Accepted on 23 April 2007
J Zool Syst Evol Res doi: 10.1111/j.1439-0469.2007.00431.x

Memorandum

The future of systematics in Switzerland: systematics as a key discipline in biology

Swiss Academy of Sciences

We live in a world full of living creatures of which we ourselves are part. Approximately 1.8 million species of microorganisms, fungi, plants and animals are known by name today, however, the number of species yet to be named scientifically is estimated at 10 to 30 million worldwide. Identifying a species and naming it is a fundamental process, for whoever works with species can only convey the knowledge surrounding them if he knows the organism's correct name.

Systematics as an integrative science names organisms, analyses their relationship to other organisms, and creates a species description and identification key. Building on this foundation, systematics investigates the relationships between species and their evolutionary development, and as a consequence, systematics forms the basis for every evolutionary observation. In addition to morphological and anatomical features, scientists use physiological, cytological and behavioural characteristics to describe and compare species. For several years now, genetic similarity as assessed through DNA analysis is also used to determine hereditary relationship directly from the genetic material. Wherever the family relationships between species are important for scientific questioning, systematics plays a significant role and has therefore become an important discipline over the past few decades for studies on population genetics and animal behaviour as well as for physiological, biochemical and molecular biology studies.

Biological diversity, whose investigation and protection Switzerland committed itself to undertake at the Rio Summit in 1992, can only be studied based on sound systematic knowledge. It is the identification of species and their protection which guarantee that the genetic resources contained within this vast species diversity will continue to be available. The conservation of sufficiently large biodiversity is also of essential importance for the continued existence of ecosystems, without which we could not exist. Moreover, the species and ecosystems contribute to the beauty of nature and are therefore important for our well-being. Ethical reasons bind us to protecting species.

Many realms of our society would be inconceivable without knowledge of systematics.

- *Biomonitoring* measures and evaluates changes in our environment by using the presence or absence of species as an indicator of the defined qualities of living environments. Consequently they are used as bio-indicators in environmental compatibility assessments.
- In the field of *biotechnology*, clearly identified species with each of their specific characteristics are a central prerequisite for industrial processes in the production and handling of foods.
- Many areas of *human* and *veterinary medicine* require profound knowledge of systematics and ecology, for instance, of pathogens. Only after a systematically exact diagnosis of the pathogen can therapy be undertaken.
- *Pharmacologists* isolate agents from the vast variety of species to use as the basis for new drugs. Previous achievements include the birth-control pill, pain and circulatory drugs and drugs to combat certain types of cancer, such that the expectations and hope of finding more drugs to treat hitherto hard-to-treat illnesses are great.
- Knowledge of systematics is also indispensable in *forestry* and *agriculture* as it is in *fisheries* and *aquaculture* when it comes to finding biological adversaries that can be used to keep pests under control. The development and security of our food is based, among other things, on the reliable identification of new species, breeds and varieties.
- *Protection of species* and efforts to control invasive species would not be possible without basic systematic knowledge.

A series of examples show that incorrect identification can lead to expensive and far-reaching misdiagnoses:

- In California, for instance, when an unknown species of insect attacked sugar beets, and transmitted a viral disease to the plants, due to a misdiagnosis it was believed that the pest originated from South America. In its supposed place of origin, however, no natural enemies were found. Only after the insect was correctly identified did it become clear that it had to have come from the Mediterranean region where natural enemies were indeed quickly found to control it.
- In a search for new drugs to treat AIDS, an originally promising species of plant suddenly no longer demonstrated effective compounds. A scientist from a herbarium finally discovered that the plant under investigation was actually two very similar but systematically distinct species from two separate regions, and one of the species did not possess the sought-after substance. Afterwards research could continue on development of the drug.
- In rare parasitic diseases, false diagnoses are made again and again. This often leads to the wrong and therefore unsuccessful treatment, in some instances resulting in severe consequences for the patients.

Knowledge of systematics is therefore not only in demand, it is also valuable for the economy. Systematics has proven to be the foundation for most biological sciences.

Foundation for protection and use of biological diversity

The continuously growing human race uses more and more habitats of the earth to produce food, energy and raw materials or to deposit its waste. This practice destroys the

original ecosystem and in doing so leads to the loss of most of the species that live there. Indeed in the history of the earth, species have always died out, however the current rate of loss has never taken on the scale or speed we are now seeing all over the entire world. Although scientists currently discover and name approximately 15 000 species each year, at the same time roughly five times that number are wiped out – each individual species biologically unique and irretrievably lost. If this trend continues, we will lose over the course of this century half of the estimated biodiversity of our planet. We will never know for certain the full extent since many species disappear before they have been discovered. This disappearance of species is tantamount to the loss of an enormous, priceless library, for every creature that dies out may possess genetic data important for our survival. When we need to justify why a specific region is worthy of protection or present scientific reasons for protecting a species, data on the biodiversity is necessary. To obtain this data, we need a considerable number of well-trained systematics researchers.

We still know astonishingly little about the biological diversity and centres of biodiversity on planet earth. Today we are still far from having assessed the planet's species diversity. Most organisms have never been seen by a scientist, let alone been systematically investigated or studied for their ecological function. In the forests of the tropics alone experts suspect millions of unknown species of insects. Even in the densely populated and relatively well-studied Switzerland, surprises are still to be found as the descriptions of new species regularly demonstrate following investigations of little-studied groups of species or habitats.

One basis for the protection and sustainable use of biodiversity is their systematic investigation. Recording and documenting biodiversity is one of the greatest scientific challenges for biology and especially for systematics. As a consequence, systematic researchers are the land surveyors of biology. In light of this major task, it appears, therefore, a paradox that systematics has been little promoted as a classic discipline of biology in the past years, and indeed has lost significant ground. The legions of unknown species and billions of sample specimens in the biological collections compare to a mere 10 000 systematic researchers worldwide. Since their number is diminishing even further, it is growing ever more improbable that systematics will master its task.

Biological collections – the library of systematic research

For centuries, scientists have collected plants and animals in all regions of the world. By now the natural history museums and botanical gardens of the world store roughly three billion dried, pressed, preserved, or in alcohol conserved specimens. Thus, the scientific collections document the enormous riches of nature and therefore are rightly described as the largest archives of life. Numerous extinct species only exist in such collections and therefore are absolutely irreplaceable as the last specimen of their kind. The treasures of every collection include the type specimens, those individuals who served as the basis for the first scientific description of that new species. It is this initial link of a scientific name to the concrete individual – the type – that makes it possible for further examination, in the process forming the basis for a stable name of the species. In this manner, the entire knowledge of this species can be clearly classified.

In Swiss museums and research institutes, huge biological collections are stored that altogether encompass over 41 million specimens. This is a considerable number for such a small land-locked country that moreover was never a colonial power. In other words: Switzerland can and should play an important role worldwide.

The organisms stored in the biological collections are historical documents of inestimable value. Plants and animals that were recorded 100 years ago and found a place in a collection prove the change in flora and fauna. Even the regional collections of Switzerland show the extent to which man has altered the flora and fauna. Moreover, the organisms contain evidence of environmental chemicals, such as DDT of the 1960's and the effects of Chernobyl in the 1980's, which allow retrospective analysis and therefore comparisons with today. Furthermore, thanks to flora and fauna inventories based on systematic knowledge, identification keys can be created for specific regions and targeted follow-up research on specific species can be carried out.

Unfortunately, it has become ever more difficult worldwide to maintain existing collections adequately and make them available to researchers. Everywhere political support is lacking along with the necessary financial resources. Above all, not only are the biological collections irreplaceable work instruments, they are also part of our common world cultural heritage that are to be preserved. The type specimen in the biological collections possess a similar value as original works of art. And who would ever think to throw away a Picasso?

Systematics in Switzerland – in danger of dying out?

As in many countries of the world, systematics in Switzerland is undergoing a crisis. This crisis expresses itself in many different forms, having different causes and effects.

The classical venues of systematic research and biological collections are natural history museums and botanical gardens. Under the pressure to save money in the cities and cantons, the budgets of museums and botanical gardens have been reduced. Scientists have been cut back or their positions have been transformed into exhibition designers and museum educators. It has become more important to make specific topics accessible to the public in ever better exhibitions and in doing so continually legitimize museums' existence. The image of the old cabinet of natural treasures became a hindrance, leading some small museums to pack their collections in mothballs or dissolve them altogether. In light of this development systematics research has often come up short.

Over the past three decades as systematically oriented professors have gone into retirement, Swiss universities have either dissolved the position or rededicated it to another field, so we now have only a few remaining professors in this discipline. The reason for this development was the poor image of systematics and the ever increasing pressure on universities to focus on and heighten their profile in presumably more modern scientific disciplines. As a consequence, courses in systematics, from practical identification to excursions and specialized events, have cut back.

Yet the curricula of most universities adhere to a broad basic education in biology which include courses in comparative anatomy and systematics. Increasingly, teaching staff for these subjects cannot be found in the universities. Therefore, many staff members from museums are involved in teaching at the universities through teaching assignments designed to

cover these gaps. More and more systematics-related courses are taught by scientists who are not trained nor conduct research in systematics. For advanced students there are fewer opportunities to specialize in systematics at university.

Systematic researchers are having a very hard time of it. Their work often appears to be not very spectacular. Following a collection tour, the extensive preparation and identification work and comparison with other collections publications can take many years. Systematically oriented scientific journals are only read by a few scientists. Modern ranking systems that measure the value of a journal according to how often it has been cited in the previous 2 years (impact factor) usually do not even list most systematically oriented journals because they do not fulfil acceptance criteria. Nor do such journals appear frequently on the internet since most online archives only go back 10 years. Thus, the majority of non-systematically oriented scientists take no notice of the publications in systematics.

A survey conducted by the Academy of Natural Sciences of systematics researchers in Switzerland showed that many species indigenous to Switzerland could not be adequately investigated. While there are enough field researchers for birds and plants, there is a lack of specialists on fungi and the many invertebrate animal groups, for instance. Moreover, the survey showed that 20% of those surveyed are over 60 years of age, including many specialists for specific groups of species. Many systematics researchers, including internationally recognized scientists, will soon enter into retirement. Therefore, valuable knowledge threatens to be lost.

Molecular systematics, in the meantime, has been able to establish itself as an independent new branch of systematics, and many of these scientists have succeeded in entering into booming disciplines of the past decades such as biochemistry, molecular and developmental biology, and population genetics. They managed the transfer by working on individual model systems, acquiring the necessary techniques and developing comparative questions: which species possess a specific chemical compound? How have certain structures or metabolic paths been modified throughout evolutionary history? What effect do invasive species or nature conservation measures have on existing populations? The answers to these questions require sound knowledge of systematics, and new disciplines such as chemical ecology, invasion biology and biological pest control have need for well-trained systematics researchers who are also knowledgeable of other disciplines. There are many professors at Swiss universities who have followed scientific research based on systematics-oriented questions, however in most cases, professors who only address systematics have largely disappeared, at least in zoology.

Measures to promote systematics

Today it is uncontested that systematics is a scientific field that must be promoted not least due to the interest of the rest of biology and society in general. Such promotion cannot rely on one mechanism but must pursue a series of measures involving general scientific funding, concerned scientists and participating institutions equally.

Scientific funding

The Swiss National Fund, as the largest national scientific funding organization, can advance the future development of systematics in at least two ways. The regular application procedure classifies applications according to priority that reflect the chances of receiving funding. Since systematics applications have generally been given low priority in the past, it is absolutely necessary to change them to high priority. Secondly, an additional support programme for the advancement of systematics would strengthen projects in this area, give the field an important push forward and promote young scholars. Such a special programme should target high-quality systematic work and could, for instance, be modelled after the successful US programme '*Partnerships for Enhancing Expertise in Taxonomy*'.

Museums

As a matter of principle, museums should be strengthened so that systematics can continue to be maintained there. An increase in the number of scientific staff members should be explicitly addressed in the goals of the museums, although consideration should be given to increased employment of scientists with limited-term contracts.

The museums are, however, called upon to pursue greater integration in national and European networks and programmes. The largest Swiss museums should, for instance, become members of the *Consortium of European Taxonomic Facilities*, an association of the largest European museums currently from 13 countries in which Switzerland is not yet represented. This initiative promotes in particular access for European researchers to collections and has been very successful in launching European projects and raising funds for research grants.

Switzerland should also increase its involvement in the initiatives of *Global Biodiversity Information Facility*, *Biological Collection Access Service for Europe* and *European Network for Biodiversity Information*. These initiatives have as their goal to make the information contained in the collections available over the Internet in the coming years. By digitalizing biological collections, their data can easily be made available to many interested parties, and in doing so create an important foundation for innovative research. For instance, regional and global distribution patterns of species and their dynamics can only be understood through an exchange of information about the organisms collected worldwide, since even the largest scientific collections alone cannot convey a representative picture of the biodiversity in each instance.

Universities

The current course offerings at Swiss universities are insufficient for in-depth training in systematics. Consequently, the Swiss universities are called upon to provide these disciplines with appropriate representation in undergraduate biology (or during the first years of the Bachelor's degree). To this end, specially trained staff must be employed as lecturers. In order to promote interaction amongst museums, museum scientists should be integrated into teaching at the universities. In the long-term, however, it will be important to reconsider reinstating a chair for systematics.

In this context, we must not forget teacher training. There are many teachers in secondary and university preparatory schools who are not able to name the most common organisms. Transporting systematic knowledge and species knowledge is heavily dependent on the personal interests and

hobbies and the accompanying biological expertise of the teachers. However, this easily leads to the impression that such knowledge is only for hobbyists and that species expertise and names are unimportant. Since the pupils of today are the university students and teachers of tomorrow, it is important that sufficient knowledge about species is taught during teacher training.

Following the Bologna Reform, the Master's degrees in Switzerland are predominantly awarded in biology and ecology. The rector's conference decided to prohibit specialized Master's programme that have a very few number of graduates. Yet the possibility exists for specialization within a Master's programme. In order to provide a minimum of specialization, a systematically oriented training programme must be offered on the Master's level. For this purpose, appropriate courses should be created with existing Master's programmes leading to a degree with 'specialization in systematics'. Alternatively, specialization in biodiversity should be examined that also includes existing courses in ecology and palaeontology. The corresponding Master's theses could also be supervised by scientists at the museums, thus ensuring additional training capacity for systematic questions.

The teaching required for such specialization in systematics can be made available if specialists from museums or from abroad offer special courses that are announced Switzerland-wide and recognized by all Swiss universities. Through coordination of their activities, the universities and museums can guarantee a continuous and diverse teaching programme with relatively little effort. The courses can be offered at the same time in whole or in part as a postgraduate or continuing educational training for doctoral students and professionals, thus occupying an important position for promoting young scholars.

It is important that systematics is taught in the universities because only in this manner can quality assurance be guaranteed. By issuing *credit points* according to the *European Credit Transfer System*, courses attended at other universities can also count toward a degree programme. In the middle-term, it would be possible to join an international training programme, possibly forming a *Graduate School in Systematics*.

Annual summer academies provide particularly attractive course offerings. In special courses on specific groups of organisms, students, postgraduates and interested professionals receive in-depth training. In the summer of 2005, two summer academy courses on spiders and wood-dwelling beetles were held for the first time within the framework of the Master's programme at the University of Basel on the Alp Fix in Graubünden. The academies were organized by the Museums of Basel and Bern and the CSCF and sponsored by the Federal Ministry for the Environment (BAFU). A initiative of the Universities of Bern and Zurich and the Museum of Basel offer additional systematics courses as of 2006.

Professional associations

In spring 2005, the Swiss Society of Systematics was founded. This is an important step to creating a professional association. The society will not only organize annual meetings, it will also raise awareness of the meaning and use of systematics in the public mind, thus creating a basis for political activity. Moreover, the Society serves as a contact for questions surrounding systematics.

To support the research community, an Internet-based directory should be created of systematic researchers working in Switzerland. The directory will enable scientists, the federal government, cantons, communities and private offices to find the right specialist for specific groups of organisms or for a specific region.

By creating an Internet portal for teaching and research in systematics, we aim to achieve our goal of strengthening coordination and collaboration between the various universities and museums. The core will be an inventory of the Swiss educational programmes. Students and other interested individuals can thus receive necessary information on relevant courses at various universities.

The goal: visions for the future

Systematics in Switzerland is a modern, integrative science, well anchored across institutes in museums, botanical gardens and universities and positively perceived in the public mind.

Swiss systematics researchers are well organized and coordinated. They are involved in national and international initiatives and enjoy an outstanding reputation worldwide.

The collections of the Swiss museums are available worldwide over the Internet, and Swiss researchers are well integrated into international networks.

Swiss universities provide a foundation in systematics within the Bachelor programme. During the Master's programme, advanced courses are offered which enable specialized degrees. Topics for Master's theses and dissertations in systematics are offered together with the museums and botanical gardens.

The Swiss National Fund provides financial support of systematics research in Switzerland through a special fund, thus promoting the quality and continuity of research in systematics.

This paper was prepared under the auspices of the Task Force Systematics of the SCNAT and in a work group of the Swiss Forum of Biodiversity. The following persons contributed to the paper in consultation: Jean-Pierre Airoldi (University of Bern), Daniel Burckhardt (Museum of Natural History in Basel), Matthias Baltisberger (ETH Zürich), Olivier Biber (BAFU), Winand Brinkmann (University of Zurich), Philippe Clerc (Conservatoire et Jardin botaniques de la Ville de Genève), Annabelle Cuttelod (Akademie der Naturwissenschaften Schweiz), François Felber (Université de Neuchâtel), Martin Fischer (University of Jena), Yves Gonseth (Centre suisse de la cartographie de la faune CSCF), Bernd Hägele (Staatssekretariat für Bildung und Forschung, Bern), Ambros Hänggi (Naturhistorisches Museum Basel), Rolf Holderegger (WSL), Beat Keller (University of Zürich), Erich Kohli (BAFU), Christian Kropf (Museum of Natural History in Bern), Irene Künzle (Swiss Forum of Biodiversity), Jean Mariaux (Muséum d'histoire naturelle de la Ville de Genève), Peter Linder (University of Zurich), Wolfgang Nentwig (University of Bern), Reto Nyffeler (University of Zurich), Martin Schmidt (University of Bern), Pascal Tschudin (Université de Lausanne), Wolfgang Wägele (Museum Koenig and University of Bonn), Jürg Zettel (University of Bern). Suzanne Albrecht (Blackwell Verlag, Berlin) kindly translated the German text. Requests to Wolfgang Nentwig: wolfgang.nentwig@zos.unibe.ch