NATUR
HISTORI
SCHES
MUSEUM
BERN

Cabinet of Curiosities

— the display collection

www.nmbe.ch

Eine Institution der
Burgergemeinde
Bern

The exhibition in figures

Total area: 340 m², Glass cube area 160 m²
Approx. 15,000 glass jars and 19,000 exhibits
Temperature: constant at 16 °C
Humidity: 40–55% relative humidity
Insulated glass to prevent condensation
Costs: CHF 1.5 million

“ Nature is under pressure. In Switzerland, a third of all animal and plant species are threatened. This we cannot accept. That’s why the Federal Council is taking action: we want to protect more land and thus give nature the space it needs. As a result, not only plants and animals will benefit —we humans will, too. This is how we can preserve the richness of species, shapes and colours which the Cabinet of Curiosities so impressively displays. This exhibition makes it clear that nature is worth protecting.”

Federal Councillor Simonetta Sommaruga
Head of the Federal Department of the Environment, Transport, Energy and Communications DETEC

“ The Cabinet of Curiosities—a unique experience—stimulates and motivates us to become more fully aware of the richness of our natural environment. This diversity inspires and encourages us—as scientists and as citizens—not only to talk about species extinctions, habitat loss and climate change, but also to think about what practical contributions we can make in our daily lives to protect our natural world. The exhibition can thus work wonders for us and for future generations.”

Marcel Tanner
President of the Swiss Academies of Arts and Sciences (a+)

“ Scientific specimens are an endless source of information and, combined into a collection, an invaluable asset for the generation of scientific knowledge. Their potential is inexhaustible—for addressing scientific, economic and social questions which we cannot even begin to imagine today. They will also be subjected to methods of analysis which we cannot yet conceive of, with the current state of our knowledge. At the same time, the exhibition showcases a rich scientific and research heritage and offers insights into the origins, evolution and diversity of life. Viewed through this lens, the position and activities of humans on this planet are placed in perspective, and our fascination with and respect for the wonders of nature can only grow.”

Christoph Beer
Director, Natural History Museum of Bern

Cabinet of Curiosities—the display collection

Scientific collections are home to millions of specimens of animals and plants. They serve as indispensable archives of the natural world, documenting life in all its many forms—what we call ‘biodiversity’—and allowing scientists to conduct essential research into the evolution, distribution and diversity of living beings. A deeper understanding of biodiversity is invaluable for our society: natural materials and substances as of yet unknown species could be the basis for future groundbreaking innovations in medicine and agriculture.

Despite the fact that biodiversity is irreplaceable and vital to humanity’s survival, it is threatened, making research in this field more essential than ever. Of the estimated 10 million species in the world, only around 2.1 million have been documented, and everyday countless disappear forever, along with their habitats, such as rainforests and wild river landscapes.

With this exhibition, the Museum is opening parts of its scientific collections to the public. A walk through our ‘Chamber of Wonders’ provides insight into our current collection activities, modern research methods and our priceless historical collections. All in all, the exhibition is an eye-opening overview of one of the most pressing issues of our time.

Naturhistorisches Museum Bern (NMBE)
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1 Why do we need collections?

Scientific collections contain a treasure trove of information. Millions of preserved animal and plant species allow, among other things, studying the origin, distribution and diversity of species, and recording the effects of environmental pollution and climate change on many organisms. These collections are an extremely valuable reference for identifying specimens of already described species, or the discovery of new species. Collections are also a window into the future: they can give us answers to questions we haven’t even thought of yet.

1.1 Understanding and protecting biodiversity

Most people know animals such as tigers and pandas. However, these well-known favourites represent only a very small proportion of global biodiversity. The majority of species are inconspicuous. Organisms like insects, spiders and snails make up a huge and largely unknown diversity of animal species, which can only be recorded, analysed and documented by specialists. Only exact knowledge of the species creates the necessary arguments to protect the last species-rich habitats, such as rainforests, from destruction.

NMBE 1061645

Black widow toad, *Ansonia vidua*
Malaysia, Island of Borneo, 2012, holotype

└↑ **Part of the research collection Fish of the peat swamp forests**
Brunei, Malaysia and Indonesia, 2009–2019

1.3 **This black widow toad is a so-called ‘holotype’ or ‘type specimen’. Such particularly valuable and irreplaceable specimens are the prototypes, the ‘standards’ on which the description of a species is based. The scientific name of a species if permanently attached to these individuals. Scientific collections have an important responsibility to preserve them.**

1.2 **Recording losses: barely discovered, these fishes—which include the world’s smallest fish—are either critically endangered or already extinct. Largely unknown so far, these very locally occurring animals are disappearing extremely quickly due to peat swamp forests in Southeast Asia being relentlessly destroyed to make way for palm oil plantations.**

The long road from the rainforest to the museum

Obtaining animals for scientific collections is easier said than done: before a frog, for example, from the rainforests of Borneo ends up in the museum, enormous efforts are required. Everything has to be done correctly—from submitting the right forms to responding to critical views.

Every expedition begins, not with adventure, but with bureaucracy. The researchers establish scientific collaborations, secure all the necessary approvals, and negotiate conditions. Once they arrive in the rainforest, it's not enough just to look around: many frogs are restricted to a particular habitat—for example, the narrow-mouthed frog. This tiny brown creature lives exclusively on an isolated mountain on the island of Borneo, hidden in dense layers of moss, leaves and roots on the floor of the rainforest. Though it is not a particularly rare species there, it took three weeks of night-time searches to find two specimens. Then came the steps which are indispensable for scientific collection work: the frogs were put to sleep and preserved on-site. For all the finds, the researchers documented the various processes involved, the precise locations, the animals' calls and much else besides.

“ Working at night in the darkness of the rainforest is the most enjoyable time. Surrounded by an incredible diversity of life, expressed through innumerable voices, I grasp the real purpose of my research. Even though the most exciting moments come much later, in the lab. ”

Stefan T. Hertwig, Head of the Department of Vertebrates, Natural History Museum of Bern

Rainforest expedition: students document and preserve the frogs collected.

The tiny narrow-mouthed frog *Kalophrynus nubicola* is difficult to track down.

Even though collection activities of this kind are performed in compliance with all the relevant scientific and legal requirements, the question is repeatedly raised whether science is not itself contributing to the extinction of such species. These concerns can be readily answered: the number of specimens collected is defined and tightly restricted. The frogs are preyed on by numerous birds and snakes, and the populations can easily withstand the loss of a few individuals. In addition, the major threat to many animal species lies in the rapid destruction of their habitat—most species become extinct due to habitat loss. Effective habitat protection depends on the findings of biodiversity research. Detailed knowledge of species and their habitats by far outweighs the loss of a handful of specimens for scientific collections.

New discoveries, intriguing diversity

On some of their numerous expeditions to the island of Borneo, the Museum's researchers have discovered hitherto undescribed animal species. The black widow toad *Ansonia vidua* and a recently discovered bush frog were previously among the estimated 8 million unknown living species. The primeval rainforests of Borneo have an exceptionally large biodiversity. Each new discovery reveals the innumerable varieties of life—from mysterious reproductive habits to sophisticated survival strategies.

In 2012, the Museum's international research team came across a small, black female toad in Pulong Tau National Park. Subsequent genetic analyses carried out at the Museum confirmed what they had initially suspected: this was a distinct species. On later expeditions, another three specimens were caught at the same site, again only females—no signs of males or tadpoles have yet been found. Because of the black coloration and the absence of males, the toad was given the specific name *vidua* (= widow). These creatures live in a small part of a protected 'rainforest oasis' in the midst of palm oil plantations and farmland. If this oasis is destroyed, the Widow Slender Toad will also disappear, together with the mystery of its reproduction.

The cloud forests of Pulong Tau National Park harbour immense biodiversity.

The bush frog *Philautus nepenthophilus* develops in the pitcher of a carnivorous plant.

In a remote cloud forest, the researchers discovered another unknown species—an inconspicuous brown bush frog. Here, too, genetic analyses and other investigations at the Museum showed that it belonged to a previously undescribed species. While these creatures' appearance is unspectacular, their life history is astonishing: the females lay their eggs in the water-filled traps of a carnivorous plant. The tadpoles develop in the security of these plants' 'pitchers', feeding on the stores of yolk in their gut. While the inner walls of the pitchers are too slippery for prey to escape, the young frogs simply hop out. Underlying this arrangement is a—not uncommon—form of animal-plant cooperation which makes life easier for both parties: the pitcher plant, growing on poor rainforest soil, requires nutrients, while the tadpoles need a safe pool—a rarity in the steep cloud forest. Hence the deal—pitcher for excreta.

1.5 Making cryptic diversity visible

Different animal species often look different from each other, but many are very similar in appearance. That is why the diversity of such groups remains hidden from the eye—only analyses of the genetic material, the DNA, reveal the differences. Genetic studies are, among other things, important for the protection of species: a large number of species that are actually endangered would otherwise be overlooked. These ‘hidden’, so-called cryptic species are found mainly in the tropics. But there are also surprises in the seemingly well-known animal world of Europe.

↓

‘Ugly brown frogs’, *Limnonectes ‘kuhlii’*-complex
Malaysia, Island of Borneo, 2012, undescribed species

NMBE 1028879 **Slow-worm,** *Anguis veronensis*
Besazio TI, Switzerland, 1995

NMBE 1037741 **Slow-worm,** *Anguis fragilis*
Aarberg BE, Switzerland, 2000

1.4 **These ‘ugly brown frogs’, once considered a single species, are a striking example of how different species can look undistinguishable from each other. In 2019, researchers identified 25 different species of brown frog, all of which probably have specific habitat and feeding requirements.**

1.6 **A discovery on our doorstep: in 2017, genetic analyses showed that in Switzerland two species of slow-worm occur instead of one, as previously thought. There is an easy way to tell them apart in the wild, though: one occurs north and the other south of the Swiss Alps.**

Biodiversity going up in smoke

What is the connection between muesli bars or instant soup and fish such as the chocolate gourami, pikehead and dwarf minnows (one of the world's smallest fish)? These species live in the ancient peat swamp forests of Southeast Asia, where this habitat is disappearing. Forests are being cleared and peatlands drained and burned to permit the development of plantations. Here, palm oil is produced, to supply the food industry. This ubiquitous ingredient may be cheap, but its true costs are immeasurably high.

Up until the 1970s, the unique peat swamp forests of Sumatra, Malaysia and Borneo were believed to be unpromising habitats, harbouring relatively few animal species. These forests are ancient, waterlogged, nutrient-poor ecosystems, comparable to Switzerland's mires. The trees grow on layers of peat up to 20 metres thick, vast accumulations of partly decomposed dead wood and other plant detritus. The tannins released by this vegetation turn the water into a dark, anoxic and acidic mixture. Not exactly ideal conditions—and yet the pools, rivulets, streams and rivers are teeming with life: research carried out in recent decades has shown that the peat swamp forests are home to more than 250 species of fish alone, including 100 only found in this habitat. But the rich diversity of animal and plant species has yet to be fully investigated, and time is running out: the unknown diversity could vanish for ever with the destruction of the forests.

" On our research expeditions, we've explored peat swamp forests that have been there for thousands of years. I was dismayed by the thought that we might be among the last people able to do so."

Lukas Rüber, Curator of Ichthyology, Natural History Museum of Bern

The waters of the peat swamp forest are murky and acidic, but teeming with life.

The world's smallest fish: dwarf minnows of the genus *Paedocypris* grow to a length of just 1 cm.

The systematic clearance of peat swamp forests for palm oil plantations is not only fatal for biodiversity—it is also exacerbating climate change: enormous amounts of carbon dioxide are stored in the peatlands, and when they are drained the soils become huge sources of greenhouse gas emissions, as the plant material decomposes rapidly without water. In addition, large swathes of Southeast Asia are frequently shrouded in smoke as a result of forest clearance by burning and peatland fires. Whenever the thick haze descends over Southeast Asia, human and animal health suffers, the economy is damaged, and political conflicts flare up.

Who do scientific collections belong to?

Around the world, millions of archived specimens of animals, plants, fossils and minerals are held in scientific collections. A previously neglected topic is now rightly becoming the focus of international debate: many holdings in European museums date back to the colonial era. They could only be acquired because scientists exploring the occupied countries had the benefit of the colonial rulers' transport network and military and missionary outposts, as well as a host of local inhabitants largely deprived of rights—even in cases where the home country (e.g. Switzerland) did not itself have any colonies.

How legitimate is the possession of collections originating from colonised countries? While this question initially concerned, above all, works of art and cultural artefacts from the colonial era, it has increasingly also been extended to scientific items. In contrast to works of art—created by humans within a cultural context—the question of ownership rights is much more difficult to answer in relation to natural objects. Here, there is no 'creative act' and no unequivocal authorship. So who do all the natural treasures, biodiversity, fossils, rocks and minerals belong to? In the case of finds of particular historical or cultural significance, such as skeletons of dinosaurs and giant ground sloths

Parrots from the historical Emil A. Göldi collection, gathered in Brazil between 1898 and 1911.

or skulls of early humans, repatriation is also important for the public at large. But the majority of scientific collections from a colonial context are of interest exclusively for the research community. Rather than returning these to the country of origin at all costs, it is more forward-looking to further strengthen long-established international scientific collaboration. Today, the possibilities for global cooperation are more varied than ever before: international loans, digital networking, joint data collection or exchange in real time enable collections to be the subject of global research wherever they may happen to be located. This could also bring us a step closer to answering the question of who the diversity of nature actually belongs to—is it, for example, indigenous peoples? Or subsequently established nation states? Or does humanity as a whole share a responsibility to investigate and preserve its natural heritage?

Who does biodiversity belong to?

Biodiversity is a precious natural heritage. At the same time, however, it is subject to hard-nosed commercial interests. Species-rich habitats such as rainforests harbour substances which may be valuable, e.g. for medicines, cosmetics or the food industry. It was long common practice for Western industrialised nations to exploit these natural treasures without compensating the countries where they originated. To prevent so-called biopiracy, the Nagoya Protocol was adopted by the UN in 2010.

The Nagoya Protocol provides for the first time, an international, legally binding framework to ensure that countries of origin share in the benefits arising from the utilisation of natural genetic resources—from animals, plants and microorganisms. The earlier 'help yourself' mentality can be illustrated by just one of many examples: in the 1960s, a pharmaceutical company developed highly effective drugs for the treatment of leukaemia derived from the Madagascar periwinkle, but the country of origin did not benefit in any way from the massive profits generated. Often, however, promising active substances can only be discovered with local support, since in tropical regions with rich biodiversity indigenous experts have long experience of the medicinal use of plant leaves, blossoms, fruits, roots or bark. Thanks to this knowledge, pharmaceutical companies have obtained numerous drugs—e.g. for the treatment of cancer, malaria, pain, coughing or diarrhoea—from rainforest plants.

Traditional medical knowledge from the rainforest: a medicinal plant market in Madagascar.

The Protocol is also applicable in cases where no direct economic benefits arise—as in biodiversity research. Here, standardised agreements govern the type of use and the sharing of scientific results, such as publications of genetic analyses for relatedness studies or species identification. This creates a basis for long-term scientific collaboration between the countries involved. However, some concerns remain: neither the Nagoya Protocol nor other regulations on the use of biodiversity make any contribution to its protection and conservation. Rather, the focus is on the utilisation of individual countries' natural resources. But in view of global problems such as biodiversity loss, habitat destruction and the climate crisis, is a purely economic and nationalist conception of humankind's shared natural heritage still justifiable?

1.7 Collections are useful

Scientific collections can be used not only to conduct basic research, but also have practical applications. Among other things, they give access to organisms not easily found in nature and, therefore, provide the specimens needed to look at many different questions. For example, poisonous species can be safely distinguished from harmless species for medical purposes. In addition, long term trends in wild populations can be detected, such as the sharp decline in insect numbers over the past few decades. The numbers show that a large fraction of the buzzing diversity has disappeared.

NMBE 1016957

South American common lancehead, *Bothrops alternatus*
Argentina, date unknown

⌞↑ **Grasshoppers and other insects,** content of a Malaise Trap
Trimbach SO, Switzerland, 1–7 August 2002

1.8 **The venom cocktails of the many species of the South American common lanceheads are deadly, but they are also used in medicine to combat cancer cells. The species look very similar, but their venoms are very different. Scientific collections enable the reliable determination of the species.**

1.9 **Insect researchers working in Krefeld, Germany, have spent 27 years collecting insects and weighing the yield. In this way, they established in 2017 that 75% of the initial insect mass had disappeared. This shocking result showed beyond any doubt that insects are dying off and sparked a strong international reaction.**

Where have all the insects gone?

Bugs and creepy-crawlies all over the place—on your ice cream, in your beer glass, in your bedroom at night. On some summer days, your home may seem to be swarming with these 'pests'. But this impression is misleading: formerly vast insect populations are now under threat. And most of these supposed pests are actually vital for humans and nature: insects pollinate crops and other plants, improve soil fertility and are an essential food source for wildlife—from trout to swallows. But insect habitats have been disappearing for decades.

People born before the 1970s may have memories of insect-splattered windscreens or meadows teeming with grasshoppers. Going back even further, the density of insects must have been greater than we can now even imagine. Evidence of this abundance and diversity—and also its decline—can be found in scientific collections. Around 1900, for example, an entomologist in the village of Peney (canton of Geneva) described over 300 species of wild bees—more than half of all those ever found in Switzerland. Today, this is inconceivable—Switzerland's cultural landscape is a wasteland for insects. Wildflower meadows, mires and floodplains have been replaced by nutrient-rich grasslands and maizefields. New toxic agents designed to control unwanted plants and animals decimate not only so-called pests but also pollinators important for food production, such as flies, butterflies and wild bees. Pesticides and slurry also destroy their food sources—wild plants. When insects are endangered, other creatures such as fish, birds or bats also start to decline: numerous insectivores are running out of food.

Insect biodiversity—formerly immense—is steadily declining.

There are certain parallels between the destruction of natural habitats in this country and the devastation of rainforests: as they disappear, biodiversity—largely still unknown—is also lost. Switzerland's biodiversity is likewise by no means fully documented. In 2016, the first comprehensive DNA analyses using barcoding revealed an as-yet undiscovered species richness in what were believed to be well-known insect groups. So we too have only a rough idea of what could well be lost for ever.

“ The Meadow Grasshopper was once common, found on every pasture, however rich. Today, there are grasslands where not a single grasshopper—not even the commonest—can live.”

Hannes Baur, Curator of Entomology, Natural History Museum of Bern

Snails—from the collection to an app

For many years, anyone wishing to identify species in the field had no choice but to pack the necessary literature—often weighty volumes with few illustrations and barely comprehensible information. This also applied to mollusc species. To remedy this situation, using snail and mussel shells from the Museum's extensive collection, biologist Estée Bochud developed a digital identification key.

Around 250 species of slugs and snails and about 30 species of mussels are known to occur in Switzerland. Visual identification of these species depends on a large number of characteristic physical features, painstakingly depicted in drawings and photographs. For Bochud, it would not have been possible to collect specimens of all these organisms in the field: many molluscs are either rare, minute, or live in inaccessible habitats such as mountain peaks or under water. For this reason, the project was only possible thanks to the Museum's extensive collection of molluscs: the laborious task of gathering specimens had already been completed by earlier researchers.

> **“ What people will still have to do themselves is observe carefully—for that, you need plenty of time, a magnifying glass and a lot of practice.”**
>
> Estée Bochud, Research Assistant Malacology, Natural History Museum of Bern

Who’s who? A digital identification key can provide answers.

Using countless items and archive images held in the collection, the biologist created hundreds of high-resolution photographs, drawings and species profiles and provided comprehensible descriptions, as the digital identification key is also designed for interested laypersons. This was no easy matter—many molluscs differ externally only in tiny details. In addition, a single species of slug may vary in colour and pattern, while many species have to be dissected, as they can only be differentiated by their reproductive organs.

In spite of these difficulties, the mollusc identification app, which has been available in a portable (smartphone) version since October 2019, is an extremely useful tool. It can be updated at any time and has a simple, intuitive interface: all the questions can be answered with ‘Yes’, ‘No’, or ‘Feature not seen’. The online tools are conceived and programmed by info fauna, the Swiss National Data and Information Centre for Fauna. info fauna has produced digital identification keys for the mammals, reptiles, amphibians, dragonflies and freshwater crustaceans found in Switzerland, and it provided vital support for the development of the digital identification key for molluscs.

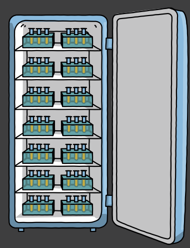
Download identification keys:
App webfauna, App Stores iOS/Android

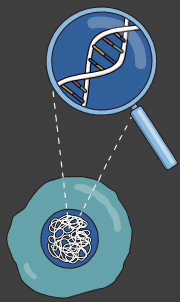
2 Life’s secrets revealed in death

This room may look sterile, but it is actually teeming with life: deep freezers set to minus 80 °C house thousands of tissue samples taken from specimens of scientific collections. Cutting-edge DNA analysis enables scientists to discover new animal species, reliably identify the species an individual belongs to, and shed light on evolutionary relationships. The frozen treasures also contain information about climate change and environmental pollution. This tissue collection is part of the worldwide efforts to understand and protect the diversity of life.

2.4 DNA extraction in the lab of the Cabinet of Curiosities

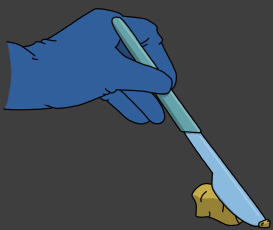
In the freezers, thousands of small pieces of animal bodies, the tissue samples, are stored.





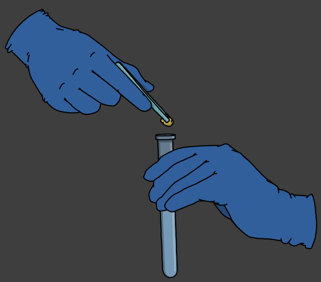
For genetic analysis, the DNA, the animal's genetic material, has to be isolated from the samples. This is done in the lab, step by step.

Taking the tissue sample out of the freezer.



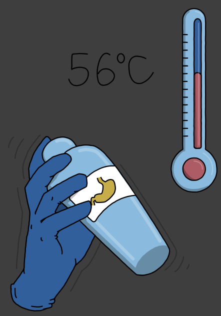
Cutting a tiny piece from of the sample at the lab bench ...

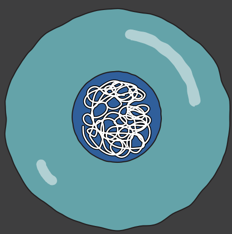
... and inserting it into a tube.



Adding digestive enzymes and a detergent solution with a pipette.

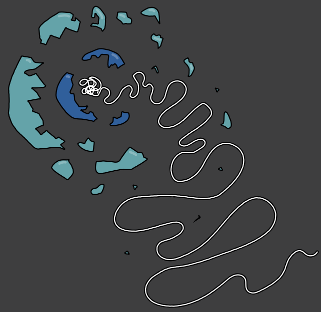
The tube is placed inside a thermoshaker. Inside this device, the tissue sample is digested with a combination of heat, movement and digestive fluids, almost as in a real stomach.



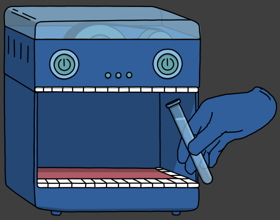


This is necessary, because the DNA is well protected and tightly wrapped inside the cell nucleus.

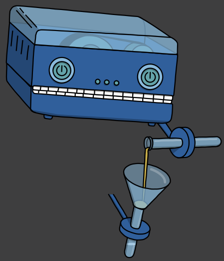
To release the DNA out of the cell, the digestive enzymes break down the cell's proteins. The detergent solution dissolves the fatty outer layer—the membrane—of the cell and the nucleus.



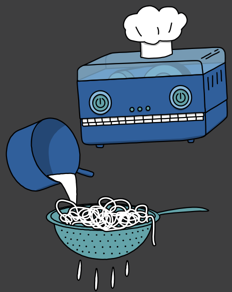
Thus, the DNA is extracted and floats inside the digested tissue sample. A strand from a single cell is quite long. A human strand, for example, is about 2 metres long.



Now, the digested, liquid tissue sample is put inside the DNA extraction robot. It takes over from here.

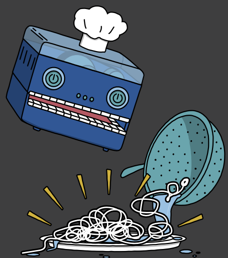


First, the robot filters the tissue sample.



The DNA gets caught on the filter. The robot rinses repeatedly all other remaining cell components out with various liquids.

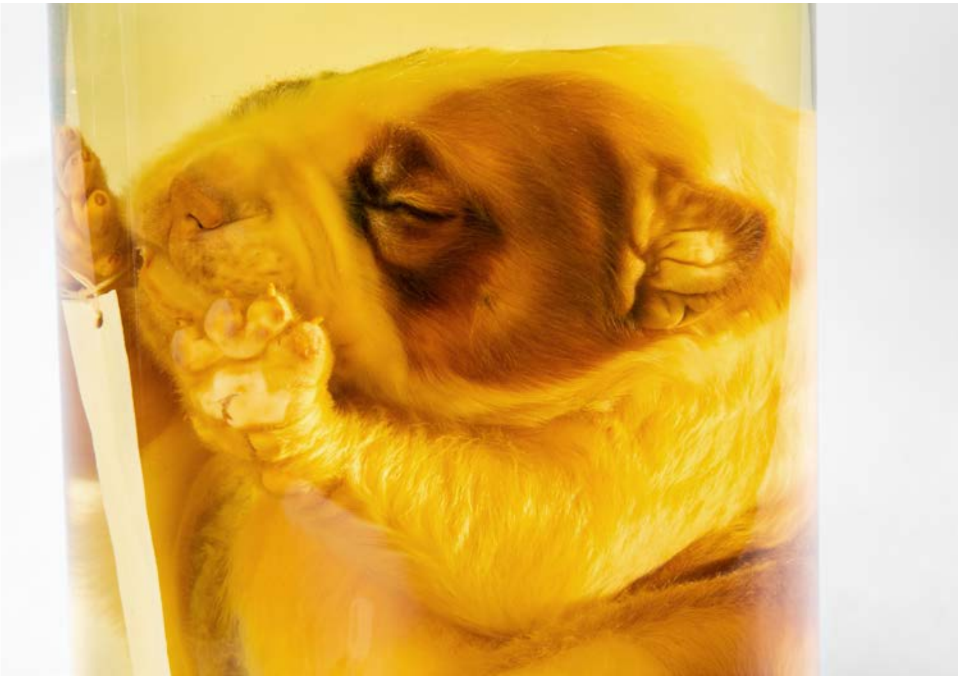
Finally, the robot rinses with water. The cleansed DNA is released from the filter and is collected into a new tube.



The DNA is now ready for genetic analyses.

NMBE 1052872

Mouse-eared bat, *Myotis crypticus*
Wohlen BE, Switzerland, date unknown



NMBE 1015697

St Bernard Dog, *Canis lupus familiaris*
Berne BE, Switzerland, 1925

⟻

Part of the Walter Küenzi research collection
1918, rack 14

2.3 **Genetic research has uncovered a few surprises in Switzerland's native bats: in 2019, researchers discovered a new species of mouse-eared bat, *Myotis crypticus* ('hidden mouse-eared bat'). This species had previously gone unnoticed, as all mouse-eared bats look virtually the same.**

2.1 **This collection of bird's eyes and brains highlights earlier research methods. Before the advent of DNA analyses, scientists used exclusively morphological features to study the evolution and development of living beings. Today research in morphology is an essential complement to genetic analyses.**

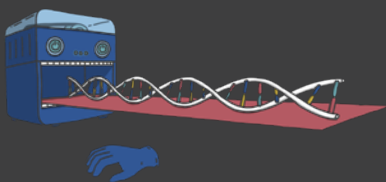
2.2 **What is a puppy doing here? With 2,800 specimens, the Museum houses the largest scientific collection of pedigree dogs in the world. All the dogs died of natural causes and were subsequently donated to the Museum. Scientists from all over the world use our dog collection to study, for example, how dogs derived from wolves.**

Stories from the freezer

The laboratories in the Museum are full of stories about life. But they're to be found in the freezers: here, stored at minus 80 degrees, are thousands of little pieces of animal bodies, so-called tissue samples—all clearly numbered, so it's clear what belongs to which animal. These little samples contain masses of information about the diversity of life. But first things first—where do the samples in the freezer come from?

Researchers capture the animals in their natural habitat—obviously with all the necessary approvals—and prepare them then and there for the scientific collections: the body is placed in formalin, and a small part of it is put in a tube containing alcohol or some other liquid used to preserve it. This sample is added to the Museum's collection of tissue samples.

Now the laboratory studies can begin. First of all, the DNA—the organism's genetic material—has to be isolated from the tissue sample. To do this, we use a DNA extraction robot.

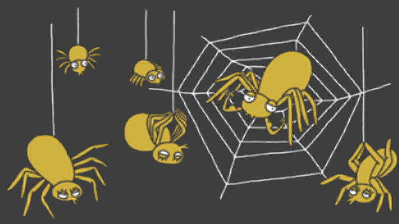


By analysing the DNA, not only can we discover new animal species and investigate how species are related to each other, but we can also find out exactly what species we are looking at. For often, animal species cannot be told apart with the naked eye.

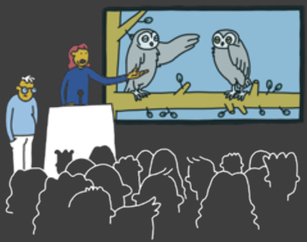
Here, one thing about DNA comes in handy: the DNA from each animal species has its own unmistakable pattern. This pattern arises from the sequence of the four different chemical building blocks that make up DNA. These patterns contain a lot of information, which we can make out using various methods of analysis.

One of these methods is known as DNA barcoding. With this method, only one particular short section of DNA is studied. In most animal species, this section has a unique pattern—like the black stripes of the barcode found on products at the supermarket. Using barcoding, we can often identify an animal species quickly and reliably.

Let's take as an example the barcoding of spiders: before this became possible, some species of spiders could only be identified if the specimen studied was male. For only mature male spiders have visible sex organs near the head, which look quite different in different species. Thanks to barcoding, we can now also reliably identify the species of female and, above all, baby spiders. Of course, this method also works with other young animals, such as tadpoles or juvenile snails.



Barcoding makes possible a whole new way of identifying animal species, as researchers around the world continue to analyse the barcodes of known species and deposit them in digital barcode libraries. Researchers at this Museum have contributed, for example, the barcodes of many European spiders, Swiss fish and numerous species of slugs and snails.

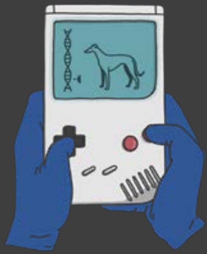


This collection of barcodes makes it much easier to identify animal species: we can find out the barcode of an unknown animal and then compare it with the known barcodes stored in the library. With this method, tricky biological puzzles can be solved: in 2013, for example, ornithologists announced that they had discovered a new owl species in Oman, on the Arabian Peninsula. But researchers at the Museum had a suspicion and analysed the barcode of an owl held in the collections, long since described. And, sure enough, what appeared to be a new discovery was in fact the same species, known since 1878!

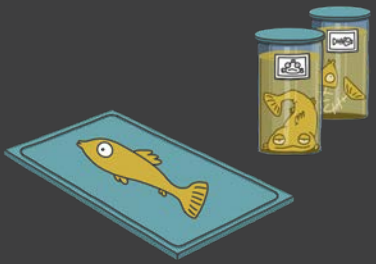
But sometimes barcoding is not sufficient to identify an animal species or detect a new one. In these cases, several sections of DNA need to be analysed, not just one short section.

One example is the discovery of the Red Hot Chili Pepper Frog: this attractive, unfamiliar creature was captured by scientists in the rainforest of Borneo. Detailed DNA analysis confirmed that it was a new, previously undescribed species.

Other types of DNA analysis help, for example, to reveal how body shapes arise from the information stored in DNA. Here, the Museum's dog collection proved extremely useful: taking the example of preserved bull terrier specimens, scientists compared the rapid changes in body shape—from unremarkable 'average' dog to powerhouse—with the underlying genetics. They found that a small number of DNA 'switches' were responsible for changes in body shape. This is why breeders can radically alter dog features such as body size, leg length, nose form or ear placement within just a few generations.



Also stored in scientific collections is information on the environment: for example, ibex horns carry signs of climate change. For each year, the grass eaten by these animals leaves chemical traces in their horns, ring by ring. Analysis of these traces in old ibex horns from the Museum's collection showed that, as it gets hotter and drier, plants save water and store more CO_2 and nitrogen—how alpine flora responds to climate change is thus recorded in these horns.



Traces of environmental pollution can also be found in animals. In 2015, scientists at EPF Lausanne analysed 40 fish specimens from Lake Geneva held in the Museum's collection and found tiny plastic particles in the stomach and gut. These micro-plastics come from the millions of tonnes of plastic waste washed into waterways each year. Although this waste is worn down by water, sand, wind and waves, it doesn't disappear altogether—and it returns to us via the food chain.

These are just a few examples—lurking in scientific collections are countless other stories waiting to be told.

Animated film

Barcodes in spiders: mysteries to be unravelled

As a general rule, many animal species can be reliably identified using DNA barcoding. But with this method, as so often, everything is rather more complicated on closer inspection. The example of spiders illustrates that, in some cases, the genetic barcode 'tag' can only help to identify a species in conjunction with the animal's external appearance and behaviour.

As far as barcodes are concerned, things get positively anarchic with certain groups of wolf spiders. These widely distributed creatures, which hunt without spinning webs, are a source of scientific mystery. For example, three closely related species of wolf spiders can be readily distinguished (with an expert eye) on the basis of their appearance and differences in their courtship behaviour: to impress the females, the males put on virtuoso displays of dancing and drumming—each species in its own particular way. But when the barcodes were analysed, the results were surprising: they are absolutely identical.

The converse was true in the case of so-called twin species of wolf spiders: physically, the two species are almost identical, with only tiny differences in the size of their reproductive organs. The similarity ended with the barcodes, however, which showed marked differences.

“ What I find fascinating about spiders is that they're completely different from us. They literally do not inhabit our world. ”

Christian Kropf, Head of the Department of Invertebrates, Natural History Museum Bern

Do the yellow, white or red markings of the Napoleon spider *Synema globosum* indicate different species?

Synema globosum with white markings: genetic analysis revealed that the different colour variants belong to the same species.

Further mysteries are posed by the Napoleon spider, a species from the crab spider group: it has striking markings on its abdomen, with white, red or yellow patterns on a black background, and its reproductive organs show substantial variation. It was suspected that this group might be found to include unknown, so-called 'cryptic' species. For this reason, researchers at the Museum compared the barcodes of a large number of crab spiders from different regions. Three groups of barcodes could be distinguished—were new species perhaps developing? Further sections of DNA were then analysed for possible differences, but to no avail. Nor was any evidence of cryptic species provided by statistical analyses of origin, coloration or the shape of the reproductive organs. The question how a species can be precisely demarcated is hotly debated by scientists. Researchers at the Museum support the view that, as well as the barcode, other genetic data, physical characteristics and behaviour should be taken into account.

3 Preserving for eternity

Building and maintaining a scientific collection is an art in itself. If animal and plant matter is not properly preserved, it will be destroyed by bacteria, mould or insects, fade in the light or rot. Wet collections such as our 'Chamber of Wonders' require preservatives such as alcohol and formalin, controlled lighting, and cool temperatures, airtight seals and the right air humidity in order to prevent the specimens from decomposing. The collection must be preserved and available for future generations.

 Collections and the ravages of time

The collection built up by naturalist Emil Göldi is both a useful historical reference and a good example of the effort required to preserve a collection over a long period of time. Between 1898 and 1911, Göldi, a pioneer of exploration in the Amazon region, sent 9,645 insects, 2,964 birds, 987 mammals and a variety of reptiles, fish and amphibians to the Natural History Museum in Bern—he did not trust the specimens to withstand Brazil's tropical climate. Over many years, the exposure to light and the high humidity and temperatures have left their mark on some of these valuable representatives of the Amazon region's amazing biodiversity—a small selection of which is exhibited here.

NMBE 1019195 — **Bullfrog,** *Rana catesbeiana*
North America, 1967

NMBE 1019192 — **Bullfrog,** *Rana catesbeiana*
North America, date unknown

Agone, *Alosa agone*
Lake Maggiore, Switzerland, not restored for exhibition purposes

NMBE 1001697 **Pale-Throated Sloth,** *Bradypus tridactylus*
Part of the Emil A. Göldi collection, 1898–1911, rack 18–19

3.1 **Improper storage has destroyed the pigments in this frog's skin: prolonged exposure to light and high room temperature have given it a bleached appearance. The undamaged specimen was kept in a cool, dark place—the same conditions as in our 'Chamber of Wonders'.**

3.3 **These fish were professionally preserved in the 1920s. However, they got damaged because of the lack of regular maintenance. As a result, the specimens have begun to disintegrate, with fat and proteins from their bodies making the preserving liquid cloudy. Mould is also visible on the lid.**

3.4 Steinmann-Eawag collection: a window into past diversity

This collection provides a unique glimpse into fish diversity in Switzerland between 1871 and 1953. It shows how rich Swiss waters were before extensive water pollution led several fish species to go extinct. It is the most significant historical reference collection for current research of the native fish diversity in Switzerland. Despite its importance, it was nearly thrown away. Fortunately, a researcher stepped in and saved the scientific treasure. The collection eventually found its way to our Museum, where it was painstakingly restored by experts.

↦ **Part of the Steinmann-Eawag collection**
1871–1953, rack 20–26

New lustre for old fish: restoration of the Steinmann-Eawag collection

When the Steinmann-Eawag collection arrived at the Museum, it looked a sorry sight. Ill-fitting lids, shrivelled-up fish, crusts of salt and fat, discoloured preservation fluids—clearly, a lot of work needed to be done. The jars had been provisionally stored for decades under varying conditions. Thanks to a researcher, they were transferred to the Museum rather than being permanently disposed of, and now for the first time the necessary resources were available to allow the collection to be professionally restored.

The Museum's preservation team faced a complex task: they wished to maintain the impression of a historical collection, while at the same time using the latest restoration methods to make the specimens once again accessible for scientific studies. Over a period of several months, the experts repaired the damage suffered by the fish and replaced defective containers and lids, cleaning and reusing the historical jars wherever possible.

The preservation fluid in the old specimen jars was a problem in itself: nobody knew the precise composition of the mixture of alcohol and formalin discoloured by fish skin pigments. It had to be assumed that the liquid also contained other toxic substances such as lead salts, arsenic or mercury, formerly used with the aim of improving the preservation of specimens. To ensure that these mixtures could be appropriately disposed of, the team had

“ It's remarkable that the best method for sealing jars for long-term storage—using negative pressure—is well over a hundred years old. But because it's a very elaborate process, it fell out of favour in museums. It took decades for its advantages to be recognised once again. ”

Martin Troxler, Preservation Team Leader, Natural History Museum of Bern

Dried-up and discoloured in non-airtight jars: the historical collection prior to restoration.

The newly restored Steinmann-Eawag collection: a highlight of the Cabinet of Curiosities.

several samples analysed by an external laboratory. Then came the ultimate 'beauty treatment': the experts used special techniques to rehydrate the desiccated fish, removed decades-old fat deposits and carefully brushed off salt crusts, so that the specimens no longer showed any visible signs of damage. Lastly, the restored fish were placed in fresh 75% alcohol, and the jars were sealed under negative pressure.

Today, the Steinmann-Eawag collection is one of the highlights of the Cabinet of Curiosities and, with appropriate management and storage, it should be available for research for many years to come.

4 Swiss fish—endangered diversity

Switzerland is a fish paradise. The last ice age created an aquatic landscape in which a unique diversity of fish could develop. Virtually every lake and river is home to rare fishes that only occur locally. But this richness is under threat of extinction: Of more than 130 described fish species in Switzerland, at least 14 have disappeared and around 50% are critically endangered as of 2020. Many species are not well known, and many are yet to be discovered. Scientist and government agencies work together to study and document the unique Swiss fish diversity—you can only protect what you know.

3.5 Documenting the loss

The Steinmann-Eawag collection shows the effect on fish diversity of the increase of water pollution after World War II. Six whitefish species have disappeared due to pollution. Phosphates from washing detergents, slurry from agricultural fields and untreated residual waters massively increased the nutrients in the lakes and rivers and the resulting algal blooms literally depleted the air in the water. Some whitefish species that live in deep, clear, oxygen-rich water, went extinct as a result. While steps were taken to reduce pollution, new threats are now emerging.

NMBE 1076371 **Gravenche,** *Coregonus hiemalis*
Lake Geneva, Switzerland, 1895, globally extinct, Steinmann-Eawag collection

NMBE 1076376 **Féra,** *Coregonus fera*
Lake Geneva, Switzerland, 1895, globally extinct, Steinmann-Eawag collection

NMBE 1076229 **Kilch,** *Coregonus gutturosus*
Lake Constance, Switzerland, 1896, globally extinct, Steinmann-Eawag collection

3.6 **Priceless rarities: many whitefish species are restricted to one or a few lakes, so their local extinction actually means that that they are lost to the world forever. Scientific collections contain just a few specimens of extinct whitefish species—the only evidence that these species ever existed.**

4.1 Projet Lac and Progetto Fiumi: a modern inventory of Swiss fish species

Approximately 50% of fish species in Switzerland are endangered. But how many species are there? Where do they live and how can they be protected in the future? To answer these questions, Eawag, the Swiss water research institute, carried out two research projects—Projet Lac and Progetto Fiumi—between 2010 and 2018. For these projects, scientists systematically collected fish from 31 different lakes as well as many rivers and streams, and compiled the first comprehensive inventory of fish in Switzerland. The around 20,000 fish sampled in these projects now constitute the national reference collection of the Museum.

⌊↑ **Part of the national reference collection Projet Lac and Progetto Fiumi**
2010–2018, rack 27–35 and interior area

4.2 **The Museum’s reference collection consists of up to 30 individuals of the same species of fish from every Swiss water body. This number of specimens is necessary to confidently detect genetic and morphological differences between species, many of which occur only locally. A single individual may not be representative of a species.**

4.4 Swiss fish diversity: a complex matter with many unknowns

Results from Projet Lac and Progetto Fiumi indicate that fish diversity in Switzerland is much more complex than previously thought. Many fish groups, such as whitefish or common minnows, include cryptic species that look virtually the same, but may occur at different depths, require different food or have different breeding times. The apparently well-known Swiss fish fauna, is actually full of surprises. As in the tropics and other species-rich habitats, however, these species may disappear before we have the chance to document them.

Selection of whitefish diversity, rack 31

NMBE 1069286–1069298 **Minnow of the Danube region,** *Phoxinus csikii*
Lake Lucerne, Switzerland, 2014, Projet Lac

NMBE 1071280 **Lake Constance deep water char,** *Salvelinus profundus*
Lake Constance, Switzerland 2014, Projet Lac

4.5 **The 'whitefish fillet' we eat belongs not to a particular whitefish species, but to a complex fish group. Collections allow scientists to keep documenting and updating the diversity of whitefish, which as of 2020, stands at 31 species. Many of these species occur in only one or a few lakes, and nowhere else.**

4.3 **In 2020, researchers working at the Museum conducted genetic analyses that show that in Switzerland there are three species of minnow: the Italian minnow and two species that had previously only been found in southern France and the Danube region. Another surprise came when the researchers were unable to find a trace of the only minnow species supposed to occur in northern Switzerland.**

4.6 **In 2014, the Projet Lac stumbled upon a fish believed to be extinct since the 1970s: the Lake Constance deep water char. This species requires deep, oxygen-rich water to breed, conditions that almost completely disappeared due to the massive over-fertilization of the lake.**

4.8 Fishes in Switzerland are endangered

Swiss fish are endangered for a number of reasons: they lack sufficient food because insects and micro-organisms are being killed by environmental toxins. The course of many rivers and streams has been straightened, which reduces the number of available spawning grounds and hiding places such as gravel banks and piles of driftwood. In addition, many fish species travel upriver to breed, yet are unable to do so due to the existence of dams and reservoirs. Climate change is also driving fish species to extinction: in summer, water temperature can reach 30 °C, and tens of thousands of fish die of stress and lack of oxygen.

NMBE 1065682 **Grayling,** *Thymallus thymallus*
Lake Geneva, Switzerland, 2012, status critically endangered, Projet Lac

NMBE 1055869 **Sea Lamprey,** *Petromyzon marinus*
Garonne, France, 2007, extinct in Switzerland

4.7 **'If we continue to experience summer temperatures as in 2018, then soon we'll find the grayling only in museums' (Patrick Wasem, fisheries officer for the canton of Schaffhausen, 2019). These fish require cool, flowing, oxygen-rich water. Extremely hot summers such as those in 2003 and 2018 led to the death of virtually all animals in some places.**

4.9 **The Sea Lamprey became extinct in Switzerland in 1884. This migratory fish travels from the sea up into rivers in order to spawn. The construction of hydroelectric power stations prevents them from reaching their breeding grounds. It is interesting to note that the Sea Lamprey is not actually a fish: this ancient jawless creature uses its sucker-like mouth full of sharp teeth to feed on living fish.**

Renovating Europe’s ‘water tower’

Water is a defining feature of Switzerland’s landscape, with 6,668 large and small lakes and an intricate 65,000-kilometre-long network of rivers and streams. From the early 19th century onwards, the country’s natural waters faced growing pressures. Wild rivers were increasingly replaced by straightened channels, streams were culverted, and mires and floodplains were turned into farmland. Hydropower plants were constructed, waters dammed, and lakes heavily polluted by fertilisers and wastewater.

Today, a dip in the Aare or in Lake Neuchâtel to cool off on a hot summer day is something we take for granted. But until the mid-1970s, many shorelines were blighted by mountains of foam, and bathing was often prohibited. With the construction of wastewater treatment plants and the introduction of stricter environmental regulations, Switzerland’s lakes and rivers—and aquatic wildlife—gradually recovered from the worst effects of direct pollution.

Over the years, however, it became clear that it was not enough merely to keep waters reasonably clean. The removal, constriction and drainage of waters and wetlands destroyed valuable habitats—and the animal and plant communities which depended on them. In addition, the massive flooding seen at the end of the 20th century showed that concrete was no longer sufficient for flood control. The aim now is therefore to return to rivers and streams some of the space which has been wrested from them over the centuries: under the Waters Protection Act, 4,000 kilometres of degraded watercourses are to be restored by the end of this century—thus creating new habitats for endangered animals and plants, areas for human recreation, and buffers for future floods.

Natural streams and rivers provide habitats for innumerable species—from fish to flies.

Hugging the bank, pike lie in wait for a wide variety of prey—fish, frogs or birds.

At the same time, improved legislation is required to address new threats: increasingly potent agrochemicals, as well as micropollutants such as hormones and pharmaceuticals, are harming aquatic organisms and contaminating water resources. While these problems can be resolved at the national level, Switzerland also has to adapt to global challenges: rising water temperatures due to climate change are poorly tolerated by certain fish species. And new shipping routes are opening the way for invasive species, such as gobies from the Black Sea, which can outcompete native fish species. This is another reason why it is important to restore rivers and lakes: natural waters, unlike straightened channels, offer a wide variety of habitats—cold-water pools, shallow riparian zones, rapids, woody debris or gravel banks. This diversity of refuges and breeding sites increases the chances that aquatic organisms will be able to survive difficult conditions.

Generating knowledge through science

The results of research projects such as Projet Lac and Progetto Fiumi provide solid evidence of the current state of fish diversity in Switzerland. The findings obtained can be used in practice, for example, to improve the management of fish stocks—for the benefit of humans and wildlife. But this sound scientific data also helps the federal and cantonal authorities to fulfil their responsibilities to protect and enhance natural waters, and to conserve the rich biodiversity of lakes, rivers and streams.

For Eawag, the Swiss water research institute, the two research projects Projet Lac and Progetto Fiumi were major undertakings: the aim was—for the first time in the history of Switzerland—to carry out a systematic and comprehensive survey of fish communities in the country's lakes and rivers. What species occur? At what depths are the various species to be found in lakes? How are they distributed in rivers and streams? The surveys were conducted using standardised methods so that they would be comparable with international studies and repeatable in the future. For this is the only way of identifying trends and changes over time, and ensuring that the effectiveness of protection measures taken today can be assessed—for example, will Switzerland's fish populations be in better shape in 2040 than they are today?

Researchers examine fish caught during a Projet Lac survey.

In addition, these research projects have shown, firstly, that 40% of the fish species observed are found exclusively in Swiss lakes and, secondly, that species diversity in rivers and streams is much greater than was previously supposed. Switzerland was already known to be a 'fish paradise', but the new findings mean that the country is now officially recognised internationally as a 'fish diversity hotspot'; they also highlight its responsibility to conserve this unique richness. From more fish-friendly hydropower operations to more natural banks and shorelines, and more space for rivers and streams in our landscape: a wide variety of efforts are needed to enable threatened fish populations to recover. But the demands placed on our water resources are complex and sometimes difficult to reconcile with protection goals. This makes scientific data indispensable—only it can provide a sound basis and arguments for far-reaching decisions.

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Nelly Rodriguez, photos of exhibition and specimens

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