Naturhistoriska
riksmuseet

Working the Earth

Research and Collections at the Swedish Museum of Natural History

Table of Contents

Photo: Anna Roos

Working the Earth!

The Swedish Museum of Natural History is a major research institute that combines a venerable tradition with modern working methods. Our collections constitute an amazing archive of the natural world and our research laboratories are of world-class. The research staff at the museum collaborate with colleagues all over the world, and we receive many guest researchers every year.

The Swedish Museum of Natural History is a member of a large international family, whose members include the Natural History Museum in London, the Smithsonian Institution in Washington, Naturalis in Leiden and the Muséum National d'Histoire Naturelle in Paris.

This brochure describes the research work, and the work carried out in the collections, at the Swedish Museum of Natural History. Visitors to our museum, and all other natural history museums, see only the tip of an iceberg. The exhibitions, teaching activities, public programmes and – at the Swedish Museum of Natural History – Cosmonova, are the parts that the visitor sees. All of these parts have in common that they are based on our research work and the work we do in the collections.

The museum currently has six permanent exhibitions and additionally, many temporary exhibitions are arranged every year. Our IMAX cinema, Cosmonova, offers a wide range of films and planetarium displays.

The museum also arranges a variety of programme activities that offer visitors the opportunity of in depth exploration and discussion. These are an important channel for our researchers to share their knowledge with the general public.

The museum, together with Cosmonova, was visited by nearly 800,000 people in 2005. Half of these were children and young people who often visit the museum as part of their education. Meetings with our teaching staff are a key part of these visits.
It is our goal to awaken interest in young people for the natural world and natural sciences, the environment, conservation and biological diversity. An important part of this is the education of teachers.

We welcome visits from students interested in nature, who can obtain work experience, mainly in our research and collections division.

Researchers from the museum give university courses and supervise research students. We host guest researchers from all over the world to carry out post-doctoral research.

The concept of "accessibility" has acquired a new dimension in recent years, one that includes access to the internet. The website of the museum, www.nrm.se, contains a great deal of information at various levels about our research and collections, making it useful both for experts and for the general public. People ask the museum a multitude of questions both by telephone and over the internet. These questions may concern any of our fields of interest and they often are associated with a current news story, or a current topic that is being discussed. We have established a special service, known as "Duty Biologist", on the website in order to be able to answer these questions, both simple and complex, and we also have the possibility of answering questions about geology.

Our collaboration has a truly international perspective. Our collections and expertise are available to researchers and the general public worldwide.

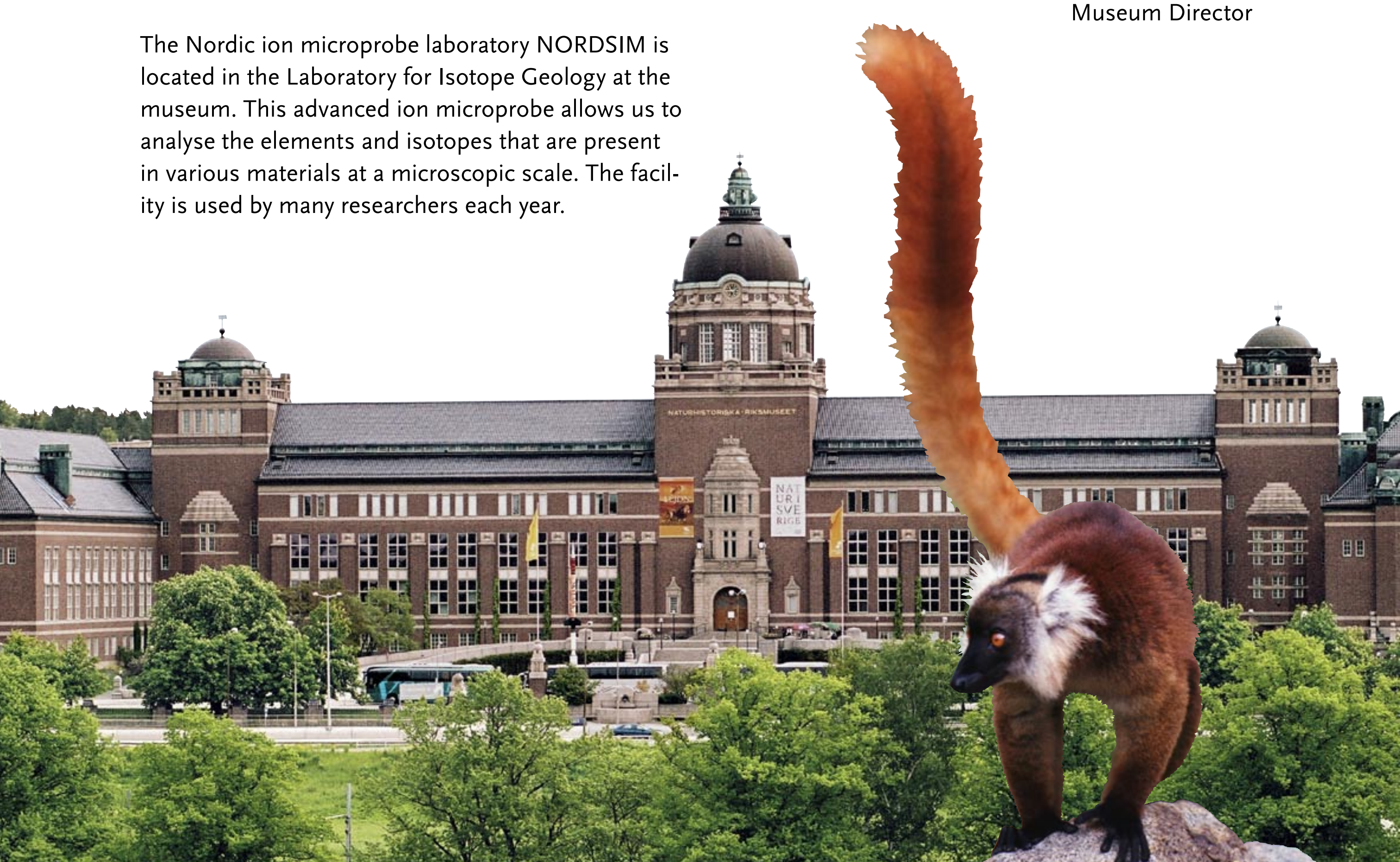
GBIF – the Global Biodiversity Information Facility– is an international collaboration to disseminate collected knowledge of the world's biological diversity to all. There were 47 participant countries and 34 global organizations in 2006, working together to build a database. GBIF is an enormous, global project within the field of biological diversity. The Swedish Museum of Natural History is the Swedish node of the GBIF.

The museum has been granted the status of "Major Research Infrastructure" by the EU, and it is a member of a network of major natural history museums in Europe that together are carrying out the SYNTHESYS project, funded by the EU. We receive many guest researchers each year within the framework of SYNTHESYS, and we participate in various activities aimed at making the natural history collections available, and curating these collections.

The Nordic ion microprobe laboratory NORDSIM is located in the Laboratory for Isotope Geology at the museum. This advanced ion microprobe allows us to analyse the elements and isotopes that are present in various materials at a microscopic scale. The facility is used by many researchers each year.

This was just a brief introduction to some of the teeming activities that are carried out in our Research and Collections Division. This brochure will provide deeper insights into the fascinating and important work that our researchers and our curators are carrying out – with roots in the past and eyes firmly fixed on the future.

Christina Hallman
Museum Director



The Swedish Museum of Natural History

The Swedish Museum of Natural History is an authority under the Ministry of Education, Research and Culture. We have a national responsibility in the field of science, which means that we have been given a special responsibility to support and collaborate with other science museums in Sweden. The museum employs approximately 250 people, 150 of whom work in the research division of the museum, mainly with the research activities and the collections of the museum. The first item in the museum's collections was donated by a member of the Academy of Sciences, Jonas Alströmer, in 1739. The collections now total over 9 million items.

Our Collections are Our Core

The basis on which our activities are founded are the collections. Nearly 300 years of research journeys and collection have resulted in more than 9 million items: animals, fossils and minerals – everything from a whale skeleton to a tiny pollen specimen, from fossils of extinct fish to contemporary tissue samples used in environmental monitoring. Our scientifically priceless collections are the key to our successful research activities, international collaboration, and vibrant exhibitions.

Examples of hoverflies in an insect box from the entomological collection. Photo: Staffan Waerndt

A museum with scientifically valuable collections provides excellent opportunities to carry out successful research, and it is an attractive focus for researchers. One important task of the staff at the Swedish Museum of Natural History is thus to conserve and develop the high scientific and cultural historical value that our collections have. This involves, for example, care, documentation, processing and supplementing the collections.

Our collections are used every day by our own researchers, and they are in large demand from researchers around the world. Expert amateurs with a special interest, principally from Sweden, are also frequent users. The high demand and the high lending frequency of our collections is not solely evidence of their high status – research loans are an efficient way to process and improve the collections. The processing that takes place in association with the visits of guest researchers and during loans to various research institutes all over the world contributes to increasing the scientific value of the collections.

A close coupling between the collections and current research

The collections consist of items that are preserved in different ways, logically coherent and arranged systematically. All of the collections are closely connected to activities that are carried out in our research groups. The sizes of the various parts of the collections reflect different collection strategies, both in the past and in the present. Collections within animal and plant groups in which the number of described species is high, such as insects, generally have considerably more items than collections that represent groups with fewer species. The number of active researchers and amateurs around the world within each research field also affects the size of the corresponding collection.

Botanical collections

Phanerogamae – seed-bearing plants

The museum's scientific collection of seed-bearing plants comprises approximately 3 million items. This is one of the largest phanerogamic herbaria in the world. Parts of Carl Linnaeus' collections are held here.

Cryptogamae – a collective term including:

Ferns, bryophytes, fungi, lichens and algae. The scientific collections comprise approximately 1.5 million specimens.

Zoological collections

Vertebrates

The collections of vertebrate zoology contain 300,000 specimens and consist of fish, birds, mammals, amphibians and reptiles. The long collection tradition of the museum has given collections that are among the world's largest, and among those that contain the largest number of species.

Invertebrates

The collections of invertebrates consist of approximately 550,000 specimens of invertebrates, such as sponges, jellyfish, corals, many types of worm, mussels, octopi, crustaceans and sea urchins.

Entomology – insects, etc.

The entomological collections contain approximately 2.5 million specimens. The collection of insects includes flies, wasps, beetles, butterflies, grasshoppers and true bugs. The entomological unit covers also other animal groups such as spiders, scorpions, centipedes and millipedes.

Paleontological collections

Paleozoology – fossil animals

The paleozoological collections (fossil vertebrates and invertebrates) at the museum comprise 860,000 items. The history of animals can be traced more than 500 million years into the past, and the collections include fossils from the whole period.

Paleobotany – fossil plants

The paleobotanical collections include 175,000 specimens of fossilised plants. These collections contain many unique items, of which fossils from the polar regions and from China are particularly valuable. The collections include also many finely preserved fossil flowers, 120-65 million years old.

Mineralogical collections

The collection of minerals consists of approximately 150,000 catalogued specimens, approximately half of them from Swedish locations. Minerals are the building blocks that make up the solid components of the Earth, planets, and meteorites.

The Environmental Specimen Bank

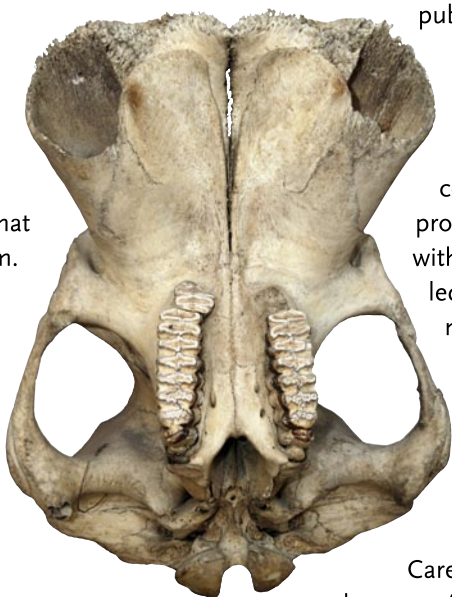
The Environmental Specimen Bank contains 270,000 samples from fish, birds and mammals collected after 1964, and it forms the basis of the museum's research into environmental contaminants. The collection also forms the basis for monitoring environmental contaminants in Sweden.

The mounted skeleton of Sowerby's beaked whale and a beluga whale, both from the late 19th century. Photo: Staffan Waerndt

The history of the collections and the museum

The collections of the Swedish Museum of Natural History have a huge culture historical value: they include, for example, parts of Carl Linnaeus' collections. The history of the museum stretches back for 250 years, and is closely coupled with Sweden's prominent history of exploration and research.

What would eventually become the Swedish Museum of Natural History was founded as early as the middle of the 18th century. Jonas Alströmer, a member of the Swedish Academy (a precursor to today's Swedish Royal Academy of Science) who is most famous for introducing the potato into Sweden, donated a fungus at the first meeting of the Academy in 1739. This became the first item in the collections of what would later become the museum. More items were added to the collection after Jonas Alströmers donation.



One of Linnaeus' disciples, Anders Sparrman, was appointed in 1777 as the first curator for the collections. Anders Sparrman had travelled widely, having accompanied, for example, James Cook on his second circumnavigation. Ten years later, the Academy introduced detailed regulations for the display of the collections to the public. This was, in effect, the foundation of the first public museum in Sweden.

The Academy collections grew with contributions in the form of donations at the beginning of the 19th century from, among others, Peter Jonas Bergius and Gustaf von Paykull. The collections continued to grow throughout the 19th century, and public interest in the museum grew in parallel. The existing premises had become too small by the end of the 19th century, and a new museum building was eventually constructed at Frescati, ready for use in the spring of 1916. The new museum premise had an area of 20,000 square metres, and gave excellent opportunities for receiving the ever-increasing public.

Care for the collections – yesterday and today

Problems arose as early as the 18th century in that the collections were prone to attack from pests. Experiments with arsenic soap when preparing skins led to the development of an effective method that revolutionised care in this early period. Many substances and methods have been used subsequently to protect the collections from pests. Most modern methods are now free of toxins.

Care of the collections remains, to this day, one of the most important tasks of the museum, preserving them for the future, and keeping them available for international research. We have established a special preservation group that works with comprehensive issues concerning the storage and preventative care for the collections. We lead and co-ordinate Swedish research into protection from pests, work that is carried out within the framework of the PRE-MAL project, described below.

PRE-MAL (Pest Research and Education - Museums Archives and Libraries)

Items in cultural history collections and natural history collections are irreplaceable. Each item is unique. The collections held at museums, museums of country life, churches, archives and libraries are continuously open to risk of damage. One of the greatest risks is that of pests. An extensive collaboration, known as the Swedish museums and archives pest control group, PRE-MAL, has for this reason been established.

PRE MAL works with research into, and information about, managing pests. The Swedish Museum of Natural History leads the group, which has broad expertise, comprising curators, entomologists, and physicians. PRE-MAL collaborates with specialists throughout the world. The group was awarded the EU cultural heritage prize, the Europa Nostra Award, in 2004, for its work in preserving our cultural heritage from pests using toxin-free methods.

Alcohol is an excellent preserving agent, particularly for fish and invertebrates. This shark is a porbeagle, Lamna nasus. Photo: Staffan Waerndt

Care of the collections is necessary to preserve them for the future. Here the cranium of a tahr from Sven Hedin's central Asian expedition in 1932 is cleaned. Photo: Anna Roos

Digital databases increase accessibility

The nine million items that we house have an intrinsic scientific and cultural value. They achieve their full potential for research, however, only when accompanied by additional information. This is primarily the location and date at which the item was collected, and the name of the collector, but it may also include, for example, details about the surroundings, observations of the animal alive, and the geological properties of the site.

The museum has drawn up descriptions and "card indexes" throughout its history, in order to describe the collections and locate the actual items in the collections. We were the first museum in Sweden to catalogue its collections by computer, at the end of the 1970s. We now have many digital databases that provide information not only that an item exists, but also the circumstances surrounding its acquisition, and other documentation. The databases are also important tools in the extensive management of loans, and in the day-to-day work of conservation.

A page from a herbarium with type material for Physochlaina physaloides L., a member of the potato family, from the Linnaeus herbarium. Much of the Linnaeus herbarium can be studied online at the website of the Swedish Museum of Natural History. Source: The Linnaeus Herbarium, The Swedish Museum of Natural History

Pyrobelonite, a rare mineral containing vanadium, from the Långban mines in Värmland. The crystals are smaller that 1 mm in length. Photo: Michael P. Cooper

Collaboration in Four Fundamental Research Themes

All activities at the Swedish Museum of Natural History concern various aspects of the development of the Earth, the life it hosts, and aspects of the interaction between humans and the world around us. Our research is an important part of our activities and covers a wide spectrum that includes botany, zoology, palaeontology, geology and ecotoxicology.

The research is financed largely by external funds. The principal sources of finance are the Swedish Research Council (Vetenskapsrådet), the Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (Formas), the Swedish Species Information Centre, and the EU. We also receive many small and individual grants from a variety of other sources.

Our research activities are focused into four themes:

The Changing Earth
Ecosystems and Species History
The Diversity of Life
Man and the Environment

These themes allow us to combine our specialist knowledge in different fields and obtain in this way increased understanding of the geological and biological diversity of our planet and the processes that have influenced, and continue to influence, the development of the Earth and life on it. The clearly defined research themes also make it easier for us to make our research available for a wider public.

The museum conducts other knowledge-based activities in relevant fields, in addition to research. An example is the administration of the Swedish programme for ringing birds, and the publication of daily pollen forecasts during the pollen season. All of these activities have in common the application of our expertise as a benefit to society in the form of concrete measures taken and information distributed.

The following pages present our four research themes and other activities related to research.

The Development of the Earth and Life on It

The history of the Earth and the history of life have been intimately woven together for billions of years. Researchers at the Swedish Museum of Natural History working in the research theme "The Changing Earth" investigate the development of the Earth's crust, its oceans, and its atmosphere, and they also investigate how changing geological conditions have affected the development of life on our planet and, conversely, how the development of the Earth has been affected by biological factors. This knowledge provides valuable insights into how the conditions for life on Earth have changed through time.

The Earth is always changing

Time – the fourth dimension – is a central concept in geological research. It is important to be able to date events and processes in the history of the Earth, in order to understand geological development. The Swedish Museum of Natural History has modern laboratories for such dating (see the box below).

The oldest part of the Earth's crust that is well-preserved is around 3.8 billion years old. Dating the rocks of the Earth's crust enables us to understand how the continents have been built up over the ages, when continental drift started, when water in liquid form started to appear, and when the conditions on Earth became suitable for life.

Much of our geological research is concentrated on the development of the bedrock in our vicinity – the Fennoscandian shield –, and how it fits into the global jigsaw of ancient supercontinents. This crystalline bedrock was formed between 1 and 3 billion years ago. It has subsequently been partially transformed and covered by younger sedimentary rocks.

Some elements of particular interest

Certain elements are particularly interesting in geological and mineralogical research. Trace amounts of boron can drastically reduce the crystallisation temperature of magma and affect the viscosity of lava. We are using newly developed microanalytical methods to help us in the study of how boron is incorporated into common minerals, obtaining in this way a better picture of the large-scale boron cycle. Other elements of interest include iron and maganese. These elements are capable of changing their valence state according to the availability of oxygen during rock formation. New analysis methods are being developed to increase our knowledge into how the various valences developed.

Minerals reveal geological processes

We also describe previously undescribed minerals and study how minerals react under various geological conditions. Spinels are a group of minerals that are used as indicators of rock-forming processes. We investigate the stability of these minerals and the way in which the composition depends on temperature by manufacturing crystals of artificial spinel with known compositions. These crystals are then studied using crystallography and spectroscopy.

Water is important for both geological processes and the evolution of life. In addition to the water that is today present in the hydrosphere, large quantities of water are bound into the structures of minerals in the form of water molecules (H_2O) and hydroxide ions (OH^-). This water is present in many minerals in the Earth's crust, and in small amounts in minerals deep within the Earth's mantle. The amount of water that is bound is probably larger than the volume of water in the Earth's oceans. We are using mineral chemical methods to study how water is bound in the minerals, and the effect that this has on dynamic processes in the mantle.

Living organisms also produce minerals, for example in the form of animal skeletons. Most sedimentary limestone on the Earth has been formed from living organisms. We are investigating the history of biomineralisation.

Biological evolution and chemical processes on the Earth's surface

One important question in geological research is how biological evolution has affected, and how it is itself affected by, changing chemical conditions on the surface of the Earth. Free oxygen in the atmosphere and oceans is formed by photosynthetic organisms. This process is necessary before eukaryotic (organisms with cell nuclei and mitochondria), multicellular organisms can develop. We are using stable isotopes to investigate how the atmosphere and biosphere of the Earth have developed through the ages. More details are given in the box below.

The history of the diversity of life

The diversity of life seen today has taken eons to develop. We can follow this development through the sedimentary layers, particularly during the past 550 million years, following the sudden appearance of a variety of life that took place in the "Cambrian explosion". The diversity has varied during this period, depending on both biological factors and the geological environment. There is evidence for a correlation between extensive plateau volcanism and the major disappearances of various forms of life. The two most extensive mass extinctions occurred at the end of the Permian period and at the end of the Cretaceous period, simultaneously with some of the most intensive periods of volcanic activity we know about. We are investigating whether other periods of mass extinction are coupled with such destructive volcanism. If this is the case, volcanism may be more significant that meteorite impacts as external brakes – and accelerators – for the development of life on Earth.

Research in natural history is based on observation and collecting samples from the natural world. Researchers from the Swedish Museum of Natural History are active throughout the world, here on a field trip in Iceland. Photo: Gerwin Gruber

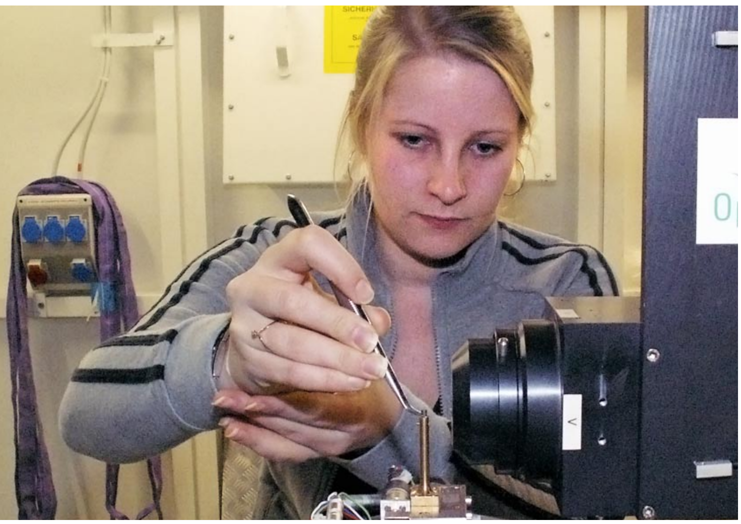
Isotope geology and radiometric dating

Most elements can exist as several isotopes with different atomic masses. Certain isotopes are radioactive. Radioactive decay, such as the disintegration of uranium to form lead, is used to determine the absolute ages of minerals and rocks. The mineral that is used most often for such dating is zircon, which is relatively stable and contains sufficient amounts of uranium. Zircon is found in most rocks. The variations in isotope profile that are caused by radioactive decay are also used to study the origin of magmatic rocks, the development of the Earth's crust, the formation of ore finds, and the modern cycles of several substances in the environment.

There are also variations in the isotope profiles of elements that are not radioactive. Studying the isotope compositions of elements such as oxygen and sulphur allows us to track processes that are intimately coupled with changes in the bedrock, biological activity, and atmospheric reactions. The Swedish Museum of Natural History has special chemical laboratories and modern mass spectrometers for measuring natural isotope variations.

Large-Scale Biological Processes in Time and Space

The ecosystems that we see today are the result of an evolutionary history that extends millions of years into the past, driven by the interaction between geological and biological processes on Earth. The historical development of processes and patterns in ecosystems is being studied at the Swedish Museum of Natural History in the research theme "Ecosystems and Species History". Our research is contributing to increased understanding for the origins of ecosystems, and the reasons that some ecosystems today display greater diversity than others.



X-ray tomography allows us to image the internal details of fossil embryos, approximately 1 mm in size, from animals that lived more than 500 million years ago.
Photo: Stefan Bengtson

The sensitivity of an ecosystem for global changes depends not only on modern processes, but also on historical processes that have been active over long periods of time. The genetic composition of an ecosystem determines its ability to respond to changes it experiences today. This composition is the result of the interaction between geological and biological processes over long periods. For example, the dryness-adapted flora in North and South America is dominated by members of the cactus family, while corresponding niches in similar ecosystems in Africa are occupied by members of the Euphorbia family. Cactuses evolved after the separation of America and Africa, and they were thus unable to spread into the African continent. Time is an important component of every ecosystem, and it is important to understand the significance of time, just as important as it is to understand the dynamic functions of the ecosystem.

The development of modern systems in the northern hemisphere

The flora of the northern hemisphere during the early Tertiary period, 65–25 million years before the present, was generally sub-tropical to warm temperate, and it was significantly more homogeneous than it is today. The flora, however, developed as a result of global changes to the same kind of ecosystems that we see today, in the form of Mediterranean systems and temperate systems. By studying the species history of various families such as beech (Fagus), oak (Quercus), elm (Ulmaceae), maple (Acer) and platans (Platanus) we can increase our knowledge of this process of change.

We use a combination of DNA methods and morphological properties to determine the relationships between different species. Fossil material can be used to determine the age of various branches within the family, and the presence of ecologically different types of vegetation. The oldest fossil species of maple, for example, from the early Tertiary period, are most closely related to modern sub-tropical species of maple that DNA studies have shown to be basal, while ecologically advanced small-leafed species from the Mediterranean first appear in the fossil record much later. This observation, and similar observations from other species show that the ecosystem of the Mediterranean did not develop until late in the Tertiary period.

Most sub-tropical species of maple have disappeared from Europe, although a few species remain in south-west Europe and in the Caucasus: regions that were less affected by the major Quaternary glaciations. These species are found in what are known as "Tertiary refuges", which reflect the ecosystems of earlier epochs.

The change of ecosystems with time

A second line is the study of the ways in which complete ecosystems change with time. A good example of this is our research into the origin of grass ecosystems. Grasslands now constitute approximately 40% of the terrestrial ecosystems in the world, but we know little of how these ecosystems arose. Grasses have their origin at the end of the Cretaceous period, approximately 70 million years ago, but they did not become ecologically dominant until the Miocene period, 25–5 million years before the present.

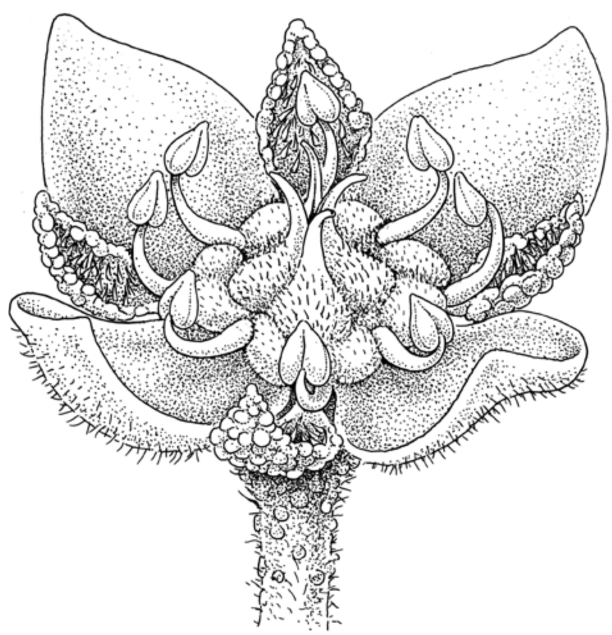
The study of fossil phytoliths, small grains of opal that are extruded by some plants and that are characteristic for different types of grass, allow us to document the development from forests to open grasslands. This gives us direct botanical evidence for the development of grasslands. Previous studies of the origin of grasslands have been based on the origin of herbivores specialised to eat grass. Our new paleobotanical research suggests that these herbivores actually evolved millions of years after the grasslands had become a dominating ecosystem. This shows how our research can contribute to knowledge about how modern ecosystems have arisen, and how plants and animals interact within these ecosystems during evolution.

The origin and development of humans

Research into historical processes and the patterns of diversity are also important in the study of how individual species affect, and are affected by, the ecosystems. The most immediate example that is included in our research concerns the first development steps of the pathway by which humans became a dominant species on Earth. We investigate in this work how the small two-legged ancestors of humans evolved from being an important prey for predators to a significant competitor to these predators.

This phase in the development of humans was, and still is, highly significant for the composition of the ecosystems. Detailed investigation of fossils of humans and predators has shown that the species adapted to each other over a period of millions of years. These investigations are supplemented by phylogeographical studies, which are molecular studies of living animals that show how genes have been rearranged over periods of millions of years.

The multidisciplinary research we carry out in "Ecosystems and Species History" provides knowledge about the mechanisms that control how ecosystems function today. Morphological and molecular studies of plants and animals when combined with studies of the evolutionary biology of organisms and isotope studies can trace backwards in time the processes by which ecosystems develop.



A reconstruction of Platydiscus peltatus, a fossil flower from 80 million years before the present, from Cretaceous deposits in Skåne. The flower is 3 mm across. The plant family Cunoniaceae no longer exists in Europe.
Illustration: Pollyanna von Knorring

Global Survey of the Diversity of Life

It is estimated that there are 5–10 million species of plants, fungi and animals on Earth, and most of these have not been described. All known species have more or less important roles to play in the ecosystems, and we can assume that many of the species that are unknown today are beneficial for humans. Around 30 researchers at the Swedish Museum of Natural History are directly involved in research in the theme "The Diversity of Life", and the work they do is both stimulating and important.

Researchers working with the diversity of life have much in common with explorers from previous ages. They are participating in global endeavours that are currently in progress to discover and survey as much as possible of the Earth's biological diversity. No single scientist can be an expert in more that a limited group of animals, fungi or plants, and thus what is required is extensive collaboration, in order to cover all organisms.

The smooth dreamer, Chaenophryne draco, a black ball with knife-sharp teeth, is an example of deep-water fauna that is difficult to study in the wild, and remains relatively unknown. Photo: Sven Kullander

Journeys of exploration
–50 new species discovered each year

One important part of the work is the collection of new material, since new material contributes to knowledge about which organisms are present in various parts of the world.

Furthermore, fresh material is often required for reconstructing family relationships based on the DNA of different species. Processing the material that is collected takes a long time. Most of the Earth's biological diversity is found in tropical regions, and it can take many years to process the material collected from a journey to these regions. The work, however, results in the researchers at the museum being able to identify approximately 50 new species from all over the world, every year. Other important results from this work include revision of various groups of organisms and species determination, and researchers from the museum often contribute to this work. This type of work is necessary for biologists working in other fields, so that they can know which species they are working with, and so that we can know which species have the greatest need for conservation measures.

Surveying diversity

Researchers from the museum are surveying diversity in exotic far-away places, and in our own neighbourhood. We are participating, for example, in the "Flora Malesiana", a flora that will cover Malaysia, Indonesia, the Philippines and New Guinea when it is complete. This project is led by Leiden Nationaal Herbarium in the Netherlands, and involves the work of 100 specialists all over the world. This is the first scientific survey of the region, where it is estimated that 40,000 species of flower can be found. Our researchers are working with three families that comprise 70-90 species in the oleander family (Apocynaceae). Preliminary studies suggest that

approximately 30% of the Malesian species in these groups have not yet been described.
The museum is responsible in Sweden for the Swedish Malaise Traps project, which is financed by the Swedish Species Information Centre as part of its Swedish Taxonomy Initiative. The name is similar to "Malesian" but this project has nothing to do with the Malesian project described above. The "Malaise" traps are named after René Malaise, their inventor. A total of 61 of these traps were deployed between the summer of 2003 and the winter of 2005-2006. These traps have collected several hundred million examples, mainly insects and poorly known insect groups such as Hymenoptera and Diptera, during this period. The collected individuals are sorted and sent to experts for species determination. The material that has been collected will take decades to analyse and we are expecting to find many new species, and to obtain a clearer picture of the distribution of many insects.

Reconstructing the tree of life

Our researchers are also working to clarify how species of plants, fungi and animals are related to each other. This is another field of research in which we are collaborating with researchers from around the world in order to reconstruct ever-larger parts of the "tree of life". Research in this field is now significantly aided by modern methods in molecular biology and modern computer-based methods of analysis. We are now able to produce and analyse enormous quantities of data far more quickly than just a few decades ago. Knowledge about the evolution and relationships between species then enables us to conclude how species with various characteristics have given rise to other species with totally different characteristics, to describe the history of different geographical regions, and to decide which animals, fungi and plants we should be examining for characteristics that may be useful to humans.

However, extensive knowledge of appearance, living environment and distribution, for example, of the organisms being studied is required in order to place the molecular results into a meaningful context. Our researchers are actively contributing to the exciting explosion in knowledge that results in this field have given rise to in recent years. One example is the radical re-evaluation of our ideas concerning the evolution and relationships between various groups of organism.

Unexpected relationships are revealed

One project is examining the development and adaptation of perching birds. Many common Swedish birds are perching birds, and this group is widely spread around the world. Birds are popular, and many people believe that we know their family relationships well, but this is far from the case. Our researchers have found using DNA studies several examples of birds that have markedly different appearance while being closely related, in contrast to previous belief. Such research has also revealed several cases of convergent evolution, which is the term used to describe the phenomenon in which species appear to be similar although they are not closely related, as a result of similar adaptation to their surroundings. We were able to show, for example, that a species that had traditionally believed to be related to crows was, in fact, a member of the tit family. Earlier studies of the behaviour of this species had been carried out in the belief that it was related to crows, and these studies required reconsideration in the light of the new knowledge.

Our researchers are participating in the production of new flora. One project has been the survey of flowering plants in Småland, leading to the production of a flora. Work is continuously under way to produce a description of all flowering plants that have been found in Sweden.

Botanical field-work involves the collection of plants that are later to be included in the museums herbaria. Collection of Pycnandra griseosepala, a member of the Sapotaceae family on New Caledonia, north of Australia, where researchers from the museum are involved in several projects.
Photo: Gordon McPherson

Research to Promote a Natural Environment and Sustainable Development

The Swedish Museum of Natural History carries out both applied research into the natural world and the environment, and fundamental ecological research in the theme "Man and the Environment". Examples of activities within the theme are national environmental monitoring, the monitoring of migration patterns of birds, and investigation into allergens. Our biological and geological research skills and our knowledge of species contribute to a better understanding of the world around us and thus improve the possibilities of attaining sustainable development.

We carry out and we participate in national and international environmental monitoring programmes studying environmental contaminants and their effects, both in the terrestrial environment and in the marine environment. This work is supported by grants from the Swedish Environmental Protection Agency. The samples that we take are used as the basis for research and for continued development of our environmental specimen bank. This bank is one of the oldest in the world and it contains, among other specimens, frozen tissue specimens. Approximately 8,000 – 10,000 samples are added each year, providing researchers with a unique material for studying environmental contaminants and their effects over long periods of time.

The studies carried out into the long-term effects of environmental contaminants are the longest-running of their type. These studies include, for example, pike from Storvindeln and guillemot eggs from Stora Karlsö, which have been collected for the analysis of environmental contaminants every year since 1967. Other studies include, moose, reindeer and several species of fish, collected in order to study environmental contaminants. The traditional environmental toxins such as PCB, DDT and dioxins are monitored, as are other substances such as brominated flame retardants and several metals.

The chlorine atoms that are part of chlorinated organic compounds consist of two stable isotopes. Small differences in the distribution of chlorine isotopes make it possible to distinguish between, for example, chlorine from the chemicals industry and chlorine produced in natural processes. Our researchers are applying new methods of chlorine isotope analysis and increasing our knowledge of how chlorinated organic compounds are formed, how they break down, and how they spread in the natural world.

Marine top consumers – a vulnerable group

One group that has been hit hard by environmental contaminants is that of marine top consumers: marine animals that are located at the top of the food chain. Study of this group is an important part of our research. The reports of harm to the seals of the Baltic Sea are the most serious reports in the world about damage to mammals from environmental contaminants. This is a consequence of the Baltic being one of the world's most polluted inland seas. We are carrying out research to document the state of health and the incidence of disease, and the reasons behind these. We are, for example, studying the increased frequency of intestinal lesions affecting grey seals. Some of the questions we are asking are why the disease is increasing, what it is caused by, and why there are regional differences.

We are also responsible for monitoring reproduction and population figures for seals in Swedish waters, and studies of their choice of food, exposure to environmental contaminants, migration, and other ecological parameters. The results will form the basis for the management of the grey seal, ringed seal, and harbour seal in Sweden.

The sea eagle is another species that has been hit hard by environmental contaminants, and we are studying this species intensely. Population monitoring, analysis of environmental contaminants in sea eagles and their eggs, and studies of their reproduction are some aspects of this research.

The otter used to be a common sight throughout Sweden, but its population and its spread have decreased dramatically since the 1950's. Environmental contaminants lie behind this reduction, and we are studying the health of the otter, its exposure to environmental contaminants, and the effects of these contaminants. One collaborative project, for example, has demonstrated a correlation between the bone density of the otter and certain environmental contaminants.

National collaboration in mussel research

We are collaborating in another research project in the extent, ecology and age distribution of the eight Swedish species of fresh-water mussel. This includes the two threatened species: the freshwater pearl mussel and the thick-shelled river mussel. Historical information from the museum collections is an important source of information in this project. Most of the Swedish populations are composed solely of larger mussels (which are older) and this means that they will eventually become extinct unless renewal is achieved. The part of the research targeted at conservation is being undertaken in collaboration with various county administrations in Sweden, and with other organisations.

Migration patterns of birds

Around two-thirds of the species of birds that nest in Sweden leave the country for some part of the year. The migration patterns of birds are being continuously monitored through the Swedish programme of ringing birds. The results from the complete programme have now been collated into an atlas consisting of three parts.

Another project is studying how migratory birds are being affected by the recent relative mildness of the climate. Initial results show that several species that winter in Western Europe have moved their winter quarters northwards after 1980. Bird migration is potentially an important factor in association with the spread of certain diseases (such as avian flu, and tick-borne diseases), and our researchers are participating in several projects dealing with this issue.

Birds must rest regularly during migration and obtain energy for the remainder of their journey. Some birds migrate over long distances: around 35 species of small bird that nest in Sweden, for example, cross the Sahara in order to spend the winter in tropical Africa. Research is being carried out in one collaborative project into the storage of fat that the birds must carry out before flying over the desert. One central question is how the inexperienced young birds can know that the journey over the desert lies ahead, and thus build up their fat reserves at the right place. Our experiments have shown that information from the Earth's magnetic field may be a part of this process. Studies have also been carried out on Crete, in collaboration with Greek ecologists.

The incidence of allergies

We are surrounded by agents that can cause allergies. Such agents, known as allergens, are present in, for example, plant pollen, and they cause considerable problems for people who are sensitive to them. We are participating in a research project, in association with our work in forecasting pollen levels, in which we are studying the size distribution of the allergens, and their principal pathways to reach indoor air.

Visiting the sea eagle. Monitoring of marine top consumers involves checking the result of nesting, taking samples of feathers, and ring-labelling the young birds.
Photo: Kurt Elmquist

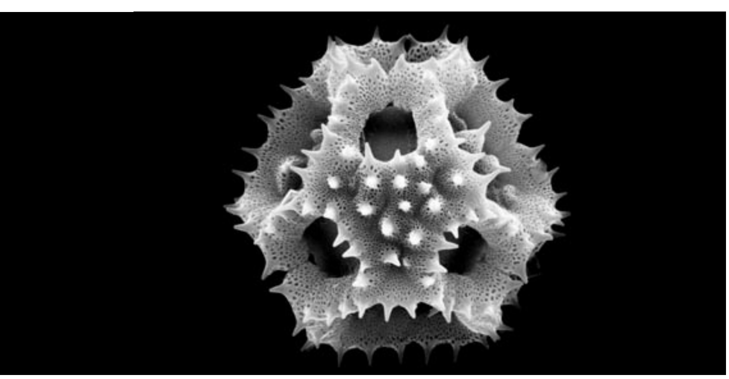
Serving Society

Our staff are involved in many other activities and collaborative efforts than the research projects that are included in the four research themes. All of our activities contribute in clear ways to increasing and spreading knowledge about the development and diversity of the Earth and life on it, and the relationship between humans and the natural world.

Pollen service

Allergy is a major problem for many people, and it is becoming more severe in the western world. Over 1.5 million people in Sweden alone are allergic to pollen. The Swedish Museum of Natural History produces pollen forecasts that help people with allergy to plan their everyday life and take their medicine effectively. Detailed pollen forecasts are published for the general public on the museum's website at **www.nrm.se/pollen** and in newspapers, on the radio, and on text-TV. The forecasts are based on measurements of the amount of pollen in the air at around 15 stations spread around the country. We can subsequently determine the plants from which the pollen came by examining it in a microscope, since the pollen of each species has a characteristic appearance. The most powerful allergens are pollen from birch, grass and mugwort.

The Swedish Museum of Natural History has continuous pollen data stretching back to the early 1970s. The measurements show a trend towards earlier flowering of the birch, which is a direct consequence of the rise in temperature that began in the 1990s. Our pollen measurements are also used in clinical research into allergy.



Scanning electron microscopy image of dandelion pollen. This grain is 0.03 millimetres in diameter. Source: Palynologic laboratory, the Swedish Museum of Natural History

Bird ringing

Ringing wild birds has been carried out in Sweden since 1911, and the activity is now fully controlled by the Swedish Museum of Natural History. Ringing is carried out by both amateur ornithologists and by professional researchers, and approximately 300,000 birds are equipped with addressed and numbered rings each year. Half of the recoveries take place abroad, and the most distant recovery was made in New Zealand. Ringing was initially started in order to map the migration of birds, and it still makes an important contribution to this puzzle.

Bird ring. Nearly 4,000 rings are recovered and sent to us each year and all submissions are answered with information about when and where the bird was ringed. Photo: Staffan Waerndt

Furthermore, some species have changed their migration patterns, something that can be coupled with the milder climate experienced in recent decades. Ringing is also used to determine whether a species has increased or decreased in number, and to study survival, fidelity to one location, and distribution. Information about the recovery of ringed birds is important in bird conservation and tells us what certain species are exposed to, such as hunting, collateral capture during fishing, and collision with power lines.

The State Game

In order to "protect species threatened with extinction, rare species, and other particularly valuable animal species, and in order to secure animals of such species for scientific and educational purposes", the government has prescribed that dead individuals of certain mammal and bird species are to be reported and, where possible, handed over to the police to be sent onwards to the Swedish Museum of Natural History (wolves, bears, wolverines and lynx are to be handed over to the National Veterinary Institute).

The species that are defined as "State Game" are specified in Section 33 of the Hunting Ordinance. The animals are investigated at the museum, and samples are taken for the collections – tissue samples, and skin or feathers for the environmental specimen bank, skin and the skeleton for the collections of vertebrate zoology. More information is given below.

The animals passed on to the Swedish Museum of Natural History each year as "state stock" include around 30 sea eagles. Photo: Staffan Waerndt

NORDSIM

The NORDSIM laboratory (Nordic Secondary Ion Mass Spectrometer) is a joint Nordic facility for geological research financed jointly by Sweden, Finland, Norway and Denmark. Operations began in 1993 and are coordinated by a Nordic steering committee. The laboratory is built up around a Cameca IMS1270 ion microprobe, an advanced instrument that allows us to measure the composition of elements and isotopes in selected areas of a specimen, down to a few micrometers in size. There are only three such instruments in Europe.

Researchers, primarily from the Nordic countries, use the ion microprobe at the NORDSIM laboratory to carry out isotope analysis at a microscopic scale. Photo: Staffan Waerndt

Microanalysis of isotope variations opens new possibilities for geological research into the development of the Earth and how conditions on the planet have changed during the past 4.5 billion years. The instrument is principally used for dating rocks, but it is also used for many other applications. Examples are studies of meteorites, mussel shells and fossilised plants (details are given on Page 13 of isotope geology and radiometric dating).

Species that are covered by the State Game regulations

Birds:

Osprey, honey buzzard, barn owl, hawk owl, eagle owl, snowy owl, great grey owl, Ural owl, great bittern, Atlantic puffin, smew, black-necked grebe, avocet, grey-headed woodpecker, white-backed woodpecker, middle spotted woodpecker, kingfisher, Eurasian roller, hoopoe, golden oriole, lesser white-fronted goose, Caspian tern, black tern, storks, eagles, kites, falcons and harriers.

Mammals:

Bear, wolf, wolverine, lynx, musk ox, mountain fox, otter, whales

The Laboratory of Molecular Systematics

The Laboratory of Molecular Systematics works with analysing the genetic material of various organisms using modern DNA technology. The determination of DNA sequences allows us to reconstruct family trees for all conceivable groups of organism, not only those that are closely related, but also organisms whose evolutions diverged hundreds of millions of years ago. These methods have revolutionised our view of family relationships and evolution for many groups of organisms.

DNA sequences can also be used to identify species. The Swedish Museum of Natural History is taking part in an international collaboration that aims to sequence a particular gene for all organisms on Earth. We hope that it will be possible to use this information to determine a species in a manner similar to that used when the price of an item in a supermarket is determined by a bar-code. It is expected that a large number of new species will be discovered during this work. DNA can often be recovered from material that was collected more than 100 years ago, and this means that our collections are invaluable resources for these studies.

Databases on the internet make it possible for everybody to see what museum collections all over the world contain. GBIF and FishBase are two global databases that Swedish Museum of Natural History is helping to build up. Photo: ESSEN

GBIF and FishBase – global information about biological diversity

The Swedish Museum of Natural History is host for the Swedish node of GBIF (the Global Biodiversity Information Facility, **www.gbif.se**). GBIF is an international project in which just over 80 countries and international organisations are participating. The task of GBIF is to make information about the biological diversity of the Earth, primarily the information in biological collections and in observation databases, available at one common internet portal. GBIF's database contained 93 million items in February 2006, and this figure is to be compared with the 2 billion items estimated to be held in biological collections around the world.

FishBase **(www.fishbase.se)** is an international project built up around databases with information about fish from around the world. The Swedish Museum of Natural History plays a central role in FishBase, which contains information intended both for experts and for the general public.

Large databases such as GBIF make it possible for us to analyse biological diversity from new perspectives. These databases may constitute our most important source of information about the distribution of species, and thus they form the basis of many decisions taken in the field of conservation. The museum's own databases contain over 1 million records in 2006, and they are growing all the time. Sections of these databases can be accessed through the museum's website **(www.nrm.se/forskningochsamlingar/databaser)** and they can also be searched through GBIF.

Our databases and GBIF also contain photographs and maps. Making photographs available in databases that can be searched over the internet is an efficient method of allowing all to share in the wealth of the museum. It also makes the work of researchers easier, and it reduces the wear and tear associated with lending specimens, since a photograph can often replace the physical examination of an animal or plant. It is also possible to follow individual expeditions and the specimens they collect, keeping in this way up-to-date with the accession status of the museum.

Visit our website www.nrm.se
for more information!

Photo: Anna Roos

Naturhistoriska riksmuseet

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