theme 5 also contributes to the representation of Belgium in international marine, maritime, polar and other commissions and intergovernmental bodies mentioned above, including OSPAR, MSFD and WFD.

The surveillance aircraft in action over the navy vessel P902 POLLUX during a national pollution response exercise POLEX.

RESEARCH THEME 6

Geosciences for a sustainable society

Our research aims to provide the society around us with science-based solutions for a sustainable use of its natural resources. These solutions are essential to sustaining our society's needs, by managing the impacts of environmental change and building resilience to hazards. All these topics require geological mapping campaigns, geological models based on digital and physical data through archives, collections and new fieldwork activities, and a digital platform to host, share and exchange all geological data. This research is done in partnership with geological surveys, universities, scientific institutes, governments, companies, and federal research institutes. It takes place at national level, but also at European level through EuroGeoSurveys partnerships, and globally, on specific case studies of interest.

OPERATIONAL DIRECTORATES INVOLVED: OD EARTH AND HISTORY OF LIFE, OD NATURE

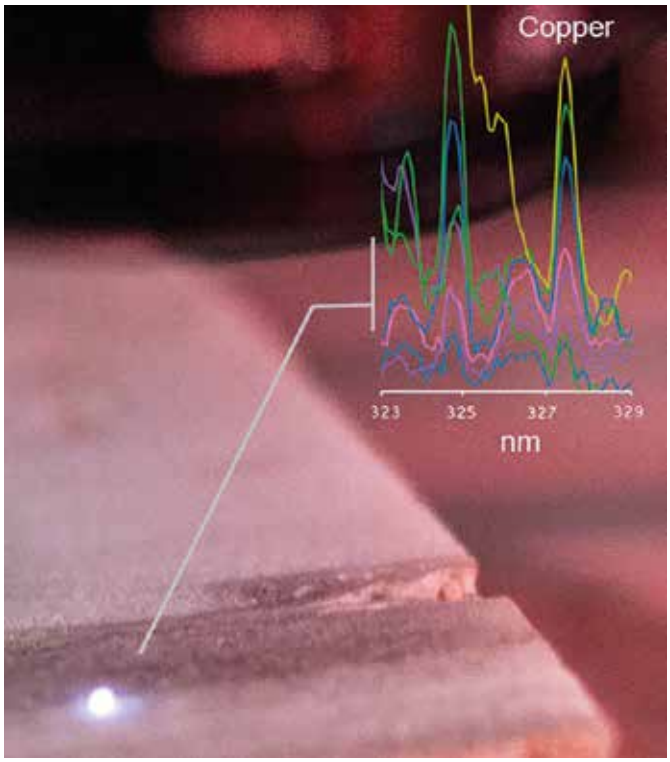
Five-year target: To establish the knowledge base and tools for sustainable subsurface management

To deliver science-based solutions on the sustainable use of Belgium's subsurface, we need solid knowledge bases of our subsurface, enabling cross-thematic use of geological information for subsurface management. The Institute of Natural Sciences has initiated the development of these knowledge bases in response to this need which is internationally highlighted as crucial and urgent. In the present-day context, geological knowledge of Belgium's subsurface (onshore and offshore) includes a large variety of related information, set against discussions on critical raw materials and the energy transition, and their relations with natural hazards, climate change and geoheritage. Research data must be brought together on provenance and occurrence of natural resources, specific geological characteristics such as rock thermal conductivity for geothermal energy exploitation, reservoir characterisation for storage of natural gas and hydrogen, seasonal groundwater buffering, different types of subsurface energy storage, CO_2 storage and radioactive waste disposal.
A cross-cutting element is linking the use of subsurface resources to our needs and our environment, evaluating trade-offs and environmental impact. The multipurpose use of our subsurface requires the development of a Belgian digital geoscience data platform, enabling a cross-thematic approach as well as dedicated thematic research as set out below.

> **BY 2027, WE AIM TO HAVE COMPLETED SEVERAL THEMATIC LAYERS OF THE DIGITAL GEOSCIENCE DATA PLATFORM OF THE SUBSURFACE OF BELGIUM TO SUPPORT RESEARCH ON HOLISTIC SUSTAINABLE SUBSURFACE MANAGEMENT.**

Focus topics

Onshore-offshore multi-scale geological framework of Belgium: the first steps towards an integrated model.
A stepwise process is foreseen for the creation of the onshore-offshore multiscale geological framework of Belgium and its use. First, a comprehensive metadata catalogue, conceptual framework and scientific vocabulary of the existing Belgian geological maps, data sets and 2D/3D subsurface models will be produced. We will then develop a digital framework following the FAIR data principle and demonstrate cross-thematic use of geological information for subsurface management and its added value for decision and policy support. This Belgian geological framework data will be included and shared at European level (European Geological Data Infrastructure, EGDI) for EU policy support.



Sustainable supply of raw materials for green energies, industries and protecting our livelihood:: a challenge at Belgian and European levels and beyond.
Europe wants to secure the supply of critical raw materials (CRMs). Indeed, the green transition, net-zero energy will require a dramatic increase in raw materials for new low-carbon technologies such as batteries, wind turbines, solar and geothermal infrastructures. Deep-sea environments, targeted for CRMs in polymetallic nodules, require their own specific considerations, with a holistic approach and thoughtful management. Meanwhile, bulk raw materials, such as sand, also need improved

management strategies because of the huge quantities involved with concerns on supply, environmental impact and coastal protection.
Our research focuses on: the supply of (non-)metallic CRMs to agriculture and green technologies, through up-to-date assessment of economic potential of key ore deposits. It explores the origin and concentration of metal occurrences for a better understanding of processes to target new exploration areas. It looks at the sustainable supply of offshore sand resources, through mapping and modelling, supporting multi-use exploitation of the seabed., for construction, coastal safety and wind energy development. It also explores geo-engineering solutions for a more sustainable production of onshore and offshore CRMs in Europe.

Subsurface solutions for a decarbonised future and sustainable energy management strategies:

A major challenge of our society is to meet CO_2 reduction commitments, known as 'net zero'. We contribute to energy security and a decarbonised future by performing research on sustainable subsurface solutions, such as CO_2 geological storage, underground energy storage, and geothermal energy. Our geo-energy research focuses on the exploration of geological solutions contributing to energy security and a decarbonised future, but also the development of techno-economic and other interdisciplinary methods for the assessment of sustainable subsurface solutions for the energy transition. It aims to create sustainable management strategies for the subsurface activities and policy support.

Geohazards within a context of increased human-impact and climate change: enhancing societal resilience

Within a complex context of increased human impact combined with climate change, Europe and Belgium increasingly suffer from geohazards: coastal flooding, impacts of extreme weather and wave events, land subsidence and seismic activity, among others. These hazards can be associated with natural processes like tectonics, sedimentary processes, or extreme events such as storms and tsunamis. But they also originate from human activities, such as land use, mining and groundwater extraction, interfering with natural processes. This research focuses on a better understanding and monitoring of hazards, in support of the development of adequate risk maps and mitigation strategies. This includes a multiproxy study of the imprint of climate change and past extreme wave events in the geological record (controlling factors, frequency, recurrence interval, size and impact). It also focuses on identifying, mapping, monitoring, modelling and understanding the causes of historical and present-day hazards, such as the impact of climate change and anthropogenic activities on land subsidence causing infrastructure instability.

Linking Belgian geoheritage and geodiversity with biodiversity

Geodiversity and biodiversity are tightly linked through the type of substrate (porosity, water content, chemical content, erosion products, nature of the stone, etc.) geodiversity offers to biodiversity. Despite its small size, Belgium shows a rich geodiversity that contains a variety of habitats and provides information on local, regional or global Earth history. With the real estate pressure and increasing land use, geoheritage is at risk. Key geosites need to be identified and characterised and a science-based policy and legal framework needs to be developed in support of their conservation. In addition, the Institute of Natural Sciences hosts important geology collections, linked to important geosites, which need a larger scale (lithostratigraphic) context to optimise their scientific and societal value. Research within this topic therefore focuses on the development of methodologies and mapping techniques to inventory and assess the geodiversity of specific environments such as coastal lowlands, caves and cliffs; but also urban areas and cemeteries. It explores the application of modern analytical techniques to add value to the Institute of Natural Sciences geology collections as geodiversity treasures. We study the interaction between biodiversity and geodiversity, to understand their mutual benefits and to secure their interlinked preservation in the long-term. A final focus is the contribution to the promotion of geodiversity to citizens throughout the RBINS-Geoparks network.

Transversal themes

Climate change

This Research Theme contributes to research on adaptation, resilience and mitigation to climate change. First, research on the contribution of the subsurface to decarbonization and sustainable energy supply contributes to mitigation and augments resilience against climate change effects. Next, research on the sustainable management of natural resources, onshore and offshore, both at the surface and deeper in the subcrop, contributes to mitigate climate change effects. A third research topic deals with the link between geohazards and climate change. We study the imprint of past hazards (e.g., coastal flooding, landslides, extreme wave events and climatic events) in the sedimentary (Holocene) sequence to identify their past impact to support science-based adaptation measures. Moreover, we use augmented monitoring and aerial or remote sensing data observations to assess the impact of present-day hazards. Lastly, research in this theme underpins the need to create a sustainable balance between the needs of continuously growing urban areas, industrial economical developments and the protection of Belgium's national geoheritage (geosites and geoparks) by raising awareness within society regarding geodiversity: "We only protect what we know best."

Science-policy interface

Research in this theme creates geological knowledge on the subsurface of Belgium (following the mandate of the Geological Survey of Belgium) and services, in order to enable our society to use its natural resources responsibly and in a sustainable way, manage environmental changes and build resilience to natural hazards. Almost all the focused themes will lead to policy supporting activities: extraction and recycling of critical and strategic raw materials, development and storage of renewable energies, working towards a decarbonized future, reducing or mitigating geohazards and raising awareness of geoheritage and geodiversity, inextricably linked to biodiversity. Most, if not all, of the service-directed research in this research theme is either aimed at federal or regional policy-support or towards support required, directly or indirectly by industry. Research Theme 6 also contributes to the representation of Belgium within national and international geology and subsurface-related commissions and expert groups, such as EuroGeoSurveys and CCOP.

TRANSVERSAL THEME 1
Climate change

Climate change refers to long-term shifts in temperatures and weather patterns. These shifts may be natural, such as through known variations in the solar cycle. But since the 1800s, human activities have been the main driver of climate change, primarily through burning fossil fuels like coal, oil and gas. This generates greenhouse gas emissions which act like a blanket wrapped around the Earth, trapping the sun's heat and raising temperatures.

Research on climate change mostly focuses on causes, impacts and mitigation and remediation, including resilience. The Institute of Natural Sciences has been involved in climate research for years, mostly regarding consequences of climate change, from the North to the South Pole, and from the North Sea to the African Great Lakes and neotropical forests. To this end, the Institute of Natural Sciences has a great deal of infrastructure, including the new Research Vessel Belgica, a survey plane, large modelling facilities, such as the in-house model COHERENS, chemical, molecular and geological laboratories, a wide microscopy park, remote sensing facilities and much more. Other resources are our extensive digital and physical library, large physical and other collections and databases, together with significant Information networks.

The Institute of Natural Sciences is one of five Federal Scientific Institutes that participate in the Federal Climate Centre established in 2022.

The six Research Themes of this Research Strategy are closely related to various aspects of climate research.

- Climate is an important driver in speciation and diversification. Biologists and palaeontologists study the effects of climate change on organic evolution in recent times and in deep time (RT1).
- Both in recent times and in deep time, the effects of climate change on the biosphere, including recent biodiversity, palaeo-faunas and palaeo-ecosystems, are being investigated. Recent polar research, surveys of alien invasive species and zoonotics are key examples of recent research. Lessons learned from the past are valuable to understand present and future processes (RT2, RT3).
- Our archaeo-scientists investigate how climate change affected human settlements in the past and vice versa: how were the economy and society at large affected by climate change, and how did they adapt (RT4)?
- All human activities in seas and oceans affect natural marine ecosystems and this is especially so in the North Sea. In addition, climate change aggravates these effects. The Institute of Natural Sciences investigates the effects of climate change on ecosystem health and on the various economic activities at sea and seeks to provide science-based recommendations regarding Blue Growth and marine management. More specifically, the effects of climate change on water chemistry, wave actions, and sea level rises are investigated to allow reliable forecasts of storm surges (RT5).
- Research on technologies of CO_2 capture at production sites and geological storage, subsurface energy storage, developing geothermal energy in Belgium and synergies between oceanographic and geological models on marine subsoil are all lines of scientific inquiry leading to a sustainable economic geology (RT6).

TRANSVERSAL THEME 2
Science-policy interface

The Belgian Biodiversity Policy Support Group (BIOPOLS)

BIOPOLS is a biodiversity knowledge platform regrouping several entities: the Belgian Biodiversity Platform (BBPf), the National Focal Point to the Convention on Biological Diversity (NFP-CBD), the Capacities for Biodiversity and Sustainable Development programme (CEBioS), the Conservation Biology research team (ConsBiol), part of the Marine Ecology team (MARECO) and more recently also the Belgian National Scientific Secretariat on Invasive Alien Species. Each of them deals with specific aspects of the biodiversity science-policy interface. Together, they form a unique policy support group with a significant critical mass of policy specialists which offers specialist advice to policy makers at various governmental levels. They also provide training activities to the Global South, including taxonomy training grant by the Global Taxonomic Initiative (GTI) of which the Belgian part is embedded in CEBioS). The Institute of Natural Sciences also host the secretariat of the Consortium of European Taxonomic Facilities (CETAF), a large association of European organisations hosting natural history collections and which is setting up a program creating a pan-European virtual natural history collection, called DISSCO, the Distributed System of Scientific Collections, comprising 1.5 billion specimens, with 5,000 working scientists in more than 170 institutions in 23 countries. The Institute of Natural Sciences is proud to be a founding member of both CETAF and of DISSCO. (RT1, RT2, RT3).

Blue Growth and Sustainable Marine Management

The Institute of Natural Sciences, through the Belgian Mathematical Model of the North Sea (now MFC); has a strong component of policy support in the marine management of the North Sea, through its own research and monitoring activities, which are conducted in the framework of both legal mandates (directly through mostly federal law) and economic mandates (activities requested from industry by law). Many of these mandates are related to international obligations, for example regarding the Belgian part of the European Economic Zone, in the North Sea. Other representations deal with the OSPAR Convention, where Belgium plays a very active role, and the MSFD and WFD, as mentioned earlier in RT5.

Sustainable subsurface management

The Institute of Natural Sciences, mainly through the Geological Survey of Belgium (GSB) and its legal mandates, offers support to policy through their research on extraction of critical and strategic raw materials, renewable energies, towards a decarbonised future, reducing or mitigating geohazards. For this, the GSB collaborates with regional and federal partner institutes, European National Geological Surveys and EuroGeoSurveys, the latter through the newly EU funded programme called GSEU - A Geological Service for Europe. (RT6)

Heritage

Many natural history institutions hold collections of human remains and cultural artefacts, mainly collected during colonial times from the Global South. There is a large movement towards the restitution of such artefacts and the Institute of Natural Sciences is in the lead of these initiatives in Belgium. As such, we provide extensive recommendations to the Belgian governments regarding all aspects and steps in the process of a restitution policy.

Research infrastructure

The Institute of Natural Sciences has a large array of technical research facilities. All these facilities contribute value to our collections and are used for the Institute of Natural Sciences' research and services activities. They also enhance partnerships, allowing facilities to be shared both among the Institute of Natural Sciences' Operational Directorates and with other scientific institutions.

These facilities include fully equipped DNA labs, an ISO-17025 accredited water chemistry lab, digitisation and imagery platforms (such as CT scans), a Scanning Electron Microscopy lab, Raman and X-ray diffraction microscopes and scanners for magnetic susceptibility and thermal conductivity. The Institute of Natural Sciences also hosts an advanced remote sensing facility with excellent spatial and temporal resolution.

Three major research facilities are deployed in our research supporting marine management. Firstly, we proudly organises the scientific and logistic management of the brand new Research Vessel Belgica, baptised by the Belgian crown princess Elisabeth in 2022. The new Belgica is a state-of-the-art 71-metre-long research vessel, about 1.7 times larger and more efficient than its predecessor, and already in use for dozens of research projects, both national and international. The Institute of Natural Sciences also owns a survey aircraft to monitor oil spills and to detect sulphur emissions from the exhaust plumes of ships with its state-of-the art sniffer equipment. The survey aircraft also documents marine mammal migration. We are also continuously developing an in-house, fully 3D modular modelling system, designed for applications across coastal and shelf seas, estuaries, lakes and reservoirs, called COHERENS.

Collections

The Institute of Natural Sciences holds by far the largest natural history collections in Belgium. These collections are in themselves its most significant research infrastructure, dating back as far as the 18th century and representing a huge archive of taxonomic, environmental and geological specimens and data.

The Institute of Natural Sciences' collections also contain a rich archive of catalogues, reports, maps, photographs and other documents as well as historical equipment, all related to the investigation of the natural world. Over the last 25 years, frozen tissue collections and DNA extractions have been added to the classical collections. Lastly, the institute's research and services produce large databases, increasing the collections with a growing digital component. Most of these collections relate to Belgian environments. However, the Institute of Natural Sciences is also home to a remarkable amount of collections and data from all over the world.

There are three main benefits that these collections offer. Firstly, the collections support scientists in establishing the basis of research and scientific communication. Secondly, we commonly reinterpret old data using new techniques to make important discoveries, hence questioning what we have established as truth. Finally, the collections help us make predictions about future changes in the natural environment, by showing us patterns and lessons from the past. In times of global and climate change and loss of biodiversity, such studies are essential.

Sustainable Development Goals (SDGs)

In 2015, the United Nations adopted the Sustainable Development Goals (SDGs) as a universal call to action to end poverty, protect the planet, and ensure that by 2030 all people enjoy peace and prosperity. The Institute of Natural Sciences adopted these SDGs.

The table below shows how the six Research Themes of our Research Strategy address these 17 SDGs.

It is of course clear that SDG 14 and 15 (Life below Water and Life on Land, respectively) score among the highest, as biodiversity is one of the prime targets of research of the Institute of Natural Sciences and science-policy interface activities.

SDG 6 also relates to our biodiversity research as freshwater biodiversity mainly figures in this SDG, whereas SDG 14 mainly deals with marine environments. Through this research in SDGs 6, 14 and 15, we also target SDG 13 on Climate Action in all of our Research Themes. Climate change is one of two transversal themes in our Research Strategy and the involvement of Institute of Natural Sciences in the Belgian Climate Centre is a case in point.

Renewable Energy (SDG 7), Economic Growth (SDG 8) and Innovation and Infrastructure (SDG 9) mostly relate to Blue Growth (RT5) and Sustainable Geology (RT6).

Several of the Institute of Natural Sciences' activities relate to SDG 4 (Quality Education), not in the least through the CEBioS component of BIOPOLS, but of course mainly through our museum and educational activities. Gender Equality (SDG 5) and the related SDG 10 (Reduced Inequality) prevails in all of activities and strategies of the Institute of Natural Sciences, also in those of our research, as can be read in our Gender Equality Plan.

As the Institute of Natural Sciences has a long history of research collaboration with other organisations, both within Belgium and in an international context, SDG 17 figures prominently in all Research Themes.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
RT1				✓	✓								✓	✓	✓		✓
RT2	✓		✓	✓	✓	✓					✓		✓	✓	✓		✓
RT3				✓	✓								✓				✓
RT4	✓		✓		✓	✓					✓	✓	✓	✓	✓		✓
RT5		✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓			✓
RT6			✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓		✓

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É. R.: Michel Van Camp

Rue Vautier, 29
1000 Bruxelles

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