

ROYAL BELGIAN INSTITUTE OF NATURAL SCIENCES
RESEARCH STRATEGY 2018-2022





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CONTENTS

PREFACE	3
PROFILE	4
MISSION & VISION	5
RESEARCH INFRASTRUCTURES	6
WHY A RESEARCH STRATEGY?	7
KEY FACTORS SHAPING THE RESEARCH STRATEGY	8
DEVELOPMENT OF THE RESEARCH STRATEGY	9
FLAGSHIPS, RESEARCH THEMES AND SUBJECTS	10
ICONS	11
12 FLAGSHIP 1: NATURE DISCOVERY	
14	Research Theme 1: Evolution, the driving force of life
17	Research Theme 2: Biodiversity inventory
21	Research Theme 3: Ecosystems dynamics
24 FLAGSHIP 2: HUMANS AND NATURE	
26	Research Theme 4: Past interactions between humans and nature
30	Research Theme 5: Blue growth and marine management
34	Research Theme 6: Biodiversity and natural resources policy support
38 FLAGSHIP 3: NATURE, OUR FUTURE	
40	Research Theme 7: Sustainable use of geo-resources
44	Research Theme 8: Predictions and forecasting
47	Research Theme 9: Biological migrations and invasions
CONCLUSION	50
CREDITS	51

PREFACE

In 1948, shortly after WWII, our institution decided to change its name to the Royal Belgian Institute of Natural Sciences. Before that, it had been known as the Royal Natural History Museum of Belgium since its creation in 1846. The switch from “Museum” to “Institute” was a clear sign that research was prioritised above other missions such as conserving collections or exhibiting natural history specimens to the public at large. **This strategic turn gave the RBINS a strong push towards modern science, and helped it to enrich its investigation of the diversity of the natural world with new techniques, new disciplines and new questions.** Very early on, the RBINS also adopted a collaborative approach in research. Over the decades it has built a worldwide network of scientific partnerships, leading to a great deal of success in competing for external research funds.

Over the last 20 years, the RBINS made a further strategic move by developing science-based activities supporting policy in a range of areas, including nature and biodiversity conservation, management of marine environments and sustainable use of geological resources. These developments added a significant portion of service-related and legally mandated activities to the RBINS portfolio, as well as numerous new stakeholders.

This increasing diversification in the RBINS’ research topics makes its research rather unique, compared to other research institutes or natural history museums abroad. The collection-based nature of our work also distinguishes it from that of more academically-orientated institutions. However, this diversity also leads to complexity, which makes it more and more difficult for observers, both from within and from outside of the Institute, to obtain a good overview of ongoing research activities within the RBINS, and a clear vision of what the RBINS stands for.

This issue was addressed five years ago, thanks to a strong reorganisation. The seven scientific departments were merged into three new Operational Directorates to reduce fragmentation and enhance interdisciplinary exchanges between teams. At the same time, a specific directorate was designated for Museum activities and a separate Service for the curation of collections.

More recently, the Strategic Plan was developed for the RBINS’ activities and initiatives, 2016-2020, with this Research Strategy as a priority component. It is the next step towards a clear positioning of the RBINS in its research fields, rooted in the RBINS’ identity and specificity and fully aware of the need for natural sciences research in a changing world.

Together with the RBINS’ Strategic Plan 2016-2020, this Research Strategy 2018-2022 will guide the research activities of the Institute over the coming five years.

Camille Pisani
General Director

PROFILE

The Royal Belgian Institute of Natural Sciences (RBINS) is devoted to nature, its long history and its sustainable management. The Institute is esteemed by the academic world and public authorities for its significant research activities and the public services it provides in terms of advice, expertise and studies. It is also much loved by the general public for the Museum of Natural Sciences and the activities organised there. Lastly, it conserves, enriches and manages immense natural history collections of specimens, samples and archives. It also manages the Belgian oceanographic vessel, the RV Belgica, on behalf of the Belgian Science Policy Office (Belspo), serving the entire scientific community around it. The Institute is one of the ten federal scientific establishments that are governed by Belspo. Up until now, the Institute has been an independently-managed government service, without the status of a juridical entity, although a reform of this status is currently underway.

Research

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

Providing services

The RBINS provides scientific expertise under Belgium's international commitments in relation to environmental protection. It develops tools and methods for monitoring natural land, freshwater or marine environments. The Institute also offers scientifically underpinned advice for the development of national and European policies for the protection and conservation of biotopes and biodiversity, and use of natural resources.

Collections

With 37 million specimens conserved as Belgian heritage of global significance, the RBINS' collections are the third largest in Europe, just after London and Paris, and are some of the largest in the world. The collections are both a reference and a research tool and form part of Europe's 'major research infrastructure.' As such, they are visited and studied by researchers from around the world.

For several years now, the RBINS has been committed to an ambitious programme to digitise its collections and to do so has developed an open-source software, DaRWIn, which has made it possible to encode all the data on any collection of specimens.

Museum

For the general public, the Museum of Natural Sciences is the most visible part of the RBINS. It has 16,000m² of permanent galleries, temporary exhibition rooms and educational workshops, welcoming roughly 300,000 visitors each year, approximately 30% of whom are school groups. Its 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 raise awareness of this knowledge as widely as possible, both within and beyond its walls, the latter notably through travelling exhibitions and events. A number of citizen science projects also allow the public to participate actively in research. Ambitious efforts are underway to gradually renovate the premises, making the museum more welcoming and meeting and exceeding visitors' expectations.

MISSION

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

This requires us:

- **to produce good and relevant science:** complex issues need sound, modern, up-to-date knowledge;
- **to maintain and enrich our research infrastructure and make it available** in the form of collections, databases and models: sound forecasts need certified long-term reference data;
- **to link our research to action and policy** as much as possible: to increase the impact of scientific results, we need relevant and targeted communication, providing independent advice at the appropriate level;
- **to enhance citizens' understanding and knowledge,** in particular through our Museum, allowing them to make informed choices regarding their own lives and futures.

VISION

**BRINGING NATURE
INTO EVERYONE'S LIVES**

RESEARCH INFRASTRUCTURES

The RBINS holds by far the largest natural history collections in Belgium. These collections are in themselves the Institute's most significant research infrastructure, dating back as far as the 18th century and representing a huge archive of taxonomic and environmental specimens and data. The RBINS' 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 RBINS is also home to a remarkable amount of information from all over the world.

There are three main benefits that the collections offer: Firstly, the collections help scientists establish the basis of research and scientific communication. Secondly, researchers have the opportunity to question what we have established as truth, taking old specimens and applying new scientific techniques to see them in a new light. Lastly, they help us make predictions about future changes in the natural environment, by showing us patterns from the past.

Looking first at this notion of the basis of research and scientific communication: the collections serve as a repository for "type specimens" that set the taxonomic standards and determine scientific names of species. As such, natural history collections are an indispensable tool for taxonomic research and provide stability for our system of naming. We can safely consider them treasures of our world heritage!

As for re-assessing what other scientists have asserted, this is particularly true for the world of taxonomy and identification. By going back to the original material, researchers can check previous studies and identifications. They can also perform additional research and analyses that were not possible at the time the specimens were collected, such as extraction of ancient DNA and isotope analyses. Thanks to the exceptional Belgian prehistoric collections, the evolution of and interactions between human cultures in Europe and beyond can also be studied. Similarly, the Institute's rich geological collections also provide unique references for scientists studying the geology of Belgium.

Predictions about future changes can be made by analysing zoological and paleontological collections, looking at changes in the past over time. These collections provide environmental baseline data and allow access to rare and even extinct taxa. Such

studies are needed in times of global and climate change and loss of biodiversity. Research on the collections therefore provides essential support to environmental management and policies, including environmental monitoring and forecasting impacts.

The RBINS has a large array of research facilities that allow in-depth studies in its fields of competence. These include a fully equipped DNA lab, an ISO-17025 accredited 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 also hosts an advanced remote sensing facility with excellent spatial and temporal resolution.

The RBINS is also continuously developing a fully 3D modular modelling system, designed for applications across coastal and shelf seas, estuaries, lakes and reservoirs. This complements the Institute's aforementioned role managing the Research Vessel Belgica for the Belgian Federal State. It also owns a survey aircraft to monitor oil spills and marine mammal migration.

All these facilities contribute value to our collections and are used for the RBINS' research and services activities. They also enhance partnerships, allowing facilities to be shared both among the RBINS' Operational Directorates and with other scientific institutions. What is more, the RBINS is part of a consortium of European Natural History Institutes that have submitted a proposal to ESFRI, the European Union's Strategy Forum on Research Infrastructures. This proposal aims at forming a pan-European research infrastructure to solve the current limitations for the use of the information and related expertise contained by the natural science collections.

WHY A RESEARCH STRATEGY?

Producing good and relevant science, and linking it to action and policy: the Research Strategy is key to fulfilling this part of the Institute's mission. The Research Strategy focuses on fields in which the Institute excels and in which knowledge needs to be enhanced, further developed and made available. It spans the various research disciplines, and as such is structured by themes across the Operational Directorates (ODs) within the Institute's work. These themes cover both fundamental research, looking at the building blocks of the natural sciences, and applied research that addresses societal challenges. The two are closely linked and crucial in ensuring that the first and third pillars of the RBINS' mission are fulfilled.

These fields are grouped under three flagships that set out the broad lines of the RBINS' work. The flagships contain research themes, each of which bring together teams from across the Institute. Spread across these themes are the 31 research subjects: crucial questions within the natural sciences where the Institute's work finds its focus.

The Institute was created 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: a rich heritage of specimens from across Belgium and the world.

The challenge now is to make our heritage relevant for the modern world around us, and for our future. The Institute must define its role more specifically: still firmly rooted into the collections, while advancing fundamental research using state-of-the-art technologies and linking its work to broader societal concerns.

The nine Research Themes of the Research Strategy are the Institute's answer to this challenge. They make it clear what kind of research is prioritised, how this work is relevant to society at large, why the Institute is the place for this and what infrastructure it provides to make this happen.

This Research Strategy also serves as a guide for the research teams at the Institute, demonstrating its shared vision of its unique strengths and lines of work that should be maintained and developed more broadly and more deeply.

By clarifying its Research Strategy, the RBINS opens itself up to new partnerships, showing its strengths that could match others' concerns. What potential do other stakeholders see in the Institute's work and what other questions are out there, to which our expertise might hold answers?

KEY FACTORS SHAPING THE RESEARCH STRATEGY

Each of the nine Research Themes is presented in this document with a short text that looks at what shapes our Research Strategy within that particular Theme. A full set of key factors was considered for each Theme, aiming to ensure a sound line of work for the next five years. These factors look first at what makes the Institute unique in its research. Next, we cover the relevance of this research with a particular focus on scientific services. We also examine what shapes the Research Strategy in terms of operability: the infrastructure, human resources, partnerships, funding potential and organisational structure that are necessary to achieve this vision. For each of these areas, we also identify opportunities and threats that are likely to affect the success of the Strategy within the five years of its implementation.

In terms of uniqueness, we look first at what makes the RBINS a leader on research within the subject areas covered within its strategy. Often, these key strengths are linked to excellence in human competences, the wealth of the collections themselves or the other research infrastructures described on page 6. But what makes the Institute unique is also rooted in its multifaceted role: as well as curating vast collections, the RBINS manages a rather unique mix of research topics and also provides support to policies in fields of societal concern. While this diversity poses many challenges, it also presents great opportunities, setting the RBINS apart from other European research bodies, institutes and universities and adding significant value to our work.

As for relevance, the Strategy details the ways in which the Institute's work is closely linked to this support to external stakeholders. The RBINS delivers support to policy and action in a wide range of contexts including topics as diverse as human health, geo-energy and biodiversity, and this is evident throughout the themes of the Research Strategy. Again, there is a clear link between the Institute's service roles and its status and the reputation of its work at national and international levels. Threats to this work vary greatly from one Research Theme to the next, whereas in terms of opportunities there is some common ground: by developing its relationships with key stakeholders, the Institute can better identify the areas in which its research can provide such scientific services.

Under operability, the Research Strategy details how the infrastructures and human competences that the RBINS offers are complemented by partnerships and possibilities of funding. These partnerships of course include "family members" such as the Royal Museum of Central Africa, the Belgian federal research institute

with which the RBINS works most closely, and several natural history museums across Europe and beyond. Other key partnerships are with research institutes at international, national and regional levels, whose areas of expertise complement the RBINS' research fields particularly well. As the structural funding needs to be complemented, access to external funding is another key factor for success. The possibilities for each Research Theme to be financed, whether publicly at European, federal or regional levels, or through service-related projects with private companies and foundations, has been assessed. A last key aspect of the Institute's Research Strategy to be considered is how each Research Theme can reinforce links between units from across the organisation's Operational Directorates. These themes often open lines of work for increased cooperation internally, maximising the Institute's potential both in terms of human resources and infrastructure.

Operability, and funding in particular, is perhaps the area where we see the greatest number of overarching opportunities and threats in the five years ahead. In terms of financing, the major challenge is that the RBINS' structural funding from the federal government has been under threat in recent years and many key retired staff members have not been replaced. Funding at European level is often challenging, particularly with the uncertainty due to the forthcoming change in funding programme. Many clear opportunities present themselves, however. For applied research, the timespan of the Strategy is covered at federal level by funding programmes BRAIN-be (2012-2017) and its successor through to 2023, for themes supporting federal competences, such as climate, health, natural resources, and so on. BRAIN-be also provides opportunities for research strongly linked with collections and databases.

At EU level, the societal challenges within H2020 may provide opportunities for funding and partnerships. For curiosity-driven research, one major potential new opportunity at Belgian level is the new federal research programme FED-tWIN that aims at supporting closer cooperation between the federal scientific institutions and universities. The EU's Excellent Science pillar also

offers funding opportunities for fundamental research in the shape of Marie Curie actions, for example. This thorough analysis aims to give a sound basis to the direction the RBINS is taking in the five years of the Research Strategy, clarifying the Institute's vision in order to guide its work.

DEVELOPMENT OF THE RESEARCH STRATEGY

Following the need for a strategy outlined on page 7, the trigger for the development of this Research Strategy was a review of the Institute's work carried out by an international panel of peers early in 2015. They assessed the scientific activities of the RBINS as part of a federal evaluation and strongly recommended that a Research Strategy be drawn up as part of a strategic plan for the Institute as a whole.

This recommendation was validated by a strategic RBINS workshop in late 2015, drafting a five-year Strategic Plan for the whole of the organisation. At this workshop it was decided that such a Research Strategy was a priority. A Head of Research was appointed, who in turn called for a task force, an internal Research Committee, to undertake this work. This Research Committee, meeting for the first time at the beginning of 2016, set out to compile an overview of all ongoing research activities in RBINS. They grouped the Research Themes into flagships inspired by the RBINS' vision: "Bringing Nature into everybody's life", setting out the basis of a research agenda.

However, the strategy was not developed solely from a top-down perspective. In order to ensure that the voices of the Institute's researchers were heard and incorporated, the Research Committee then launched an appeal to the RBINS' scientists to submit priority Research Subjects from their own field. These Research Subjects had to respond to two criteria:

- Evidence of the excellence of the RBINS in the given research subject;
- Demonstrated necessity to be maintained and prioritised over the coming five years (2018-2022).

This call received an enthusiastic response, with dozens of Research Subjects submitted, covering the priorities among the ongoing research activities of the Institute. The Research Committee worked to group and rearrange the fields, transforming the Research Agenda into a true Research Strategy with three flagships, nine Research Themes and 31 retained Research Subjects.

All of these research activities are in line with the RBINS' vision and mission statements. Almost all Research Themes are a mixture of fundamental research and research in view of legal obligations, although it can be noted that Research Themes 5-8 are largely in support of governance.

This Research Strategy is itself a living document, to be evaluated and revised periodically to ensure it is serving its purpose. Feedback will be sought from the Institute's researchers at least every two years and from external peers every five years, shaping and refining the strategy to best guide the Institute's work.

FLAGSHIPS, RESEARCH THEMES AND SUBJECTS

FLAGSHIP 1: NATURE DISCOVERY **Research Theme 1: Evolution, the driving force of life**

- 1.1. Adaptive radiations
- 1.2. Major events in the evolution of life
- 1.3. Novel mechanisms in the genomic landscape

Research Theme 2: Biodiversity inventory

- 2.1. Taxonomy and its tools
- 2.2. How reproductive strategies shape adaptability
- 2.3. Biodiversity patterns and processes across multiple scales

Research Theme 3: Ecosystems dynamics

- 3.1. Recent processes affecting species communities
- 3.2. Palaeo-environmental changes and bio-events during the Palaeozoic
- 3.3. Meso-Cenozoic biostratigraphy and ecosystem evolution

FLAGSHIP 2: HUMANS AND NATURE **Research Theme 4: Past interactions between humans and nature**

- 4.1. Anthropology: biological and cultural evolution of human populations
- 4.2. Subsistence, health and social organisation of (pre-) historic human populations
- 4.3. Environmental impacts of climate and humans
- 4.4. Raw material characterisation and sourcing of archaeological and historical artefacts

Research Theme 5: Blue growth and marine management

- 5.1. Innovative approaches in oceanography
- 5.2. Marine pollution research
- 5.3. Multi-scale marine ecosystem mapping
- 5.4. Evidence-based marine management and policy

Research Theme 6: Biodiversity and natural resources policy support

- 6.1. Improving the Science-Policy interface in biodiversity studies
- 6.2. Conservation and sustainable management of biodiversity in the global South
- 6.3. Geology in an economic context, addressing societal challenges

FLAGSHIP 3: NATURE, OUR FUTURE **Research Theme 7: Sustainable use of geo-resources**

- 7.1. Origins of strategic raw material deposits
- 7.2. Sustainable use of marine raw materials
- 7.3. Geo-energy: from down-to-Earth assessments to complex interactions
- 7.4. From fieldwork mapping to digital geological models

Research Theme 8: Predictions and forecasting

- 8.1. Marine forecasting
- 8.2. Multiproxy investigations of natural hazards in aquatic environments
- 8.3. Predicting recent and regional impacts of climate change in marine and freshwater habitats
- 8.4. Human-induced hazards linked to geo-resources exploitation

Research Theme 9: Biological migrations and invasions

- 9.1. Biology of invasive alien species
- 9.2. Disease vectors and epidemiology of zoonotic infections
- 9.3. Bird migrations

ICONS

Each of the Research Themes is introduced with an infographic that shows the key collections, physical infrastructure, analytical techniques and Operational Directorates within the Institute that are most

relevant to its activities. We also see the total number of scientific staff working on this theme, expressed as full-time equivalent (FTE).

COLLECTIONS



Physical Geological



Physical Fossils



Physical Biological



Physical Archaeological / Anthropology



Database

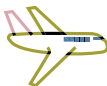


Molecular

PHYSICAL INFRASTRUCTURES



RV Belgica



Surveillance aircraft



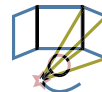
Molecular Lab



Microscopes



Electronic Scanning Microscope



Micro-CT scanner



Chemistry Lab



Remote Sensing Platforms



Geological Laboratory

ANALYTICAL TECHNIQUES



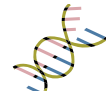
Remote Sensing



IT Processors



Modelling



Classical Sequencing



Next-Generation Sequencing



Morphological Analysis



Water Chemistry Analysis



Chemical Analysis

OPERATIONAL DIRECTORATES



Operational Directorate Earth and History of Life



Operational Directorate Natural Environment



Operational Directorate Taxonomy and Phylogeny

FTE





OVERVIEW

RESEARCH THEME 1: EVOLUTION, THE DRIVING FORCE OF LIFE

- 1.1. Adaptive radiations
- 1.2. Major events in the evolution of life
- 1.3. Novel mechanisms in the genomic landscape

RESEARCH THEME 2: BIODIVERSITY INVENTORY

- 2.1. Taxonomy and its tools
- 2.2. How reproductive strategies shape adaptability
- 2.3. Biodiversity patterns and processes across multiple scales

RESEARCH THEME 3: ECOSYSTEMS DYNAMICS

- 3.1. Recent processes affecting species communities
- 3.2. Palaeo-environmental changes and bio-events during the Palaeozoic
- 3.3. Meso-Cenozoic biostratigraphy and ecosystem evolution

FLAGSHIP 1: NATURE DISCOVERY

The diversity in the living world around us is astonishing. Plants and animals abound in a seemingly endless array of shapes, sizes, colours and behaviour. This diversity is underpinned by a genetic variability so vast that we are only just beginning to scratch the surface.

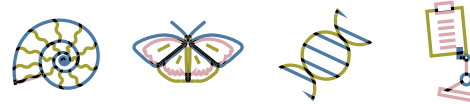
The RBINS catalogues the diversity of life in rich and vulnerable ecosystems and preserves it in collections and databases (RT 2). In so doing, the Institute investigates the evolutionary mechanisms that have given rise to the patterns of diversity and distribution we see in nature in the past and in the present (RT 1). Historically, the RBINS has greatly invested in expeditions, surveys and monitoring programmes to catalogue and inventory biodiversity across our planet, and continues to do so (RT 2). Special attention is given to the way organic and inorganic components interact and drive each other's diversity at ecosystem level (RT 3). A better knowledge of genes, species and ecosystems is necessary to protect life on Earth in all its diversity.

RESEARCH THEME 1: EVOLUTION, THE DRIVING FORCE OF LIFE

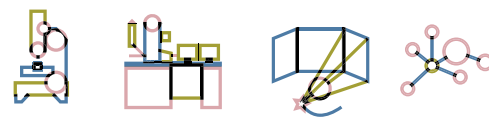
WHAT Study of the processes of evolution

WHY Evolution shapes the diversity in the world around us and affects everybody's daily life

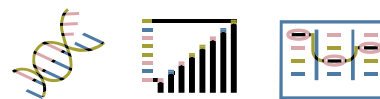
ICONS COLLECTIONS



PHYSICAL INFRASTRUCTURES



ANALYTICAL TECHNIQUES



OPERATIONAL DIRECTORATES



WORKFORCE 7.50 FTE (1.1: 2.50; 1.2: 3.00; 1.3: 2.00)



Evolutionary processes have driven the diversity of life over different time scales: from a few generations to billions of years. However, while evolution produces biodiversity, that very same biodiversity also provides the basic material on which evolution works and continues to work. Thus, biodiversity and evolution are two sides of the same coin. If we want to understand how evolution works, we need a sound knowledge of past and present biodiversity. In this Research Theme, the Institute investigates the evolutionary processes that have shaped biodiversity at various levels, including genes, species and ecosystems, in the past as well as in the present.

Research subjects

1.1. Adaptive radiations

Speciation, the process during which new species are formed, has been of interest to biologists ever since the publication of Darwin's "Origin of Species". The most interesting models to study such processes are endemic species flocks, i.e. groups of species all descending from a common ancestor, typically found in isolated systems such as islands, ancient lakes and groundwater. Such species are mostly still living in the cradle in which they originated. These systems are thus natural laboratories for speciation research.

1.2. Major events in the evolution of life

Organisms are forced to deal with important alterations in their environments. Populations and species respond to such challenges through adaptations: physiological, structural or behavioural. Signatures of adaptive processes are visible in the fossil record up to about 3.5 billion years ago. Under this research subject, the Institute studies the adaptations to major environmental changes in the past, with a particular focus on the origin and rise of major vertebrate lineages.

1.3. Novel mechanisms in the genomic landscape

Several genetic and genomic processes are known to be directly related to phenotypic diversity: the variations in the way these genotypes manifest themselves. Mutations, recombination and natural selection are amongst those thought to be the main drivers of evolution in metazoan (multicellular) organisms. Recently, however, several other mechanisms have been described that may also underlie phenotypic changes, such as interspecific gene transfer, the expression of cryptic genetic variation, transposable elements, endosymbiotic bacteria and epigenetic mechanisms. At the RBINS, non-model organisms like beetles, molluscs and ostracods are the main targets of this research.



A case in point

Feathered dinosaurs and early birds

The recent discovery of exquisitely-preserved fossils of feathered dinosaurs support a hypothesis that birds evolved from small carnivorous dinosaurs during the Jurassic. This was also confirmed by looking at ancient museum fossils with new methods such as micro-CT scanning, and from different evolutionary perspectives. The RBINS' palaeontologists have described a series of new feathered dinosaurs and fossil birds from China and Russia that shed light on a long series of evolutionary changes: smaller size, lighter skeletons and changes in limb proportions and feather complexity. All these evolutionary innovations contributed to the origin of birds.

A case in point

Galapagos and other biodiversity hotspots

The RBINS has a long-standing tradition of work on particular hotspots of biodiversity. The Institute investigates how species are formed in a variety of island-like habitats, such as the Galapagos (beetles and spiders) and the Azores (terrestrial snails). This is also done in so-called ancient lakes such as Lake Baikal in Siberia (ostracods and cottoid fish) and the East African Lakes Tanganyika and Malawi (ostracods and cichlid fish). Such habitats are natural laboratories for evolutionary studies as the very rich species flocks are still living in the cradle where they originated.



Key factors shaping this Research Theme

Evolution pervades the research of all institutes of natural sciences, and is among the oldest topics still central to the RBINS' strategy. Across the three Research Subjects within this Theme, success is particularly dependent on the RBINS' specialisations, as well as a growing number of partnerships. This is one of the Research Themes in which our collections play a particularly key role: the general zoological and entomological collections for research subject 1.1, the fossil collections for 1.2 and the relatively recent molecular collections for both 1.1 and 1.3.

Evolution is a common concern to the RBINS and the Royal Museum for Central Africa. It is also a key concept in science that opens fruitful partnerships with the universities. At the Belgian level, the upcoming FED-tWIN programme will provide a great deal of support. At the EU level, the challenge is to reach the requested level of excellence for fundamental

research, to obtain European Research Council grants, for example. But it is worth stressing that high level research can be achieved thanks to excellent permanent researchers funded by the RBINS, and fieldwork funded by organisations such as the Leakey Foundation or the National Geographic Society. Maintaining high level staff capacity needs therefore particular attention.

The RBINS has a reputation for excellence in this field, with many papers published in high ranked journals like Nature and Science, also thanks to a wide cooperation with international partnerships.

By 2022, the Institute aims to maintain its position at the forefront of research within its specialised subject areas, continuing to broaden its sources of funding where possible through strategic partnerships such as those mentioned.

RESEARCH THEME 2: BIODIVERSITY INVENTORY

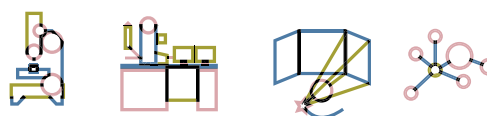
WHAT Study of the patterns of evolution

WHY What we do not know, we cannot protect, manage or use

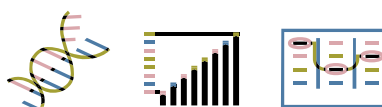
ICONS COLLECTION



PHYSICAL INFRASTRUCTURE



ANALYTICAL TECHNIQUES



OPERATIONAL DIRECTORATES



WORKFORCE 9.83 FTE (2.1: 5.33; 2.2: 1.00; 2.3: 3.50)



Biodiversity comprises the variety of life in all of its forms from the past to the present. It includes all species of animals and plants, the genetic diversity among them and their complex ecosystems. Under this Research Theme, the Institute's teams study a number of inherent features of organisms' phenotypes – the way in which we see their genotypes manifest themselves. Their morphology, the way they communicate and their means of reproduction all determine their evolutionary identity. More specifically, we highlight tools with which to study these features in order to characterise and identify

organisms and their relationships. Taxonomy is a strength of all institutions of natural history as an essential tool to communicate about the living world – it is the common language in all biological disciplines. This research deals with faunas from around the planet, but biodiversity studies in polar regions receive particular attention.

Research subjects

2.1. Taxonomy and its tools

Taxonomy is a fundamental discipline that underpins most research domains and human activities that deal with the living world. It does so in two ways. The first is by describing phenotypic variation of organisms – this provides the basic questions and data to study evolution and organism-environment interactions. The second is by inventorying and classifying variation at organism level. As such, taxonomy is not only essential for evolutionary research, but it also delivers knowledge that supports an overwhelming array of human activities. A range of methodologies are used to extract taxonomically relevant data including classical morphological and anatomical work, as well as DNA sequencing, scanning electron microscopy and micro-CT scanning. 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 ancient museum specimens ("museomics").

2.2. How reproductive strategies shape adaptability

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 reproduction, hermaphroditism, brooding, hybridisation, the caste systems of social insects and many more. These reproductive strategies strongly influence how species have originated and how they adapt to future changes. In short, these inherent biological characteristics contribute to the identity of the species. As such, they also contribute to the basis of concepts like the biological or sexual species and the agamospecies (a group of asexually-reproducing lineages, which are considered as equivalent to a species).

2.3. Biodiversity patterns and processes across multiple scales

Documenting and measuring biodiversity is a core mission of natural history museums. The RBINS conducts biotic surveys and impact assessment studies in terrestrial, freshwater and marine realms. These surveys cover multiple scales: from small ponds and pools to large river basins, deep lakes, tropical rainforests, high mountains or sea beds. They generate large quantities of material for further taxonomic, ecological or phylogenetic work, allowing a better understanding of how biodiversity is distributed in space and time.

A case in point are the polar regions, which are among the most fragile ecosystems on Earth, given their extreme environments and the special adaptations of organisms there. They are also under constantly increasing pressure from human activities and global warming. These regions can thus serve as models to assess the effects of climate change for the entire planet, because of the polar amplification of global trends.



A case in point Reproductive systems

The way an organism reproduces can have profound evolutionary implications. Many, such as ostracods, reproduce asexually. But obligate asexuals are thought to be prone to early extinction because they accumulate harmful mutations and evolve too slow to adapt to rapidly-changing environments. How then, can some groups, such as darwinulid ostracods, have survived millions of years without sex? Hermaphrodites, like terrestrial snails, can either self-fertilise or can be outcrossed with other individuals. This can lead to sexual conflicts, sperm competition, exuberant genital phenotypes and ultimately to rapid speciation: the formation of new species.

A case in point African small mammals

Species tend to retain their ancestral traits, and this concept is known as phylogenetic niche conservatism. The RBINS has undertaken a series of phylogeographic studies that investigate the evolutionary histories of Afrotropical mammals in relation with the paleoclimate and tectonic history of sub-Saharan African habitats. This work relies on RBINS' expertise in molecular phylogenetic research and the taxonomy of African mammals, in particular rodents.



Key factors shaping this Research Theme

A great strength of the Institute under this particularly broad research theme is its deep knowledge of taxonomy, a competence that is becoming rare outside of natural history museums, which brings a highly recognised capacity to identify species and other taxa. Another strength of the RBINS is its interdisciplinarity. Research topics such as survival, reproduction and biodiversity patterns clearly span a range of fields and require a critical mass of human competences to carry it, with a sufficient combination of skills in place. This also requires cooperation between Operational Directorates within the Institute.

A third particular strength of the Institute in this domain is its strong investment in DNA techniques put at the service of taxonomy and the study of collections. Classical DNA sequencing is used to study phylogenies of selected taxa. The RBINS also implements next generation sequencing and DNA barcoding through the Joint Experimental Molecular Unit (JEMU), which the RBINS manages with the Royal Museum for Central Africa, among others. Expertise in next-generation sequencing technologies is crucial here, for example in order to relate the formation of species with regions in the genome.

The BopCo project, supported by Belspo, aims at supplying identifications of organisms of policy concern and their derived products. It is bringing together a growing number of teams and experts across relevant animal groups, that deliver an increasing range of services to private companies and public services. BopCo's relevance and further funding will be assessed in 2020. BopCo is part of the European LifeWatch infrastructure, contributing to a virtual European infrastructure for biodiversity research.

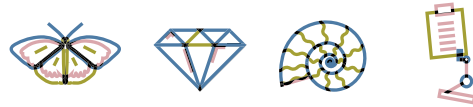
Success within this research theme should ensure that cooperation among the directorates continues to develop, that the Institute further leverages its DNA-related expertise and technologies, and that the assessment of BopCo confirms its relevance, positioning the RBINS as a European key player on applied taxonomy.

RESEARCH THEME 3: ECOSYSTEMS DYNAMICS

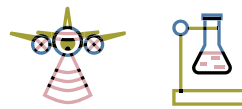
WHAT Studying how the living and the non-living interact in ecosystems

WHY Ecosystem management must be underpinned by research

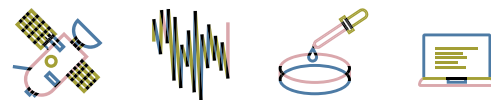
ICONS COLLECTIONS



PHYSICAL INFRASTRUCTURES



ANALYTICAL TECHNIQUES



OPERATIONAL DIRECTORATES



WORKFORCE

6.50 FTE (3.1: 2.17; 3.2: 1.33; 3.3: 3.00)



How ecosystems function, both on land and in water, is influenced by the way living and non-living things interact. In this Research Theme, the Institute aims to study this interaction in past and present settings. Understanding these processes allows more targeted research on ecosystem health and the provision of ecosystem goods and services. It helps to identify potential threats to ecosystem health, such as invasive species, extinctions, habitat loss, connectivity, eutrophication and algal blooms. It also supports adequate protection and sustainable management of the natural world. Using fossil evidence from

the deep past, we can learn how natural changes in the climate caused biotic events, where there were significant modifications in the plant and animal life of a region.

Research subjects

3.1. Recent processes affecting species communities

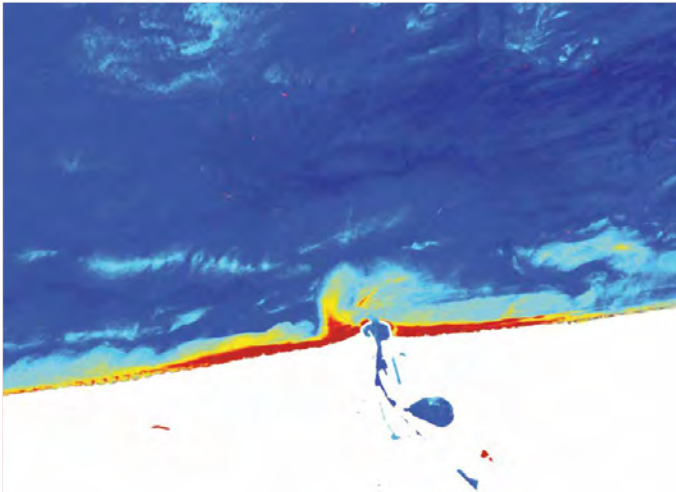
Humans' ecological footprint has an overwhelming impact on species communities. Human activity alters the temperature and nutrient load of the environment, for example. We affect species interactions by introducing alien species and depleting vulnerable populations. Humankind also has an effect on spatial processes: fragmentation and habitat turnover rates. A growing number of studies indicate that environmental change can result in rapid evolutionary change. These mutual impacts on ecological dynamics are known as eco-evo dynamics. The RBINS hosts several databases resulting from sampling schemes and long-term data series on large spatial scales: nationwide and even continental. This has allowed the RBINS' research to generate important insights into how major human impacts, like agricultural intensification, urbanisation and deforestation, alter species communities by filtering particular traits at both community and species level.

3.2. Palaeo-environmental changes and bio-events during the Palaeozoic

This research focuses on the complex interactions between biodiversity and the environment throughout the Mid and Late Palaeozoic interval, around 400 to 250 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 research subject aims at reconstructing biodiversity and sedimentary dynamics to clarify many fundamental questions related to mass extinctions – what caused them, what followed them, and how did ecosystems recover? It also gives insight into climate changes, evolutionary patterns and other decisive questions on the history of life on Earth.

3.3. Meso-Cenozoic biostratigraphy and ecosystem evolution

This specific Research Subject works to reconstruct the evolution of abiotic and biotic environments in selected sedimentary basins during the Mesozoic and the Cenozoic, between 145 and 23 million years ago. By monitoring the evolutionary changes of micro- and nanofossils, researchers can recognise the standard biozonations or develop new, more refined biostratigraphic frameworks, which can be tied to the standard magneto-biochronologic time scale. These temporal frameworks are crucial for unravelling the temporal stacking of depositional sequences, which, together with magnetic susceptibility data, enables reconstruction of the eustatic sea levels and the tectonic history of basins. Special attention is also given to the palaeo-environmental evolution of important fossil localities through the investigation of lithofacies (bodies of rock characterised by lithologic features such as grain size), microfacies (characterised by aspects visible under the microscope), palynofacies (groups of organic microfossils, mostly fossilised pollen, in a local portion of sediment) and stable isotopes, in association with taphonomic reconstructions (relating to the conditions affecting fossilisation) and descriptions of fossils.



A case in point Remote sensing

The RBINS invests in coastal observatories to build up sets of continuous, long-term data bases about ecosystem processes: 1800 days of measurements from 2005 to 2015, for example. Combining this with the Institute’s remote sensing data and ecosystem models means these processes can be studied with unprecedented spatial and temporal resolution, including the exchange of fluxes between land and sea.

A case in point Farm ponds

Another example of the RBINS’ analyses on ecosystem functioning is in small farm ponds. The Institute looks at the effects of local and regional factors on these ecosystems and has established that biodiversity in such small aquatic habitats is very volatile and can change rapidly from year to year. It has also been found that these are landscape types that are among the most easily and readily managed to maintain high levels of regional biodiversity.



Key factors shaping this Research Theme

This Research Theme is another that is particularly interdisciplinary. Indeed, research on ecosystems functioning in the far past is deeply rooted into the rich RBINS collections. The factors affecting extant ecosystems are biological, geological, chemical and so on. Therefore, only a truly multidisciplinary institute like the RBINS can address them fully. Again, this theme lends itself particularly well to inter-OD collaboration.

The deep knowledge on subjects such as the Palaeozoic environment also represents a particular strength of the Institute. It is such a notable specialisation of the RBINS that in fact it is not easy to find partnerships on this topic at national level. Regarding the Meso-Cenozoic, one key university partnership is with the KU Leuven. Both the Palaeozoic and Meso-Cenozoic are fields of largely fundamental research that is not always easy to finance through external

partners, and without at least one permanent scientist it is a challenge to be able to continue these research subjects. FED-tWIN could also bring new opportunities in that direction.

One area in which partnerships can be developed is in innovating tools for research. A platform is currently under development with external partners to improve isotope analyses on fossils. The Institute has a wealth of Palaeozoic samples and collections on which to apply such analyses.

Looking to the year 2022, the Institute should continue to deepen its unique specialisations and strengthen relationships, particularly with partners that have the technologies to make the most of this expertise and can also support the RBINS in securing project funding.

OVERVIEW

RESEARCH THEME 4: PAST INTERACTIONS BETWEEN HUMANS AND NATURE

- 4.1. Anthropology: biological and cultural evolution of human populations
- 4.2. Subsistence, health and social organisation of (pre-) historic human populations
- 4.3. Environmental impacts of climate and humans
- 4.4. Raw material characterisation and sourcing of archaeological and historical artefacts


RESEARCH THEME 5: BLUE GROWTH AND MARINE MANAGEMENT

- 5.1. Innovative approaches in oceanography
- 5.2. Marine pollution research
- 5.3. Multi-scale marine ecosystem mapping
- 5.4. Evidence-based marine management and policy

RESEARCH THEME 6: BIODIVERSITY AND NATURAL RESOURCES POLICY SUPPORT

- 6.1. Improving the Science-Policy interface in biodiversity studies
- 6.2. Conservation and sustainable management of biodiversity in the global South
- 6.3. Geology in an economic context, addressing societal challenges

FLAGSHIP 2: HUMANS AND NATURE

The background of the page is a photograph of two offshore wind turbines in a misty sea. The turbines are dark silhouettes against a grey, overcast sky. The water is calm, reflecting the turbines and the sky. The overall mood is serene and somewhat somber.

As humans, we typically see ourselves as separate from nature; perhaps above it, but rarely as part of it. And yet that is exactly what we are. We are the result of the same evolutionary processes that have shaped all the animals, plants and microbes around and inside of us. We have survived because natural and sexual selection have moulded and pruned our ancestors to what we are now: the species *Homo sapiens*. We are not distinct from nature and we are certainly not above it, although it is also true that no other animal species has had such a profound impact on the rest of nature as we have had and continue to have, for better or for worse.

in the Research Themes grouped under this flagship, the Institute investigates “Past interactions between Humans and Nature” (RT 4), as well as the biological and cultural evolution of humans within a changing environment. In “Blue Growth and Marine management” (RT 5), a large interdisciplinary research group studies various aspects of marine ecosystem management, mostly but not exclusively, in the North Sea. And in RT 6, “Biodiversity and natural resources policy support”, various teams (mostly project-based) deal with research on Science-Policy interfaces regarding biological and geological resources.

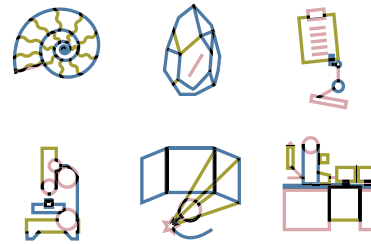
RESEARCH THEME 4: PAST INTERACTIONS BETWEEN HUMANS AND NATURE

WHAT Humankind has always influenced nature and vice-versa

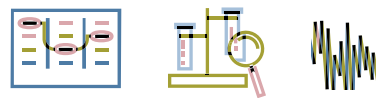
WHY Only by understanding the past interactions between humans and nature can we influence our future interactions

ICONS COLLECTIONS

PHYSICAL INFRASTRUCTURES



ANALYTICAL TECHNIQUES



OPERATIONAL DIRECTORATES



WORKFORCE 7.67 FTE (4.1: 1.67; 4.2: 2.17; 4.3: 1.83; 4.4: 2.00)



Humankind is part of nature and the biological and cultural evolution of our species have always been strongly influenced by the natural environment around us. However, the relationships between humans and their environment have changed dramatically from the early periods of human settlement on Earth to the present day. They have also varied from place to place at any given period. Over the last millennia, humankind gradually started to increase its own influence on nature, first by controlling animal and plant populations and later by domesticating several species. The impacts of human actions on biophysical systems – particularly the global

biodiversity and climate on Earth – have recently become so broad and deep that many observers now speak of human-dominated ecosystems and argue that we have entered a new planetary era, labelled as the “Anthropocene”.

Research subjects

4.1. Anthropology: biological and cultural evolution of human populations

Anthropology is the study of various aspects of humans within past and present societies. At the RBINS we focus on physical and evolutionary anthropology and prehistoric archaeology. Belgium has a central place in research on the history of paleo-anthropology and the acceptance of human evolution by the scientific community: the RBINS' human fossils collection, with Neanderthals from Belgium and Anatomically Modern Humans from Belgium and Africa, plays a key role in recent international studies about the origin of modern humans in Europe and Africa. The re-study of old collections and the exceptional preservation of DNA and proteins offer great potential for genetic and isotopic studies. The RBINS also has the largest Belgian collection of modern human remains and of prehistoric archaeology from the Institute's excavations over more than a century. These collections are the basis of numerous scientific studies, both as subject or as reference material.

4.2. Subsistence, health and social organisation of (pre-) historic human populations

Reconstructing the subsistence, health, demography and life style of past human societies requires the integration of data and information from various disciplines. Subsistence studies are particularly important because they reflect the social organisation and cultural context of a population, and its interactions with its environment. The health of past populations can be studied through macroscopical analyses of human skeletal remains, including bone and tooth pathologies and reconstructing dietary behaviour of past societies. Funerary practices are also particularly important for evaluating the socio-cultural context of past societies. Humans' shift from a semi-nomadic, hunter-gatherer existence towards sedentary agricultural societies has had a profound effect on the evolution of our species and is closely intertwined with the progressive domestication of animal and plant species around us.

4.3. Environmental impacts of climate and humans

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. The impact of Neolithic, Bronze Age, Iron Age, Roman Age and Medieval farming and economy on the animal and plant environment and the interaction with climate is studied using independent palaeo-climatic proxies from speleothems (stalagmites, stalactites and so on). This is combined with a wide range of bioarchaeological and other proxies. Geoarchaeological and bioarchaeological analyses allow the researchers at the Institute to document processes such as deforestation, resulting in erosion, overgrazing, overhunting, overfishing, extinctions, invasions and pollution. This adds a historic dimension to biodiversity studies and allows more precise reference conditions to be defined that are of relevance to policy makers dealing with conservation issues.

4.4. Raw material characterisation and sourcing of archaeological and historical artefacts

The RBINS' geologists and archaeologists work together to unravel the geological, natural and geographical provenance of materials that were used by humans since the Palaeolithic up to present times. These include derived products like architectural ceramics, alloys, metal and glass as well as lithic materials like tools, pigments, building and ornamental stones, which can reveal commercial networks and represent excellent markers for reconstructing transport routes and inferring cultural exchange paths. It is also possible to recount the functional and cultural biography of stone objects and of their re-use in different functions and places. Archaeologists provide geologists with the exact chronological context and add socio-cultural dimensions.



A case in point Domesticating animals

One of the most interesting stories in the history of our species is that of the domestication of animals and plants. The RBINS has a rich tradition in the study of the interactions between humans and various kinds of domesticated animals, recently focusing on the domestication of dogs, our “best friend”!

A case in point Neanderthals

One particular focus of the RBINS' work is the study of the transition between Neanderthals and Anatomically Modern Humans (AMH) in Europe. Skeletons of the last European Neanderthals (discovered in Spy and Goyet in Belgium) and the first AMH (from Goyet) are hosted in the RBINS' collections. These specimens are under study with direct radiocarbon dating of the fossils as well as full genome sequencing coverage, in collaboration with partners, owing to the excellent preservation of the material. As such, the RBINS is uniquely placed in Belgium to study biological human evolution.



Key factors shaping this Research Theme

With this Research Theme the RBINS holds a unique positioning: it brings a broad set of disciplines from the natural sciences to research questions that are usually seen from the point of view of the humanities, using other tools and techniques. This wide range of fields, from anthropology to mineralogy, again underlines the multidisciplinary nature of the Institute's work. It raises both opportunities and challenges in terms of human resources and funding, partnerships, publications, organisational structure and policy support.

The present Research Theme is dependent on the work of a core of statutory scientists divided over several archaeological and geological research teams who have declined somewhat in number, and retention of staff is a key challenge. Much of the funding comes from regional sources - which in itself is recognition that the Institute excels in these fields, since the RBINS is a federal Institute, whereas the excavations are mostly coordinated at the regional level.

Partnerships are crucial, not only for funding but also for expertise. In terms of the work on maintaining and enlarging the collections under these topics, the Botanic Garden in Meise is a key partner with their large botanical collections. The Institute is also part of the European Research Network BIOARCH where there is the potential to seek common funding and further cooperation. University partnerships are key, such as KU Leuven's Centre for Archaeological Sciences and the VU Brussels, who have a laboratory for the analysis of archaeological remains. The Institute also works in close collaboration with the Royal Institute for Cultural Heritage on human remains, isotopic studies and carbon dating. Stronger partnerships with other federal institutions (such as the Royal Museums for Art and History) or with universities (through FED-tWIN, for example) could be a future strategy, but as most collaborations are international, the challenge is to better explore international funding opportunities linked to culture.

International partnerships have also led to joint publications in journals like Nature and Science. In fact, one significant shift across these topics has been a reduction in the number of publications, due to fewer researchers, but an increase in the quality of publications, reflected in the higher impact factor of the journals in which they are published.

To further improve the quality of research, further cooperation could take place between the directorates of the Institute itself. Ancient DNA is a good example, that can be analysed in the in-house DNA lab, a key asset to be further exploited. Other opportunities for greater internal cooperation include the effect of humans on the environment in terms of erosion, overfishing and overhunting.

Supporting services are also relevant to this Research Theme. The RBINS brings a huge competence in managing reference collections, a key point for these topics and recognised by the Regions. The challenge then is certainly to maintain this expertise and knowledge, unique in Belgium. Policy support could be developed further; for example, when plans are made for nature conservation, existing reports on previous explorations are studied, but historic documents are not always complete – the Institute can often fill in the gaps to show where a species like the carp or European catfish appeared for the first time.

The strategic vision within this Research Theme is therefore to collaborate more closely both with international partners and within the directorates of the Institute itself. Policy support is a key area that can be further developed within the five years of the strategy, as detailed further in Research Theme 6.

RESEARCH THEME 5: BLUE GROWTH AND MARINE MANAGEMENT

WHAT Ensuring a long-term strategy for sustainable exploitation and growth in marine and maritime sectors

WHY Seas and oceans hold great potential for economic growth, but these ecosystems remain understudied and pressure on them is increasing

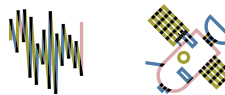
ICONS COLLECTIONS



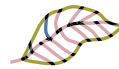
PHYSICAL INFRASTRUCTURES



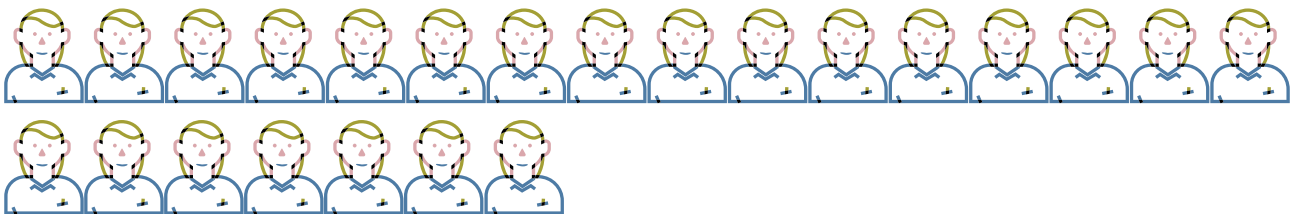
ANALYTICAL TECHNIQUES



OPERATIONAL DIRECTORATES



WORKFORCE 23.00 FTE (5.1: 5.67; 5.2: 3.33; 5.3: 4.5; 5.4: 9.50)



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, aquaculture and even tourism have started playing an ever-increasing role. Gone is the idea that oceans are endless sources of riches for our use – we know now that these environments are stressed and become fragile.

Seas and particularly oceans represent a vast potential for innovation and economic growth, but are greatly understudied. Examples of these challenges include recent renewable energy

initiatives such as wind farms and the potential exploitation of deep-sea mineral resources.

This new evolution is best described by the term Blue Growth: the long-term strategy to support sustainable growth in the marine and maritime sectors. “Sustainable growth” means that technical and industrial development is framed in a sound knowledge of the marine environment and takes the health of the seas and oceans into consideration. Achieving it depends largely on a well-managed trajectory of industrial activities at sea. For that, an adequate scientific knowledge base embedded in legal and regulatory guidance is indispensable.

Research subjects

5.1. Innovative approaches in oceanography

Operational oceanography involves systematic and long-term routine measurements of the seas, oceans and atmosphere. It is a rapidly evolving discipline, requiring ever more complex and accurate mathematical and numerical models. However, the most striking revolution in this field is the current transition from a product-based service paradigm (such as the delivery of a storm surge forecast) to a new service paradigm based on the development and operation of fit-for-purpose interactive decision-support systems. This change of paradigm needs significant R&D efforts in order to integrate state of the art tools and knowledge from disciplines as diverse as maritime pollution modelling, marine chemistry, marine biology, marine ecology, marine ecotoxicity, marine habitat mapping and marine spatial planning, all into one unique decision support system. Autonomous underway measurement systems are used more and more to supply mathematical models with a flood of data, especially on gradients from nearshore to offshore. If one manages to link these to existing high-quality data, then this can offer a further improvement through “external calibration”.

5.2. Marine pollution research

Research on marine pollution comprises a wide range of activities. One subset is the application of various assessment, monitoring and modelling approaches. 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. Lastly, the RBINS performs trend and risk analyses on marine pollution. Recently, more and more emphasis has been placed on the assessment of pollutant pressure instead of on absolute concentrations. Research has revealed that only a fraction of actual pollutants has an effect, or is readily available, while part is tightly bound and not to be liberated under environmental conditions. Researchers use passive samplers to estimate the freely dissolved fraction, which is in direct relation to the degree of exposure of organisms.

5.3. Multi-scale marine ecosystem mapping

Underwater acoustic mapping is powerful as it allows direct imaging of biodiversity hotspots. Using this information, environment-animal relationships can be hypothesised and tested through multi-scale modelling.

Light is also an essential component of habitat, determining which plant and animal life may develop. The underwater light field is itself affected by phytoplankton, mineral or detrital particles and by the sea bottom. The optical impact of these particles can be seen from space. It is therefore possible to measure phytoplankton, submerged and floating vegetation and suspended sediments in the world's oceans, seas and lakes by satellite remote sensing.

Lastly, recent increases in underwater noise pollution are affecting marine life. In the North Sea, many marine mammals use sound to communicate, navigate and feed. The Institute monitors the increasing levels of noise from human activities that affect them such as shipping, offshore construction, oil and gas exploration and sonar.

5.4. Evidence-based marine management and policy

Human and global impacts increasingly pose a double 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 towards integrated assessment of the North Sea. 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 comprises aquatic ecosystem studies. 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 transport model 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.



A case in point Wind farms

Offshore wind farms are implemented more and more by governments to ensure they reach their legal quota of renewable energy. The RBINS studies the potential environmental impacts of such developments. What are their effects on bird migration? What are the consequences of sediment plumes in the water column, generated by wind turbines?

A case in point RV Belgica

The Institute is proud to manage the Belgian oceanographic research ship: the Research Vessel A962 Belgica, or RV Belgica. The Belgian Navy provides the crew, operational support and a mooring in the home port of Zeebrugge. The RV Belgica is a floating laboratory, and a key research infrastructure: it is out at sea for up to two hundred days a year to collect data. Scientists take samples of water, soil and living organisms. They test new fishing techniques, investigate the influence of sand extraction on the sea bed and study the effect of wind farms on sea life. The Belgica is therefore important in monitoring the quality of the North Sea waters and ecosystems, improving management of the North Sea as well as supporting fundamental research in neighbouring seas and oceans.



Key factors shaping this Research Theme

The Management Unit of the North Sea Mathematical Models (MUMM) is a scientific service of the RBINS and a key player in Belgium in blue growth and marine management. This makes the Institute unique in a role that is usually reserved for designated marine research institutes. In remote sensing, the RBINS is a world leader and it has an extensive global user community of its models with which no other coastal area can compete. It supports large research groups at a European scale, as well as various research projects at national and regional level, as well as marine management. In terms of policy support, the scope is also broad. The Institute's work has influenced international policy where some Belgian statements resulting from RBINS/MUMM research have been incorporated into European law related to marine management.

In the field of blue growth and marine management, research is closely intertwined with service activities of various kinds, including high-profile positions at international level: coordinating the implementation of the EU Marine Strategy Framework Directive in Belgian waters, for example. Most of these service activities are largely secured. Today the challenge is to secure the related research activities. Applied research supporting federal competences falls under the scope of the federal BRAIN-be programme; fundamental research may be strengthened by FED-tWIN and by international calls.

The coming years will also see the RV Belgica replaced with a new research vessel able to travel further and for longer periods of time. The present ship is 30 years old, and ready to be decommissioned. At the end of 2017, the federal government of Belgium decided to build a new ship that should be ready to be deployed from the end of 2020. This is of great strategic importance for all marine work in the RBINS as well as for all Belgian marine scientists. The Atlantic Ocean will then represent a new frontier for the RBINS' oceanographic research, supporting the future sustainable management of resources from the deep sea.

RESEARCH THEME 6: BIODIVERSITY AND NATURAL RESOURCES POLICY SUPPORT

WHAT Providing and improving advice to policy makers on management of biodiversity and other natural resources

WHY Policy decisions must be scientifically underpinned

ICONS
COLLECTIONS



OPERATIONAL DIRECTORATES



WORKFORCE 10.83 FTE (6.1: 5.83; 6.2: 2.83; 6.3: 2.17)



One of the RBINS' main functions is to support policy development and implementation. It supplies credible expert advice to policy makers and communicates relevant outcomes of scientific research and monitoring activities. The Institute also informs scientists of research-relevant policy measures such as the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilisation (ABS) to the Convention on Biological Diversity (CBD) and the work of the European Commission's DG Energy via the GeoEnergy Expert Group. Improving and consolidating the quality for this function needs primary research on the effect and efficiency of policy support. How much of the information that scientists provide is effectively translated into policy? To what extent does current scientific research meet the needs of policy makers? And how do other stakeholders perceive the science-policy interface? All these questions will be addressed in collaboration with external partners.

Research subjects:

6.1. Improving the Science-Policy interface in biodiversity studies

A recent internal survey revealed that the RBINS holds extensive empirical knowledge on Science-Policy interface (SPI) functioning and that SPI activities are critical to ensure the relevance and long-term sustainability of the Institute and its research. Nevertheless, the Institute's effectiveness as an SPI needs strengthening by building a solid academic knowledge base. While RBINS scientists have published relevant research on SPI, further developing the SPI as a relevant research subject within RBINS is in order, especially considering that the official policy-related mandates of the RBINS offer unique opportunities for such research.

6.2. Conservation and sustainable management of biodiversity in the global South

The RBINS is an important player in capacity development for biodiversity in the global South, especially in Africa and Vietnam, in terms of policies, conservation, science communication and awareness raising, Clearing House Mechanism activities and monitoring. Its scientific expertise is a prerequisite for credibility at a national and international level. The Institute's work links biodiversity to stakeholder practice and policies, bridging the gap between science and the practice of conservation. Applied research is needed on capacity development methods, stakeholder engagement, perception of riparian human populations on biodiversity and its conservation. The fate of ever-dwindling populations of large vertebrates will be a point of attention, as it is, at least in public perception, the ecological and cultural foundation of biodiversity conservation, restoration and promotion.

6.3. Geology in an economic context, addressing societal challenges

Geological economics addresses climate, energy, and natural resource challenges in an uncertain world. There is a growing awareness that resources such as raw materials are limited, and that economies should increasingly become circular. At the same time, natural and human-related subsurface processes can induce hazards such as earthquakes, ground subsidence, groundwater pollution and flooding. Raw materials, geo-energy and geo-hazards are placed in a wider context to investigate the societal transition towards sustainable use of the subsurface, and its impact on society and environment is assessed. Dealing with the fundamental uncertainties surrounding these elements, both for scientists and policy makers, requires an integrated geological economic approach to reliably model the processes. Only in this way can science provide managers with the necessary background on which to base decisions. This is a prime prerogative to improve the interface between science and policy on geological economy.



A case in point

Capacity building under CEBioS

As Belgian National Focal Point for the Convention on Biological Diversity, the RBINS is centrally placed to bring together key biodiversity actors. The CEBioS programme, funded by the Belgian Development Cooperation, carries out capacity building, that gives the basis for cooperation on research projects, empowering the Institute's partners in the global South to carry out crucial research in the field of biodiversity conservation and sustainable management linked to poverty eradication.

A case in point

Zero-waste extraction

Ore or metal-rich mineral deposits commonly host several potential commodities. Only few are typically exploited, and the remainder regarded as a non-profitable residue. The RBINS is now starting to be involved in zero-waste extraction research programmes to valorise secondary and low-grade mineral occurrences.



Key factors shaping this Research Theme

The Institute has significant status in policy support roles, among others through the Belgian National Focal Point for the Convention on Biological Diversity, the Clearing House Mechanism and the Global Taxonomy Initiative. The RBINS also has the Belgian Geological Survey as part of its scientific Operational Directorates. Staff from the Institute represent Belgium in a number of international bodies. As such, the RBINS has a crucial part to play in ensuring politicians' work in these fields is underpinned by sound scientific evidence.

The BIOPOLS group, comprising several, mostly project-driven research teams, performs research on the Science-Policy Interface (SPI) regarding biodiversity studies and management. Several of these policy-driven activities are legally mandated, so that a sustainable continuation must be ensured. A special subset of the Biodiversity SPI relates to conservation and sustainable management of biodiversity in the global South. For historical reasons, most of these activities are conducted in Africa, more notably in the Democratic Republic of Congo. A third research subject deals with sustainable exploitation of geological resources, and concentrates on the collaboration between economists (University of Antwerp) and geologists (the Belgian Geological Survey at RBINS).

The research strategy in this field is shaped by a number of external factors. The UN Sustainable Development Goals for 2030 and the activities of the United Nations Framework Convention on Climate Change both feed into the RBINS' work to maintain its status as a global player. Many of the Institute's international projects in this field have their own strategies to be aligned.

The RBINS' greatest strength in this field is its capacity. Over 10 FTE scientists at the Institute work directly on policy support for natural resources, whereas other institutes typically only have one member of staff devoted to this topic. A challenge for the institute is increasing awareness of its science policy activities within the organisation itself, so as to engage more internal expertise into training and capacity building in the global South.

Greater internal cooperation can also maximise the Institute's capacity to analyse the policy support work related to other Research Themes. Best practices can also be exchanged more regularly – between the Distributed European School of Taxonomy (DEST) and CEBioS on capacity building, for example.

Within the five years of the Research Strategy, a focus on internal awareness and cooperation among operational directorates should ensure that the Institute is able to take full advantage of its national and international standing. By 2022 the RBINS should be establishing new kinds of partnership with universities that have the economic, human and social science expertise to complement our work.



OVERVIEW

RESEARCH THEME 7: SUSTAINABLE USE OF GEO-RESOURCES

- 7.1. Origins of strategic raw material deposits
- 7.2. Sustainable use of marine raw materials
- 7.3. Geo-energy: from down-to-Earth assessments to complex interactions
- 7.4. From fieldwork mapping to digital geological models

RESEARCH THEME 8: PREDICTIONS AND FORECASTING

- 8.1. Marine forecasting
- 8.2. Multiproxy investigations of natural hazards in aquatic environments
- 8.3. Predicting recent and regional impacts of climate change in marine and freshwater habitats
- 8.4. Human-induced hazards linked to geo-resources exploitation

RESEARCH THEME 9: BIOLOGICAL MIGRATIONS AND INVASIONS

- 9.1. Biology of invasive alien species
- 9.2. Disease vectors and epidemiology of zoonotic infections
- 9.3. Bird migrations

FLAGSHIP 3: NATURE, OUR FUTURE



Our present generation is the custodian of Earth for future generations. It is up to us whether we leave a dead and empty world to our descendants, or a living planet, full of biological and geological resources. Global disasters occur naturally as well as due to human activity, but it is what we do to remedy them that will determine what our world will look like in 10, 50 or 100 years. Action is required now! Like all natural history institutes in the world, the RBINS contributes to this by educating the public through its exhibitions and by safeguarding natural history collections, but also by providing fundamental and applied research. Three major Research Themes are encompassed in this flagship: how to promote the sustainable use of geological resources through research (RT 7), how to forecast and predict effects of natural and anthropogenic changes in aquatic environments (RT 8) and how to mitigate the effects of “species on the move” (RT 9).

RESEARCH THEME 7: SUSTAINABLE USE OF GEO-RESOURCES

WHAT

How can we minimise human impact on geological resources?

WHY

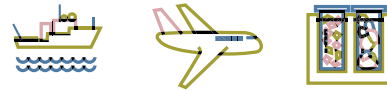
The human ecological footprint has become unsustainable at global level

ICONS

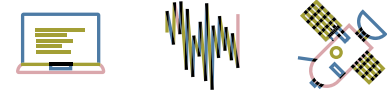
COLLECTIONS



PHYSICAL INFRASTRUCTURES



ANALYTICAL TECHNIQUES



OPERATIONAL DIRECTORATES



WORKFORCE

8.50 FTE (7.1: 2.50; 7.2: 2.33; 7.3: 1.67; 7.4: 2.00)



Humans have always used natural resources. Early on, such use was limited to animals and plants for food, wood for fire and stones for tools. The effects of such resource use will have been hardly noticeable, even at a regional level. However, with ever-rising global human populations and with increased use of resources, the human ecological footprint has become unsustainable. Our need for natural resources continues to grow – in the case of minerals, right across the bulk of the periodic table. Future technological developments rely on a safe supply

chain to exploit these resources. To fulfil the basic needs of current and future generations, our natural resources need to be both safeguarded and used in a sustainable way.

Research subjects

7.1. Origins of strategic raw material deposits

This research subject studies ore deposits comprising strategic raw materials by determining the primary source of these metals, by deciphering the processes leading to the metal concentration, and by characterising the minerals constituting the ore. For example, the Institute studies the potential occurrence of several critical raw materials in Belgium. We also assess the distribution and concentration of phosphorus and rare Earth elements in alkaline complexes in countries such as South Africa and Finland. Other research items include the origin of gold and platinum in the Kaapvaal Craton, South Africa, and the evaluation of cobalt, nickel and copper concentration in Mn-Fe nodules and crusts in deep-sea deposits.

7.2. Sustainable use of marine raw materials

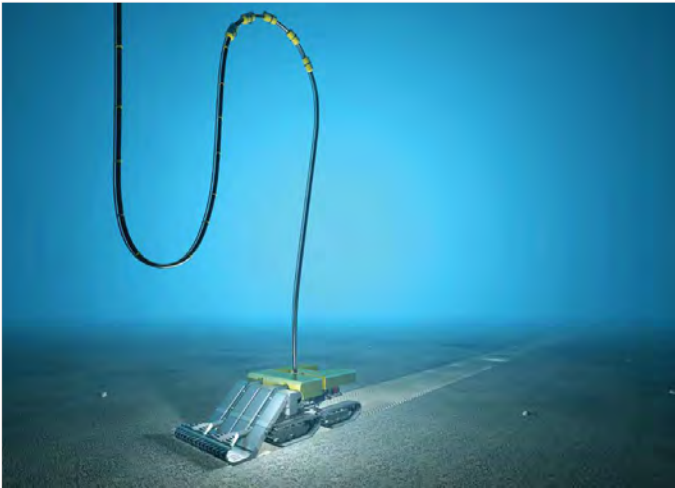
Most raw materials are non-renewable on timescales relevant for decision-makers. The sustainable management of these resources requires a careful balancing of quantity and quality versus environmental controls and impacts and considering changing socio-economic needs. The RBINS has a track record in assessing environmental impacts related to sand and gravel extraction and is expanding its expertise to the mining of deep-sea minerals. The Institute is pioneering the development of a 4D voxel-based resource decision support system that uniquely combines environmental impact models with 3D seabed habitat and geological models in a management and policy context. Scenario analyses of extraction practices can account for realistic seabed conditions, at unprecedented level of detail, and for thresholds regarding allowable habitat change. This is a new era in resource management with ample opportunities to expand research towards geological, environmental and engineering sciences, computer and data science, as well as science-policy interfacing.

7.3. Geo-energy: from down-to-Earth assessments to complex interactions

Subsurface space and its resources are limited and increasing exploitation can lead to conflicts of interest in economic operations in the deep subsurface. The GeoEnergy group of the Belgian Geological Survey was formed to explore the regions of Flanders and Wallonia for subsurface supplies of coal. From the year 2000 onwards, further research topics in the field of geo-energy were added, namely the possibilities of geological storage of CO₂, CO₂-enhanced oil recovery offshore and onshore, and shale gas. In the challenge of energy security and sustainability, geothermal energy is considered a highly relevant option, because it is a widely applicable renewable source of energy. Geothermal energy is studied in field-exploration projects, local to pan-European resource assessments, and experimentally by determining the thermal conductivity of different rock types.

7.4. From fieldwork mapping to digital geological models

Geological models and especially 3D models have more and more impact, increasingly supporting the decision-making processes of policy makers concerning the management of our Earth's resources, for example for land planning and engineering works. In Belgium, for example, the border regions often lack unambiguous geological information to ensure a sustainable use of their subsoil. Cities, on the other hand, tend to concentrate populations, economic assets and heritage into small areas, resulting in an increasing number of conflicts in land use at the surface level as well as on the subsurface. It is clearly necessary to create advanced representation of the subsurface and improve our understanding of the geology underneath our feet by collecting geological data through fieldwork activities and storing and managing them in a GIS database. These geological models will also support the mapping of geohazards and energy resources described in other research themes.

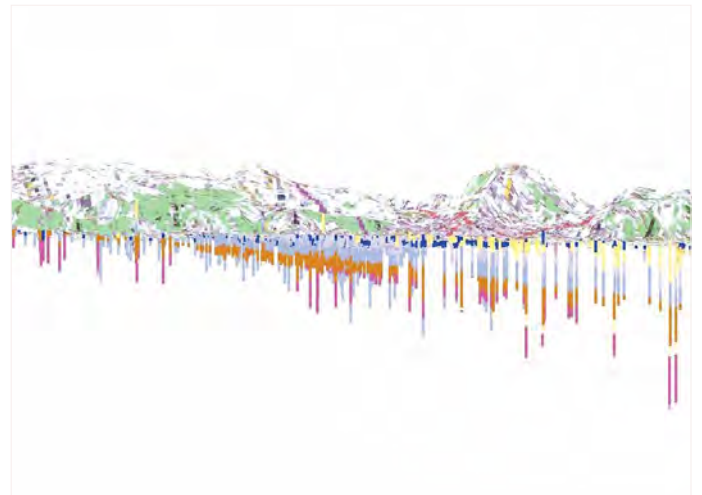


A case in point Deep-sea mining

Activities of deep-sea mining disturb the seafloor and the overlying water column. The habitats of unique benthic and pelagic communities may be affected depending on the technologies used as well as on the size of the area impacted directly by mining and indirectly by the dispersion of sediment plumes and mining debris. Researchers at the Institute assess the ecological impacts which could arise from commercial mining activities in the deep sea of the Pacific Ocean.

A case in point Monitoring tools

The RBINS is presently developing management and monitoring tools for a 3D (sub-) surface inventory, that takes into account superimposed projects, for example nature conservation at ground level, together with subsurface mining in the same area. In the same spirit comes the development of a decision support system for the exploitation of marine resources combining 3D geological models with 4D environmental impact models. Another example of research on potential new and innovative extraction models for combined use of resources is the combination of deep geothermal and mineral extraction while preserving shallow ground water resources.



Key factors shaping this Research Theme

The Belgian Geological Survey is a significant asset to the Institute in its work on this field. It works very much on the border between research and policy support, and delivers many databases and maps in addition to published papers in scientific journals. One key resource is the analytical geological laboratory, which allows the characterisation of samples using a set of state of the art tools that can often not be found elsewhere in Belgium.

As such, work in this Research Theme has a strong link to societal challenges defined at the European level. The Institute represents Belgium as part of EuroGeoSurveys, where research activities include an ERA-Net project on applied geosciences covering raw materials, geo-energy, groundwater resources and data infrastructure. A European Geological Survey is now under development within which the Institute would represent Belgium. Geo-energy in particular is a very specific strength – the Institute works directly with economists to look at the economic context.

The Belgian Geological Survey is unique at the federal level and works increasingly closely with its regional counterparts, moving from occasional cooperation towards structured collaboration. Key partners include the Royal Observatory whose role also includes research and policy support, and with whom the Institute could work towards joint acquisition of common equipment and tools.

Financing for this work comes from a range of sources including European, federal and regional funds. In terms of human competences, the strategy of the research team is to empower contractual scientists as much as possible to spark their own projects and partnerships. This helps to support staff retention.

In this Research Theme there are ample opportunities for inter-OD collaborations within the RBINS, especially between the Belgian Geological Survey and OD Natural Environments, for example in the field of deep sea mining (Research Subject 7.2) and regarding various modelling techniques.

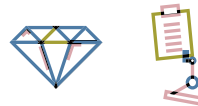
In the coming five years, the Institute will continue to build a more structured cooperation with the Flemish and Walloon geological services and will develop key partnerships at national level in order to sustain its work within this Research Theme.

RESEARCH THEME 8: PREDICTIONS AND FORECASTING

WHAT Providing a knowledge base for the management and planning related to natural hazards

WHY Scientists have a role to play in addressing the public demand for information on potential risks

**ICONS
COLLECTIONS**



PHYSICAL INFRASTRUCTURES



ANALYTICAL TECHNIQUES



OPERATIONAL DIRECTORATES



WORKFORCE 7.00 FTE (8.1: 1.50; 8.2: 1.83; 8.3: 2.67; 8.4: 1.00)



Many hazards threaten nature and society. Epidemics, coastal and river flooding, earthquakes, tsunami and storm surges can cause major loss of life and destruction of infrastructure, at great cost to society. Understanding the causes, risks and effects is critical, since this allows the most appropriate management, contingency and mitigation strategies to be developed. The RBINS is involved in geological research, including modelling and mapping, vital to our understanding of natural hazards, providing long-term perspectives on the causes and characteristics of flooding. For Belgian

waters, the Institute is pivotal in the prediction of storm surges, and has the legal obligation to follow up on marine pollution events. The researchers strive to continually improve their models, increasing the quality of products and services and helping to explain the underlying processes in more detail.

Research subjects

8.1. Marine forecasting

Marine forecasting is a strong developmental axis of OD Natural Environments. This research subject aims to provide sustained, systematic, long-term routine marine measurements, analyses, predictions and assessments for use in improving public safety and national security. This work supports the management or mitigation of natural and man-made hazards such as storm surges, floods, climate change and maritime pollution. The Institute monitors marine environment and ecosystem health and supports the shipping industry and other offshore activities. The main model used for marine forecasting in the North Sea is COHERENS, which has proved to be an indispensable tool for all kind of studies: physical, biological and more recently sediment transport. As well as scientific studies, COHERENS is used to monitor the direct effect of human activities on marine ecosystems, assess the impact of climate change and provide operational forecast services.

8.2. Multiproxy investigations of natural hazards in aquatic environments

Natural hazards can affect coastal land environments including plains, deltas, estuaries, shore lines, as well as aquatic environments like coastal lakes, freshwater lakes and the open sea. Investigating the imprint of natural hazards or extreme events in the sedimentary archive of both types of environment significantly enhances our understanding of their causes, frequency, size and impact. Robust high-resolution age models are established to accurately date the traces of natural hazards and associated evolutionary events detected in various sedimentary records. We use an interdisciplinary approach to identify, differentiate and date past events in ancient lakes, for example. Existing multi-proxy toolkits are further extended by incorporating innovative techniques from different disciplines such as environmental DNA analyses of key microfossils, geochemical analysis, molecular spectroscopy, anisotropy of magnetic susceptibility measurements and μ CT scanning.

8.3. Predicting recent and regional impacts of climate change in marine and freshwater habitats

Climate change is a threat both to the environment and to society. The RBINS has been involved in climate research for years, from the North Sea to the African Great Lakes. The next step in knowledge development for mitigation strategies is to focus on regional impacts. These include changes in sea level, hydrodynamic patterns, water temperature, pH, sediment transport and morphodynamics. One way to produce valuable information on the evolution of these variables and parameters is to combine a modelling approach with different scenarios of greenhouse gases emissions (high, medium and low level). The Institute's research focuses on new methods to assess sea level rise, ocean acidification, changes in wave climate, residual circulation, sea floor, sediment transport, migration routes and patterns and invasive species.

8.4. Human-induced hazards linked to geo-resources exploitation

Natural hazards are associated with natural processes like tectonics, sedimentary processes, soil weathering and extreme weather. They can also be caused by human activities: impacts of land use, mining activities, groundwater extraction, oil, gas and wastewater spills and global change. Policymakers at national, regional, and local levels must understand the causes, distribution and risks of such hazards, to be able to develop adaptation and mitigation strategies. The RBINS' scientific knowledge is based on the use of advanced remote sensing techniques for mapping and monitoring the Earth's surface, including multi-sensor and multiscale, aerial and satellite data, GNSS and GPS. It also requires in-situ recording of geological and geotechnical parameters through the Belgian Geological Survey's collection and archives and field sensors, along with model development to help evaluate, forecast and respond to hazard occurrences.



A case in point

The “Sinterklaas” storm

The RBINS operates the Belgian Marine Forecasting Centre, enabling authorities to take adequate preventive measures to ensure everyone’s safety and protection. A striking example is the highly accurate prediction of the dangerous “Sinterklaas” storm surge that peaked in Ostend on December 6th, 2013. Using similar techniques to those used by weather forecasting models, twice a day the RBINS’ models calculate five-day forecasts of all the physical parameters which determine marine traffic in the Channel and the North Sea. They use data collected on the tide, wind speed, wave height, currents, temperature and salinity, among other factors.

A case in point

Preserving cultural heritage in Belgium

Belgium has one of the largest and most diverse collections of built heritage in Europe, visited every year by millions of people. These buildings are at risk from heavy industrial and urban development, groundwater extraction, digging of underground galleries and temporary excavations. The Institute works to improve the management of federal heritage by integrating data from its archives and assessing the stability of monuments using radar interferometry.



Key factors shaping this Research Theme

This Research Theme is another clear example of an area where increased cooperation between OD Natural Environments and the Belgian Geological Survey is of great benefit. This inter-OD collaboration has great potential for obtaining projects with external funding.

In Belgium, policy on the exploitation of North Sea resources is developed and implemented at federal level, and as such, the Institute is requested to provide policy support. Inland resources, however, are largely managed at regional levels in Belgium and the RBINS therefore works closely with its regional counterparts on this topic. Further development of applied research on the topic of sustainable use of geo-resources has great potential for the Institute and is very much in line with the present Research Strategy as it stands.

Natural hazards also come under the Institute’s aforementioned work as part of EuroGeoSurveys. In general, a certain amount of flexibility is required in the strategy under this research theme, since the political landscape in this area is constantly shifting owing to increasing competition and geopolitics.

On the whole, the Institute aims to ensure closer cooperation among directorates over the next five years and to ensure that its robust policy support continues to feed into an ever-changing political landscape.

RESEARCH THEME 9: BIOLOGICAL MIGRATIONS AND INVASIONS

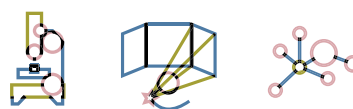
WHAT Dispersal is a natural phenomenon in most animal and plant species

WHY “Species on the move” can have profound impacts on both natural ecosystems and human societies

ICONS COLLECTIONS



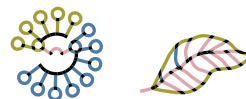
PHYSICAL INFRASTRUCTURES



ANALYTICAL TECHNIQUES



OPERATIONAL DIRECTORATES



WORKFORCE 4.17 FTE (9.1: 1.67; 9.2: 1.67; 9.3: 0.83)



Biological migration, or dispersal, is a widespread phenomenon in the natural world. Dispersal can be a cyclical event, such as in the seasonal migration of birds. It can also be a one-way mass event, such as in some butterflies and dragonflies, or it can be a slow, stepping-stone process. Dispersal can lead to a simple expansion of the area in which a species lives, but when it is a fast and “aggressive” expansion the species becomes invasive. Climatic and anthropogenic effects can facilitate invasions of alien species. Furthermore, invasive species can act as vectors of parasites and disease pathogens.

In a profoundly unstable living world, patterns of dispersal and invasions are changing while the processes are increasing in speed and magnitude. The RBINS investigates natural bird migrations, but also causes and effects of invasive alien species as well as vectors of potential zoonotic infections. The Institute’s long-term Belgian Bird Ringing Centre databases have been gathered over a 90-year period. Together with our vast physical collections of potential disease vectors, these provide real assets with which to expand on this research.

Research subjects

9.1. Biology of invasive alien species

Invasive alien species (IAS) are one of the major threats to biodiversity and ecosystem functioning. They can also provoke huge societal problems by becoming agricultural pests, acting as disease and parasite vectors, damaging human infrastructures, infesting houses, and so on. IAS are therefore of major policy concern at all levels of decision making and control management. It needs excellent knowledge on their position in the new ecosystem. Fundamental research on genetic drift, dispersal, adaptation, hybridisation and phenotypic plasticity in expanding populations under varying environmental conditions is therefore highly necessary. Several cryptic species can make up IAS and each of these might have different biological properties. As such, they may be good model taxa to assess and predict effects of environmental change like global warming, urbanisation and habitat fragmentation. The public attention they attract can be a particular motivating factor in involving citizen scientists in policy-relevant research.

9.2. Disease vectors and epidemiology of zoonotic infections

Since the publication of the Millennium Ecosystem Assessment in 2005, there has been an increased interest in the links between biodiversity, ecosystem services and human well-being. This requires research that links human, animal and ecosystem health. These research programmes explain how the relationship between biodiversity and epidemic diseases is affected by factors such as land use changes, game harvesting, the influence of climatic oscillations on tree fructification and animal migrations. Based on the uniquely rich specimen and tissue collection of vertebrates in the RBINS and ongoing projects on emerging zoonotic diseases with partner universities in the Global North and South, the Institute addresses these concerns through a multidisciplinary integrated One Health approach. It integrates data on species occurrence, presence of blood sucking ecto-parasites, movements and environmental data of both wildlife and people to improve our understanding of the emergence of pathogenic landscapes by assessing the risks of epidemic or epizootic outbreaks.

9.3. Bird migrations

Some of the most impressive examples of migrations are the annual bird migrations between Europe and Africa. Thanks to the data provided by the Belgian Bird Ringing Centre dating back to 1927, it is possible to reconstruct migration maps, to test if migrating birds act as carriers of viruses like influenza, West Nile fever and Newcastle disease, to track individual birds and to monitor endangered species. Migrating birds are also important dispersers of resting stages for species like non-marine crustaceans, facilitating genetic exchange between populations in Africa and Europe and among European populations. In this way, migrating birds are most likely involved in the introduction of invasive species.



A case in point

Tracking the Bewick's swan

The RBINS has been working closely with partners in Greece to study the behaviour of swans in the regional unit of Evros, their distribution between the different lagoons, and their demographics. GPS transmitters accurately determine the habitats and migration routes of this “sentinel swan” which is very useful for providing measures for conservation of the species. We see the arrival of thousands of Bewick's Swans in the Evros Delta in Greece and a decrease of Bewick's Swans in the North Sea area. Is it a population shift, and what are the causes?

A case in point

Tracking introduced species

As an active partner in the Belgian Platform on Invasive Species and the European Alien Species Information Network, the Institute detects, identifies and tracks down newly introduced species. As such it contributes to the eventual implementation of policies to prevent invasive species outbreaks. Current projects include the monitoring of introduced disease vectors such as culicid mosquitoes, the spread of canine nematode parasites, the colonisation histories of agricultural pest slugs and snails, and the introduction of carnivorous flatworms.



Key factors shaping this Research Theme

Much of the work under this Research Theme involves applications of the fundamental research on evolution covered in earlier Research Themes. As such it serves as direct support for policy and conservation action.

Collaboration is primarily at an international level, considering the global nature of the field. BopCo, as mentioned in Research Theme 2, is a good example of global cooperation relevant to this theme. But key partners are also necessary at national and regional levels. For example, the Institute works specifically on vectors of disease, but naturally does not have medical competences in house to deal with the actual pathogens and their effects of the hosts – for this, an excellent partner would be the Institute of Tropical Medicine in Antwerp.

Another asset for this Research Theme is the high relevance of our bird banding data. Belgium rings

the most birds of any country in the world, relative to its area. The Belgian Bird Ringing Centre's database is unlike that of many other countries in that its data collection has not been driven by specific projects but by continuous collection by certified individuals since 1927. This provides an excellent resource for cooperation with academia and policy support, and also allows the Institute to develop its own research projects. Such projects can respond directly to global crises such as the work carried out to support policy on bird flu after the global outbreak in the early 2000s.

The Institute must build on existing partnerships and develop new relationships to best complement its expertise across the three research subjects within this theme in the coming five years to ensure its success. Initiatives should be taken to increase the use and thus the valorisation of the bird banding database.

CONCLUSION

The RBINS' collections began from a series of startling discoveries. Over the years the collections grew, accumulating a vast wealth of specimens and data on which fundamental research continues to be carried out. These collections are indeed important as a heritage, but much more important is their potential as a reservoir of answers to the questions of today. Of these questions to which our collections can respond, the biggest come from beyond the walls of the Institute. These are broader societal challenges: how is human health connected to the health of natural ecosystems? What effects is human activity having on environmental change? And how can we sustainably manage the parts of our economy that use renewable biological resources from land and sea?

The challenge, then, is finding the questions for which our collections and databases may be the tools with which to seek answers. This Research Strategy rises to that challenge by clearly setting out the nine Research Themes within which the RBINS excels, in seeking answers through its fundamental and applied research in natural sciences. The years to come will tell how far these priority lines of the Institute's research are properly designed for that challenge. Feedback from experience as well as from external peers will help to shape and refine the strategy, to best guide the Institute's work.

The best news of all, however, is that only a fraction of the 37 million items and species in the RBINS' collections have been subject to thorough analyses. Concerted research activities on our collections continue to reveal unexpected discoveries, such as a series of previously unknown Neanderthal fossils and ancestors to our domesticated dogs, much older than expected. In addition, the arrival of novel analytical techniques allows re-examination of previously investigated specimens, for example the previously mentioned genomic techniques which the JEMU lab can further develop for use on museum specimens. Finally, the ever-growing databases of the RBINS now span, in some cases, decades of monitoring and can either serve to discover trends in ecosystem decline or recovery or be used to detect further natural cyclicities.

The RBINS has existed for more than 170 years and throughout that period built extensive physical collections and databases, as well as a very valuable mass of knowledge, tools and expertise through its scientific staff. The RBINS' scientists are often among the top in their fields where they make significant contributions and on occasion break new ground, and they have built an extensive network of partners among research institutions in Europe and worldwide. We are confident that the major assets of the RBINS as outlined above will create new opportunities to ensure the continuation and improvement of the research activities in which we excel, and which need to be perpetuated.

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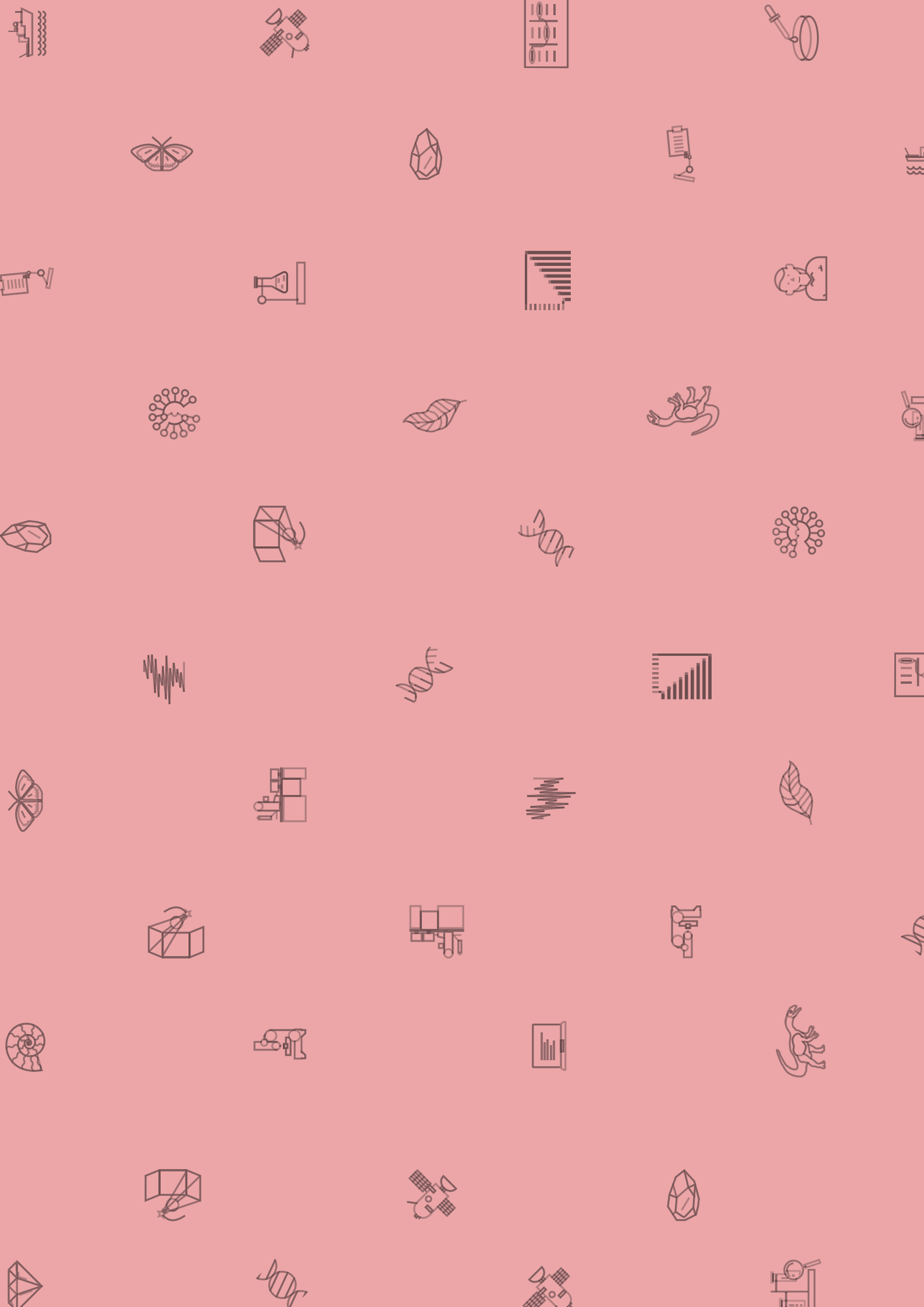
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