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OBJECTS IN NATURAL HISTORY COLLECTIONS AND THEIR AUTHENTICITY IN LIGHT OF TRADITIONAL AND NEW COLLECTION STRATEGIES

Many historical or ethnological objects are authentic due to their originality, their representativeness in space and time as well as their socio-cultural and historical context and purpose (function, aim, intention). In any event, however, they are man-made and therefore »artificial«. Many such museum objects have remained unchanged for decades, centuries or even millennia. Damage or modifications brought about by aging may be compensated by restoration (and then demonstrated on the object and documented) or they may be left untouched. Their authenticity, though, is generally not in doubt.

Thus, the discus of Phaistos discovered in Phaistos, Crete, for instance, was produced around 1500 BC during the period of the Minoan civilization; it is exhibited as it was originally found. By contrast, the Sistine Madonna painted by the artist Raffaello Sanzio da Urbino, commonly known as Raphael, in 1512 AD was restored to renew its original brightness. These two objects are world-renowned representatives of the museums they belong to. And they stand for thousands of other objects of the same period and region in those collections that are not exhibited. These collections are the basis for all research and the real treasure of the museums.

In natural history museums (NHM), too, only small parts of the collections are displayed in the exhibitions and a thousand times as many objects (and often even more) are stored in the collections and not accessible to the public. In the exhibitions of NHM, exhibited animals and plants serve as representatives of species (in exhibitions on biodiversity and systematics) or of ecosystems (e. g. in dioramas). Due to the display, the visitors expect to see »real animals, plants and biotopes« (**fig. 1**)[1]. In reality, however, dermoplastics are mostly pure skins filled with plaster, excelsior, cotton wool and threads, while plants were specifically dried and dioramas are just virtual showcases into ecosystems.

It is even more so the case that the specimens displayed are not typical for the objects in the collections, although these collections constitute NHMs' main research infrastructure. Nevertheless, as with objects from historical, ethnological or art collections, objects in natural history collections are authentic in respect of their originality and representativeness for nature in space and time.

COLLECTION OBJECTS OF NATURAL HISTORY MUSEUMS: AUTHENTIC IMAGES?

The biological collections (»behind the exhibitions«) often comprise between hundreds of thousands and several millions of objects, mainly from the fields of zoology, botany, palaeontology and geology and – sometimes – microbiology[2]. These objects are representatives and, in themselves, documents of the inventory and development of nature in space and time. Thus, natural history collections fulfil their primary function as archives of nature: they constitute a permanent reference for species, their identity, biology, intraspecific heterogeneity and interrelationship with environmental parameters, for instance, biotopes, regions and climate.

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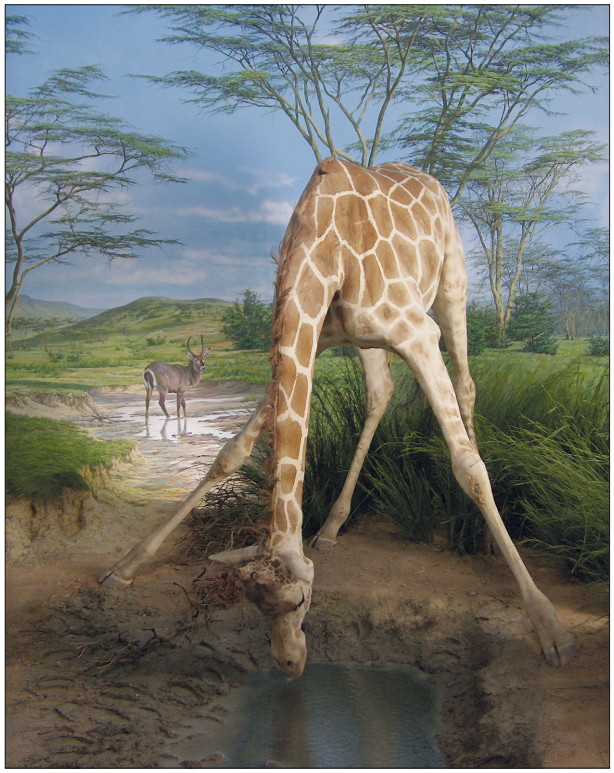

Fig. 1 Giraffe from the Africa diorama of the Überseemuseum, Bremen. – (Photo W. E. R. Xylander).

Fig. 2 Skulls of the European wolf (*Canis lupus* L.) in the mammal collection of the Senckenberg Museum für Naturkunde Görlitz. – (Photo W. E. R. Xylander).

Many collection objects are not one-to-one images of the living representatives of the species they belong to: they frequently are, physico-chemically modified, as many objects are prepared in chemicals such as alcohol, formaldehyde, sodium chlorate or borax to guarantee long-term preservation. Often, only parts of the animals are included in the collections (such as skulls, skeletons, furs or feathers in the collections of birds and mammals; fig. 2). In such cases, those body parts are collected that are representative, allow the verification of species' identity and may be of relevance for further research, for instance on taxonomy, population ecology, biogeography or phylogeny. Other specimens may be embedded in resins or separated into body parts for identification or conservation.

In many taxonomic groups, it is indispensable to dissect (and, thereby, partly or totally destroy) specimens for determination of the species' identity (e. g. in many butterflies, spiders and millipedes). Without a qualified and reliable determination at the species level, however, biological objects are often worthless. In some cases, even the most valuable specimens (the type material) must be dissected for documentation of the typical characters, as a whole mount of complete specimens does not allow reliable diagnostic differentiation of characters when describing a new species (an example of a dissection of the holotype of the springtail *Sanaaiella multisensillata* by the prominent specialist Gerhard Bretfeld is shown in figure 3.

Reflecting museums as institutions responsible for the maintenance of their cultural heritage, there is an obvious conflict between the curatorial obligation for conservation and the demand to identify the specimens in the collection, thereby increasing the authentic information and elevating the value of the collection. The responsibility for the decision pro or contra semi-destructive impacts lies with the curator; nor-

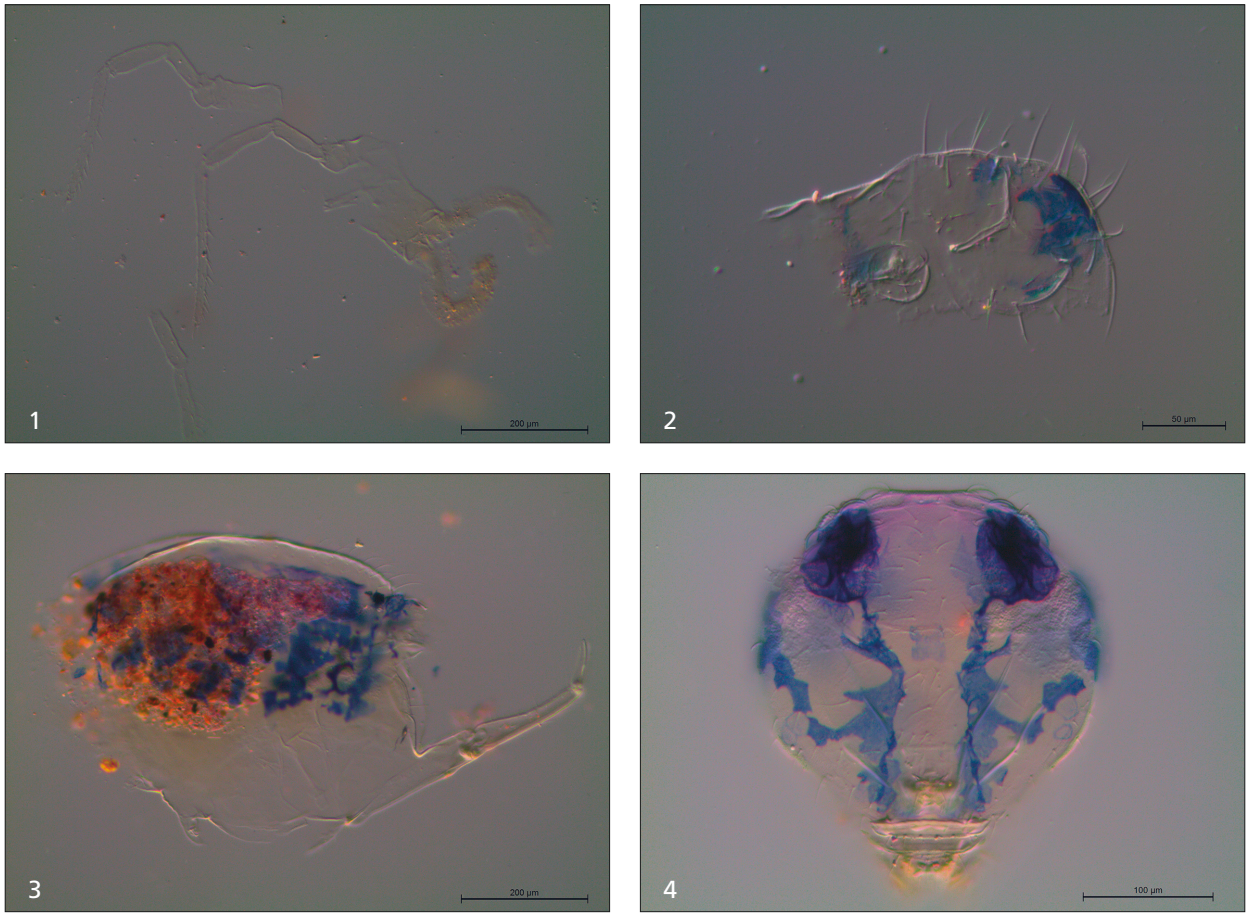

Fig. 3 The body of the holotype specimen of the springtail *Sanaaiella multisensillata* was subdivided into four parts (**1-4**) mounted on different microscope slides by the expert who described this species. Without such semi-destructive preparation, the diagnostic characters are hardly visible. – (Photo D. Görnert, Senckenberg Museum für Naturkunde Görlitz).

mally, he/she will rather decide in favour of the information, as can be seen from thousands of research publications on museum objects.

Modifications (and semi-destructive impact) may also happen during research work, for example on the age structure of populations, as performed for many years now in the mammal section of the Senckenberg Museum in Görlitz. For such investigations, molar teeth are temporarily removed from the skull and their roots are micro-sectioned using diamond knives. In polarized light, lines become visible, indicating the age of the specimen (**fig. 4**) at the time its skull became part of the collection[3].

These few examples demonstrate that the objects in natural history collections have often undergone a severe modification and – subsequently – are not untouched or unmodified representatives of nature

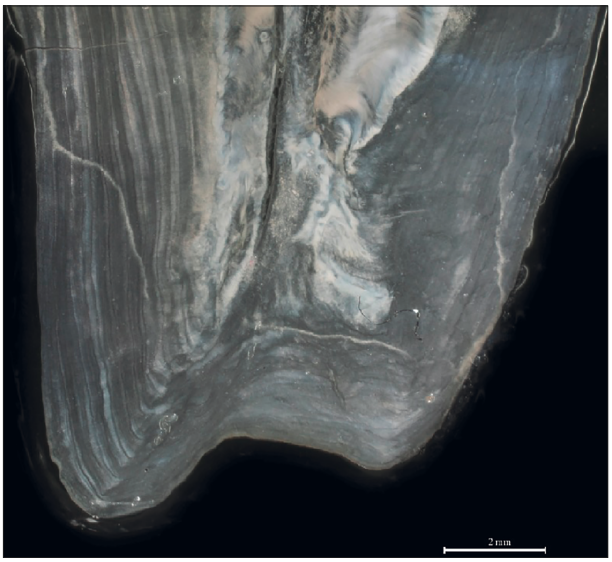

Fig. 4 Lines in the molar cementum indicate the age of an Asian wild ass. – (Photo H. Ansorge, Senckenberg Museum für Naturkunde Görlitz).

Fig. 5 Needled insects with information labels on the needles documenting the species name, describing scientists, date and location of acquisition, inventory number and fate of the object. – (Photo W. E. R. Xylander).

or the species they belong to. However, objects of natural history collections are – even if modified as described – authentic with regard to their

– genuineness,
– originality,
– unambiguity,
– and they represent nature in space and time.

Specimens' completeness or their anatomical, chemical or physical state are not necessary for their authenticity, as during qualified modification the information content of the collection increases. This, furthermore, guarantees their authenticity with regard to the primary function of NHM collections.

DOCUMENTATION OF NATURAL HISTORY COLLECTIONS – INDISPENSABLE PREREQUISITE FOR THEIR AUTHENTICITY

As with objects from historical, ethnological or art collections, objects in natural history collections are authentic. Their authenticity is – to a high degree – based on the comprehensive documentation for each specimen or object. And both – authenticity and documentation – make the collections valuable, not only as reference but also research infrastructure[4].

In biological collections, objects are correlated with information such as species' identity (a »binomen« in the case of biological and paleontological collections), locality and date of acquisition, the name of the collector and the name of the taxonomist who described the species. This object information is documented in

an inventory book (of the museum or collection) and – simultaneously – printed on labels, which are mostly deposited with or in the direct vicinity of the objects (**fig. 5**). In this way, the correlation of information and object is absolutely clear and unmistakable. In the inventory books or on the labels, furthermore, information on the provenience and history of the objects and their fate (e. g. taxonomic revision, preparation) should be documented.
Often, additional data (metadata) are available and documented on labels, in the inventory books or other forms of documentation, such as digital databases. Such metadata may relate to habitat type at the site and weather conditions during the period of acquisition, stratigraphy, taxonomic verification by a specialist, synonymy or other information.
Documentations of collection units often already commence in the field when the material is collected. During the subsequent steps of preparation, additional information is recorded, for instance on the diet of the specimen, the number of offspring (visible in mammals by virtue of the uterus scars in females), developmental stage (infant/larva, adult, in reproductive state, senescence), coloration pattern, pathological alterations, etc. Furthermore, tissue samples may be taken. All these tangible or intangible pieces of information are directly correlated to an »inventory number«, which is permanently addressed to the specimen and characterize it individually. If a specimen is split up into several collection units (e. g. skull, skeleton, fur, tissues or head, trunk and genital organs), these units are clearly correlated with the specimen's inventory number as a unique identification label. This is also true – to refer to the examples mentioned above – for the various body parts of the springtail, the copulatory organs in dissected millipedes and spiders but also for a microtome series of sections of a platyhelminth. All units are unmistakably labelled, documented and deposited.
The original (and all its conserved parts), as well as its comprehensive documentation, guarantees the authenticity and the value of collection objects for any further purpose or use, e. g. in research, conservation, exhibition or academic education.

NEW COLLECTIONS GENERATE NEW INSIGHTS

However, the collections and the collection strategies in NHM have significantly changed over the last 20 years. New types of collections and collection units that have emerged as new techniques have made tangible as well as intangible characters more easily accessible, recordable and conservable for museum scientists. Nowadays, collections in many NHM also comprise gene banks, tissue samples, audible collections (e. g. of birds, insects and frogs), as well as photo and movie documentations of the species sampled. All these data can be made available via complex databases[5].
Often, such »supplementary« documents are directly correlated to a) single specimens (DNA, tissues) representing their individual characters (here the specimens in the collections may serve as reference »vouchers« and vice versa) or b) a specific collection site and period (audio, photo and video collections) mostly representing characteristics of the local population. All these documents increase the authenticity of the collection and their units as a reference of species in space and time.
During the last two decades, DNA collections have increased in number due to the expansion of new molecular methods and applications. These new techniques have become state of the art in many NHM and – combined with classical methods – have developed into powerful tools to address typical museum questions. Thus, in many taxa, larval stages cannot be determined easily or at all by morphology but must instead be identified by their genome. Furthermore, close evolutionary relationships may result in high morphological correspondence, leading to uncertainty with regard to species' identity and/or separation (e. g. in so-called cryptic species). As the genome in specimens belonging to a single species is mostly 98-99 %

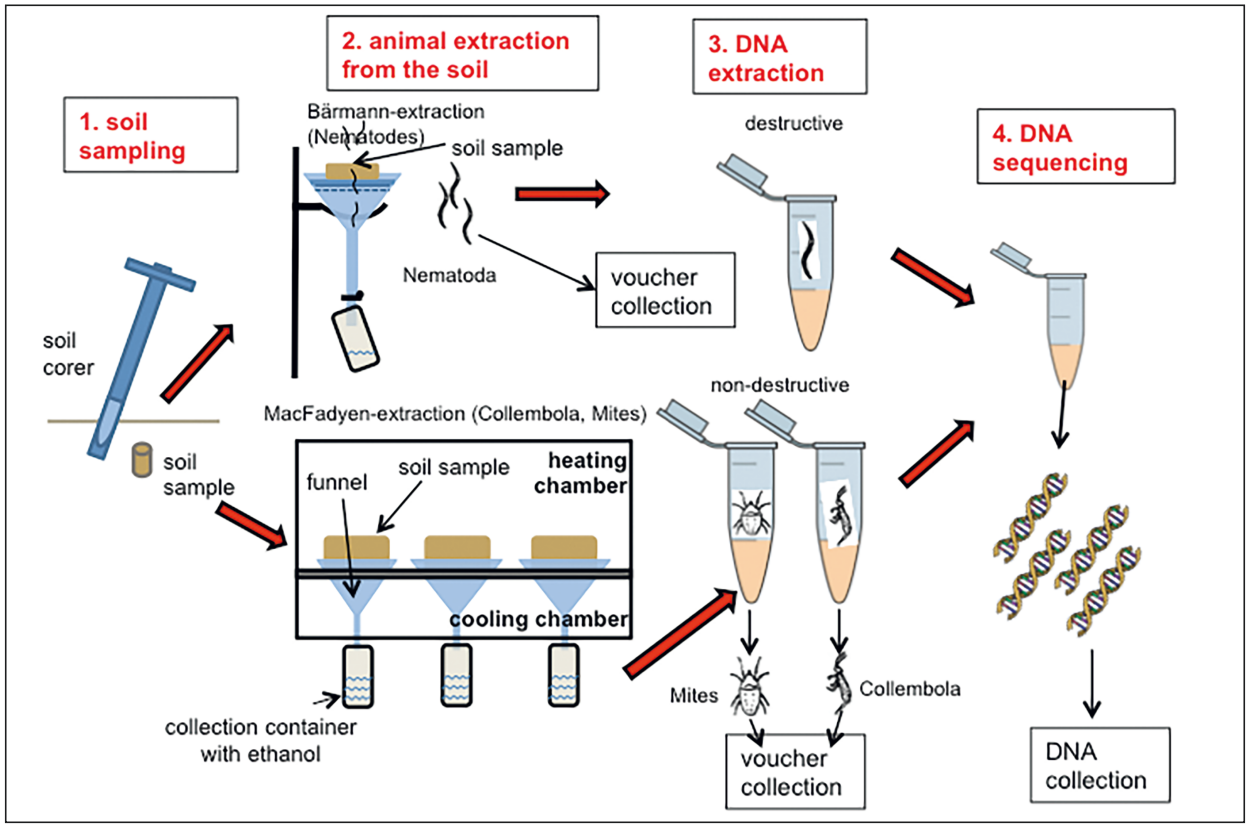

Fig. 6 Procedure for developing bar codes for tiny soil animals: in mesofauna organisms (about 1 mm in size), after extraction of body tissues the cuticle with the species-specific characters is deposited in the collection. In microfauna (< 1 mm), destructive preparation is necessary and specimens of the same species from the same sampling site are used as reference in the collections. – (After R. Lehmitz, Senckenberg Museum für Naturkunde Görlitz, unpublished, modified).

Fig. 7 Correlation of various body parts (fur, skull, skeleton, tissue samples) interconnected by an unmistakable inventory number. – (Photo W. E. R. Xylander).

identical, molecular methods such as barcodes may help to identify and assign specimens to the correct species. Moreover, phylogenetic interrelationships between taxa, intraspecific variability, hybridization or conservational issues such as population size, endangerment, gene flow, habitat fragmentation and many others may be studied. The results increase the information content on the collections, their reliability and authenticity.

Organisms that are very small and where the extraction of DNA as a prerequisite of barcoding is tricky constitute an extreme challenge, especially if remnants of the body (displaying the species' specific characters) are needed as »vouchers« for correlation of DNA and species morphology. As part of the German Barcoding of Life project (GBOL), DNA was extracted from soil meso- (mean body size: about 1 mm) and microfauna (body size 0.1 mm). The DNA processing was different in both groups for the purpose of obtaining DNA barcodes as well as »vouchers« in the collection for verification (fig. 6): in mesofauna (springtails, mites), fine pipettes were used to suck out

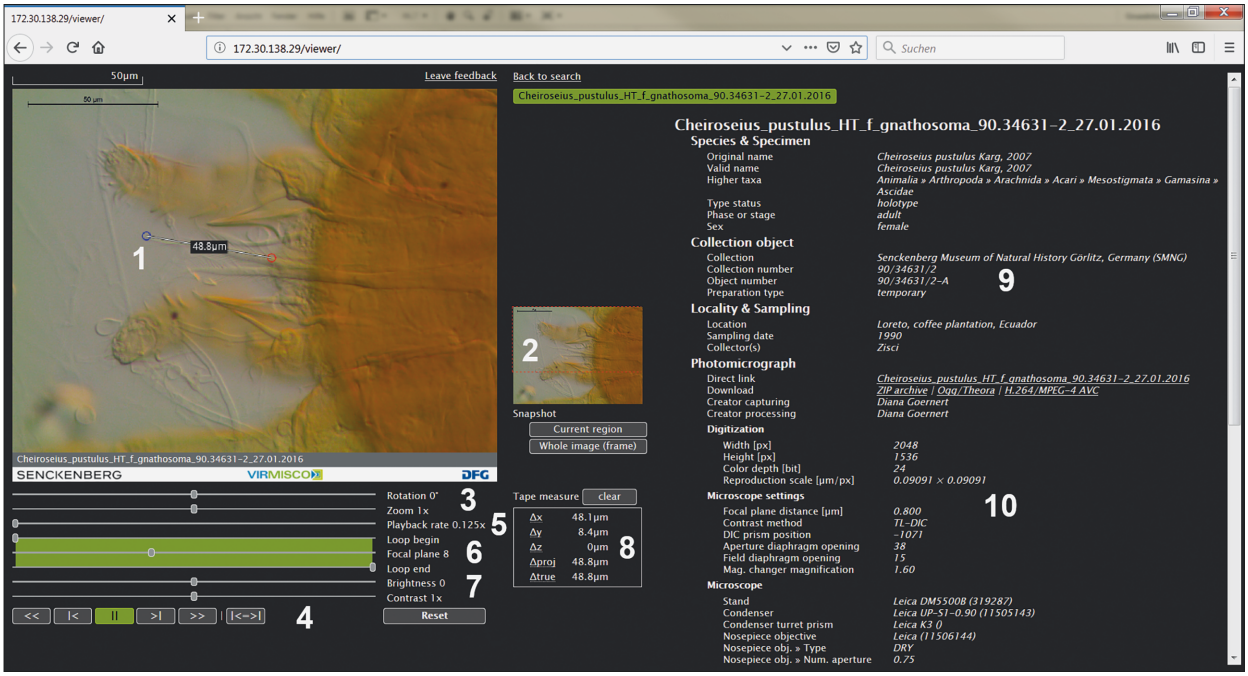

Fig. 8 Screenshot from the virtual microscopic slide projection programme VIRMISCO allows digital documentation of objects on microscopic slides. This permits the storage of such information and the saving of it in case of destructive alterations caused by embedding media. – (Source www.virmisco.org [21.12.2018]).

body tissues, from which DNA was extracted; the remaining cuticle with its species-specific morphological characters was deposited as reference in the collection. Microfauna (nematodes) was microscopically determined to species level by an expert. Specimens morphologically identified as belonging to the same species originating from the same sample were separated. One was embedded in resin for the reference collection, while the other underwent destructive DNA extraction. The correlation of DNA barcodes and morphological »vouchers« documented in the collection (and a database accessible worldwide) guarantees authenticity and the availability of reliable information for reference and further research.

By means of the correlation of tissue samples with traditional collection units, the latter become »vouchers« for applied environmental research (**fig. 7**). Thus, traditional collections are supplemented by tissue, gene and genome collections and conventional collection shelves are found side by side with -70 °C deep freezers in the collections, not only to preserve the DNA, but also tissues. Thus, in the mammal collection in Görlitz, for example, tissue samples from Upper Lusatia are stored for more than 20 years. These tissue samples (mostly from muscles, brain and liver) allow for the extraction of DNA but also for determining the content of residues of environmentally relevant substances (such as lead, cadmium or pesticides). Nowadays, tissue sampling has become a routine procedure in many research museums. This enables comparative research on the geographical distribution and accumulation of toxic residues in single individuals, populations and species, as well as in the food chain and thus the environmental impact of man at a chosen period even after decades have passed. The unambiguity and thus authenticity of reference objects is guaranteed by labelling and documentations.

For a long time, water-soluble embedding media have been used in NHM collections to store small organisms on microscope slides. These media fix specimens in their position under a cover slip, prevent desiccation and thus destruction; they enable microscopic investigation immediately after preparation and good conservation of the soft as well as the hard structures. A drawback of such media is that they may modify

chemically and/or due to aging or shrinking. These modifications (e. g. crystal formation or peripheral air-filled spaces in the media at the margins of the cover slip) may destroy not only the media but also the organisms embedded. If such artefacts occur in the vicinity or on the surface of specimens, visibility may be reduced and microscopic investigations rendered impossible. Resolving the media and re-embedding is scarcely feasible without impacting on the specimens.

However, during the last ten years, imaging programmes and the image-based documentation of collections have developed fast. A new tool for the visualization of small, hard-bodied organisms was developed in Görlitz to save the object information of specimens of high taxonomic value (e. g. type material) in case of destructive changes caused by embedding media: this »virtual microscope« stores images of specimens or significant body parts at different focus levels to digital photo series. Photos are compressed and can be provided as video via a special programme (**fig. 8**). This virtual microscope (named VIRMIS 60) simulates focusing through different levels of an object and has various applications[6]. Even if the original specimen has been destroyed by destructive physico-chemical alteration brought about by embedding media, VIRMISCO helps to save the object information. VIRMISCO may also be useful for reducing loans and images can be used as digital supplementary information in taxonomic publications: for the description of new species as additional (online) material deposited together with the type specimens as digital reference for specific species characters (digitypes). Last but not least, such digits may be used in academic education (e. g. in determination courses).

The new collection strategies and formats help to deposit results of new research methods, make them accessible and increase the value of collections as an archive of nature. They, furthermore, enable the correlation of all types of collection units with other external metadata (GIS, gene banks). New techniques lead to new results on new issues, which may increase research output (e. g. the number of publications) and its relevance for society. This may enhance networking of scientists and institutes and support research via third-party funding. All this, moreover, increases the standing of the NHM collections and their objects as reliable, verifiable, applicable, relevant and authentic archives of nature in space in time.

CONCLUSIONS

Biological objects in natural history museums are documents for species in space and time. Their authenticity may vary with regard to the purpose: a) for collections as research infrastructure, authenticity comprises a combination of »the original specimen« (or, often, parts of it), determination to the species level, the documentation, appropriate preparation and storage, b) as objects for presentation and education, major aspects of authenticity are often easy visibility of species-specific characters (including behaviour) and/or arrangement in a natural environment. Due to preparation – a prerequisite of maintenance – the majority of natural objects must be modified and do not represent the »living specimen«. By representing the original, however, the comprehensive documentation and determination of specimens is unique and authentic with regard to their genuineness, originality, unambiguity and representativeness.

With new research techniques and museum infrastructure applications, the nature – and thereby the authenticity – of objects as document may change. The specimen may become »just a voucher« that allows verification for a tissue, DNA or genome sample or a video, audio or photo document. In any case, the documentation is indispensable for the value of the collection and the reusability of the object data, which makes natural history collections reliable, verifiable, applicable, relevant and authentic archives of nature in space in time.

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Notes

1) Geller-Grimm/Kridlo/Lerp 2015. – Ohl 2017. – Xylander 2017.
2) E. g. Pyke/Ehrlich 2010; Türkay 2018; Xylander 2018.
3) Ansorge 2001. – Ansorge/Schipke/Zinke 1997. – Lkhagvasuren et al. 2013.
4) See, e. g., Holmes/Hammond 2016.
5) E. g. Burkhardt et al. 2014; www.edaphobase.org (26.09.2019).
6) Decker/Christian/Xylander 2018a; 2018b. – See also www.virmisco.org (26.09.2019).

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Zusammenfassung / Summary

Objekte in naturwissenschaftlichen Sammlungen und ihre Authentizität
im Lichte traditioneller und neuer Sammlungsstrategien

Biologische Objekte, die in naturwissenschaftlichen Sammlungen hinterlegt sind, stellen Dokumente für das Vorkommen von Arten in Raum und Zeit dar. Allerdings können sie im Rahmen von Präparationsverfahren zur Haltbarmachung, während der Bestimmung oder durch spezielle wissenschaftliche Methoden, die das Objekt zerstören, modifiziert werden und verlieren so »ihre Natürlichkeit«. Ihre Authentizität und ihr dokumentarischer Wert (als Repräsentant der Natur) basieren dann auf den Resten der in den Sammlungen hinterlegten Individuen sowie auf der zugehörigen Dokumentation. Neue Sammlungsstrategien können den Blick verändern auf das, was »das Hauptobjekt« ist: So können die Individuen in den Sammlungen »nur noch ein Voucher« für eine DNA-Sequenz, eine Gewebe- oder Genomprobe bzw. ein Video-, Audio- oder Fotodokument sein (z. B. wenn diese besser zeigen, was dokumentiert werden sollte, als das Original). Auf der anderen Seite können Audio- bzw. Fotodokumente oder DNA-Proben eine neue dokumentarische Bedeutung erlangen, wenn die Originale nicht länger verfügbar sind (z. B. aufgrund einer Zerstörung des körperlichen Originals) oder niemals verfügbar waren. Diese »Translokation der Authentizität« wird an Beispielen erläutert.

Objects in Natural History Collections and their Authenticity
in Light of Traditional and New Collection Strategies

Biological objects in natural history collections constitute documentations of species in space and time. However, they have to be modified and thus loose some of their naturalness by preparation (which is indispensable for their maintenance), determination or destructive scientific research. So their authenticity is based on the (rest of) specimens stored in the collections and the documentation related to the objects. New collection strategies may shift the view on what is the »major object«: The specimen/collection object may become »just a voucher« for a tissue, DNA or genome sample or a video, audio or photo document (e. g. if they show what should be documented and is not visible on the original). On the other hand, audio and photo or DNA samples may become the primary authentic documents if originals are no longer (e. g. destruction) or have never been available. Examples for this authenticity shift are indicated.