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A synthetic biodiversity? Natural history museums and the use of artificial replicas as supplement to taxidermied specimens

ABSTRACT

Natural history museums are institutions dedicated to research, dissemination and exhibition of nature. They have developed scientific rigor in collecting specimen series (including tissue samples, photographs, videos and sound recordings), contributing to taxonomic, ecological and biogeographical studies. In the 20th century, museums became centers for natural science education and public outreach, often using historical and scientific collections to engage visitors. The use of original specimens for education and science communication presents challenges: long-term preservation issues, potential data loss, and their growing historical value. Moreover, acquiring zoological specimens has become increasingly difficult due to ethical and legal constraints. We propose an integrated approach using high-quality replicas and hyper-realistic models - a form of "synthetic biodiversity." Combining original materials with these synthetic representations offers museums new opportunities without compromising their historical and scientific collections.

Keywords: Biodiversity, Casts, Educational activities, Models, Natural history museums, Replicas, Scientific Collections, Technological Innovations.

What about natural history museums?

Natural history museums (from here onwards “Nhms”) are institutions regarded as dedicated to research and science dissemination. Their daily activities combine these missions in the best possible way, hence represent interesting ‘hybrid’ places and hubs. Born as an evolution of the ‘chambers of wonders’ or “Wunderkammern”, the Nhms have evolved and consolidated their missions of collecting, studying and preserving naturalistic specimens, developing permanent and temporary exhibitions, while at the same time proposing a varied activity of popularisation and scientific education. Besides their research activities - especially taxonomic - Nhms have pursued dissemination through exhibition paths, in which, although with different declinations and varied emphasis (often depending on the economic resources and size of the museum itself), specimens from their scientific collections are used for research and also displayed to the visiting public (Andreone *et al.*, 2014).

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So far, a sort of dichotomy is often evident between these two "souls" of the Nhms, e.g., aspects and purposes concerning discovery, study and research on nature (e.g., extremely useful to reduce the so-called "taxonomic gap") and aspects concerning scientific display and dissemination, with specialised staff operating in the best cases (e.g., in large state or national museums) separately dealing with these missions. Although Nhms have always developed and cared for scientific collections primarily for the preservation of research material, the so-called voucher specimens (a preserved example of a biological organism, such as a plant, animal, or fungus, that is kept in a scientific collection - like a herbarium or museum - as permanent evidence of the organism studied in a scientific project) have been (and still are) also used often for exhibition and educational initiatives. In some cases, particularly in recent decades in university museums, specimens were also used for practical and frontal lessons. This poses clear problems for the conservation of scientific (and sometimes historical) specimens, since exhibition and manipulation can accelerate the process of degradation of the specimens themselves.

Here we provide an overview of the use of models and hyper-realistic replicas and advocate for their integrative use in Nhms. We are interested in understanding how the use of artificial replicas can be complementary and necessary, avoiding relying directly on valuable historical collections and thus preserving voucher specimens, which are indispensable. The development of modern information technology, including computer graphics, artificial intelligence and 3D-printing, combined with the use of models, casts and replicas may provide innovative tools to get a high quality of activities without sacrificing hands-on experience with the exhibits (D'Agostino *et al.*, 2022).

Voucher specimens in evolving collections

Originally, Nhms emerged as institutions merely shaped by simple curiosity and personal passion of collectors, who sought to display the astonishing variety and wonders of the natural world. These early collections were usually filled with a heterogeneous mix of specimens and materials - ranging from minerals and fossils to preserved exotic plants and animals - alongside rare archaeological relics and ethnographic objects. Their purpose was to offer visitors a glimpse into the breadth and strangeness of nature.
During the Victorian age (1837-1901), the role of Nhms expanded significantly, influenced by the exploration and colonization of distant lands - often motivated by imperial trade and scientific ambition (Lightman, 2007).

. As European powers mapped uncharted territories, accompanying naturalists documented countless new species, and Nhms became central hubs for preserving and studying these discoveries. Leading institutions took an active role in specimen collection, not only amassing their own holdings but also sponsoring expeditions and naturalists. In many cases, Nhms also acquired collections from explorers, further enriching their displays and contributing to the growing body of scientific knowledge.

The tendency to increase Nhms' exhibition aspect grew in these periods, as specimens and other materials collected during explorations were shown to the public with great emphasis. At the same time, collections developed towards greater scientific rigour, with the creation of voucher series, referring to preserved zoological specimens (collected in the field), herbarium sheets and, more recently, other types of material, such as tissue samples, photographs, videos and sound recordings. Sometimes even with living animals and plants (as, for example, at CosmoCaixa in Barcelona, the California Academy of

Sciences in Los Angeles or at MUSE in Trento). Nhms became important components of the documentation of biodiversity and geodiversity, enhanced by taxonomic, ecological, faunistic and biogeographical studies. The description of new taxa usually involves the deposit of type specimens (i.e., the specimens on which new taxa are described) and the study of the taxonomic variability of organisms, confirming for example the distribution of species. Nhms, therefore, became privileged places to study the variety of nature, with a vocation to become centres dedicated to science dissemination.

At the transition from the 19th to the 20th century, many Nhms became centres for the diffusion of the natural sciences, often intended as educational centres for science, where the natural history collections became fundamental parts of the exhibition routes. Nhms opted to deal with major themes of natural history and their own history, also using exhibits collected by explorers and naturalists of the past, shown to arouse the public's interest as well as to document their own history.

In other cases, mainly limited to zoological exhibits, these specimens could originate from private collections, donated or acquired by owners or heirs, from deceased animals, e.g. run down by car traffic, or in facilities for their breeding, such as aquariums, zoos and bioparks. At the same time, with a growing disinterest in naturalistic collections occurring in the first decades of the 20th century, many of the precious taxidermy specimens housed in the zoological collections were frequently used for teaching activities, which were becoming increasingly important in Italian universities. During the development of exhibition and teaching activities, many kinds of specimens were therefore used, characterised by a different degree of historicity, often from historical collections and scientific archives, showing a diachronic cross-section of the methods of conservation and valorisation through naturalisation as well.

Museums and the use of artificial replicas

Many of the zoological specimens still housed in Nhms today are taxidermy specimen of mammals and birds, mounted skeletons, and, to a lesser extent, other skeletal materials, such as shells or exoskeletons. Only in a few cases are liquid-preserved specimens (usually in alcohol, though formalin and other fixatives are also used) exhibited: this is true for fish, amphibians and reptiles, as well as for many aquatic invertebrates such as ctenophores, coelenterates, molluscs and crustaceans, and also for anatomical organs mainly from comparative anatomy collections. The use of liquid-preserved specimens is often controversial, due to the challenges of displaying them attractively.

Today, the growing tendency is to display zoological specimens in as natural poses as possible, although this also (and above all) depends on the period in which the specimens were prepared. Clearly, "historical" specimens (dating back to the 18th or 19th century) were often prepared in poses that were not always true to life, whereas more recently modern taxidermy tends to display naturalised animals in dynamic poses, often within dioramas. While current taxidermy techniques evolved extremely well for birds and mammals, being now able to achieve an appearance and posture very similar to that in life, the situation is much more complex for animals traditionally preserved in liquid, such as many invertebrates, fish, amphibians, and reptiles. In these and other cases replicas of live animals were often used and thus became frequently used in exhibitions. Models, casts, and replicas have long been recognised as useful tools for both museum displays and educational purposes, particularly for showcasing specimens - especially animals - difficult

to present to the public in their original form. Tracing the precise historical development of these artificial representations in Nhms is challenging, primarily due to the wide variety and global distribution of such institutions. Given this complexity, we briefly concentrate on a selection of examples that illustrate their evolution and impact.

It is worth remembering that the use of models for those specimens that are impossible to preserve through taxidermy, especially because of their considerable size, is already documented at the end of the 19th century in some American Nhms where sculptors and painters were present in the laboratories together with taxidermists. Among these models, in particular, the giant squids (*Architeuthis*) reconstructed for the Peabody Museum at Yale University and the Museum of Comparative Zoology at Harvard University between the 1870s and 1880s (Ellis, 1997) and the two blue whales for the American Museum Natural History of New York and the Smithsonian's National Museum of Natural History at the beginning of the 1900s (Rossi, 2010). In Italy, this union between art and science will develop much more slowly and only in relatively recent times.

It is essential to distinguish between the three types of artificial objects listed in Tab. I. Models, as they are commonly called, are typically simplified or artistic representations usually used to illustrate anatomical structures in animals and plants. Models are often scaled, sometimes detachable, and are not intended to replace real specimens in exhibitions. Therefore, their primary purpose is educational, making them particularly useful in schools and museum teaching activities. In Italy, model production flourished during the 20th century. A prominent manufacturer was the Torino-based company G.B. Paravia & C., which produced an extensive and diverse catalogue primarily aimed at schools. Their models were frequently accompanied by other educational materials, such as posters and books, reminiscent of the style of Brendel's botanical models (Fiorini *et al.*, 2007). Although these models were occasionally used in natural history museums, their role was mostly limited to educational purposes rather than museum displays.

The use of casts and replicas has followed a different trajectory, often serving to enhance and complement museum exhibits alongside taxidermy specimens. Unlike models, these reproductions have been widely employed to faithfully replicate original subjects - primarily amphibians, reptiles, and fish. Their primary role is to replace alcohol-preserved specimens in displays, as fluid-preserved organisms tend to be less visually engaging and more logistically challenging to exhibit due to the need for specialized containers. Typically, resin casts are produced from frozen specimens using silicone molds, allowing for dynamic, lifelike poses that can be integrated into dioramas. In some cases, they are even hand-sculpted from resins or other materials. For many years now, the use of 3D scanning and printing has provided another method for creating models. When crafted with precision, these replicas achieve remarkable accuracy, especially when enhanced by skillful painting techniques that improve their realism. The result is an aesthetically compelling display that effectively captures the natural appearance of the species.

Casts and replicas have often played a significant role in museum exhibitions, particularly for specimens that are difficult to preserve or display. Notable examples include the *Andrias* model in the Firenze Museum and the amphibian replicas featured in the "Amphibia & Licheni" exhibition in Torino (1995) and the Madagascar rainforest diorama in the newly opened section of the MRSN (Nicolosi *et al.*, 2019).

FEATURE	MODEL	CAST	REPLICA
PRIMARY USE	Education / visualisation	Exact bone / fossil or ectotherm body duplication	Display substitute for rare / delicate items
DETAIL	Simplified or artistic	High (matches original surface)	Very high (lifelike appearance)
SCALE	Often scaled down/up	Usually 1:1	Usually 1:1
MATERIALS	Foam, clay, plastic	Plaster, resin, silicone	Resin, synthetic materials
EXAMPLE	Anatomic parts	*Tyrannosaurus rex* skull cast	Artificial mammoth fur replica

Tab. I. Summarising table showing features of models, casts and replicas, and their use and finalities in museum exhibits.

Sculptures and models have also been employed to recreate other organisms, such as fungal fruiting bodies, as seen in the unique *"Mario Strani Collection"* at the Museo Didattico di Storia Naturale in Pinerolo (Cavallero, 1986). Another striking example of artistic craftsmanship is the Blaschka collection housed in the Museo di Calci in Pisa, which includes 51 glass models of marine invertebrates (Faustini & Lolli, 2017). Created for educational purposes, these delicate glass reproductions - likely from Leopold Blaschka's early work (1822-1895) - blend science, art, and meticulous craftsmanship into stunningly lifelike displays.

Another key application of casts is for paleontological displays, where replicas allow the reconstruction of prehistoric creatures that cannot be preserved intact. The MRSN, for instance, used dinosaur models in temporary exhibitions, such as those featuring the genera *Mamenchisaurus* and *Tsintaosaurus* (exhibition titled: "Mamenchi & Tsintao. Dinosauri", Torino, 1992). A further notable example from MRSN's recent exhibit history was the *Giganotosaurus* replica displayed at Caselle International Airport in 2013, and more recently in the hall of Regione Piemonte's skyscraper (Anonymous, 2025) as a symbolic welcome feature.

More recently, an *Anancus* mastodon skeleton has been installed as a centerpiece in the museum's newly reopened exhibition space (January 2024). These examples highlight how artificial reconstructions - whether casts, replicas, or artistic models - serve as indispensable tools in museum education and display, bridging gaps where original specimens fall short. Another main reason why casts are used in paleontological reconstructions is that original pieces are often heavy and could be damaged if mounted. An example can be found at the Napoli Paleontology Museum, where the original skull of the *Allosaurus* is displayed separately to avoid compromising the structural integrity of the complete specimen.

Replicas represent highly accurate (sometimes hyper-realistic) reconstructions of zoological specimens, often employing techniques borrowed from cinematic special effects and artistic sculpting (Letze *et al.*, 2018). In NHMs, replicas frequently serve as substitutes when original specimens are difficult to obtain. While taxidermy remains the preferred method for contemporary mammals and birds, replicas provide a crucial alternative when preservation is impractical.

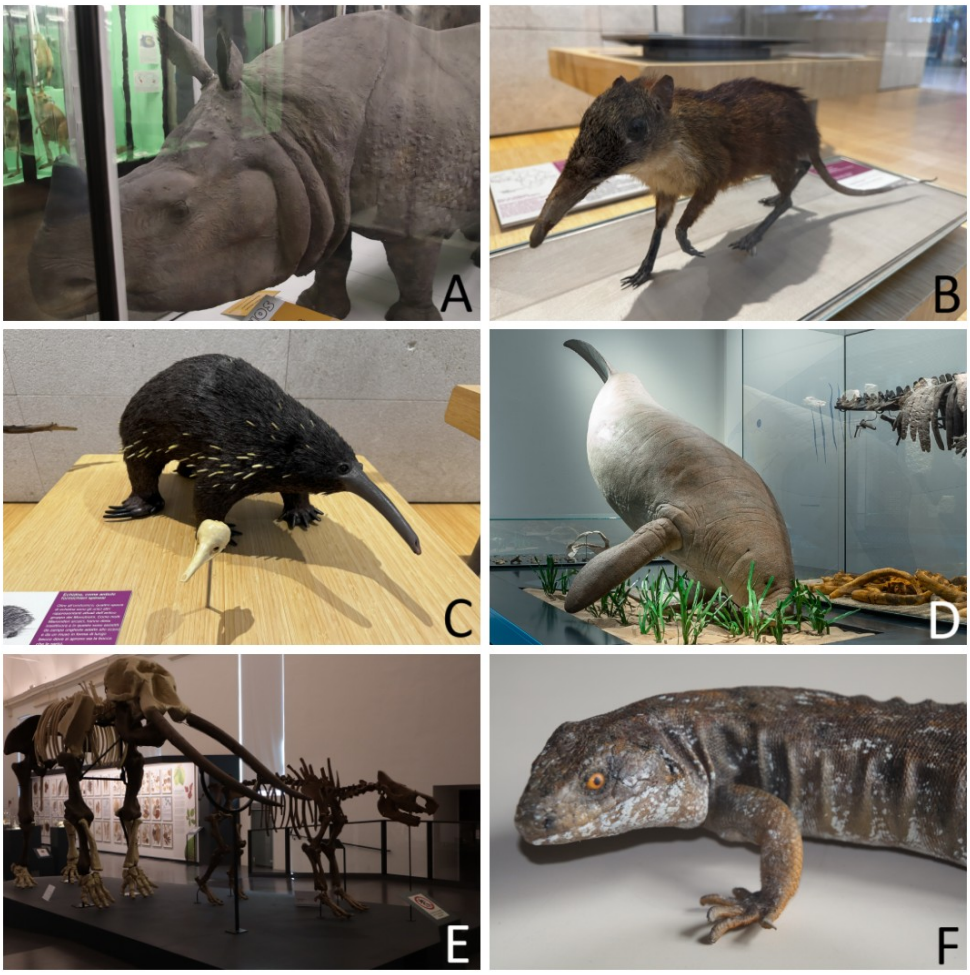

Fig. 1. Examples of zoological replicas and casts. (A) the Indian rhinoceros *Rhinoceros unicornis* realised by Rutilio Sermonti and hosted at the Museo Civico "G. Doria" di Storia Naturale, Genova (photograph by F. Andreone); (B) the grey-faced sengi (*Rhynchocyon udzungwensis*) at the MUSE, Museo delle Scienze, Trento (photograph by K. Tabarelli De Fatis); (C) the eastern long-beaked echidna (*Zaglossus bartoni*) at the MUSE, Museo delle Scienze, Trento (photograph by K. Tabarelli De Fatis); (D) the extinct dugongid *Kaupitherium* sp. displayed alongside its fossil skeleton at the Naturhistorisches Museum Mainz (photograph by R. Lopéz); (E) skeleton casts of the extinct mastodon *Anancus arvernensis* and Dusino's rhinoceros *Rhinoceros etruscus* at the Museo Regionale di Scienze Naturali in Torino (photograph by F. Andreone); (F) the extinct Capo Verde giant skink *Chioninia coctei*, replica based on a preserved specimen housed in Museo Regionale di Scienze Naturali in Torino (photograph by F. Andreone).

One of the earliest documented replicas in Italian NHMs is the Indian rhinoceros crafted by the artist Rutilio Sermonti for the Museo Civico di Storia Naturale "G. Doria" in Genova. This sculpture was so lifelike - modeled after a living rhinoceros from Roma's

Zoological Park (now Bioparco di Roma) - that its artificial horn was stolen by thieves mistaking it for a real trophy (Ponte, 2015).

Another realistic model of an Indian rhinoceros was created for the Kaziranga National Park diorama in the Museo Civico di Storia Naturale in Milano, chosen due to the impossibility of obtaining a taxidermied specimen and the difficulty of preparing such a large mammal (Bianchi *et al.*, 2008).

Hyper-realistic replicas are currently widely used in reconstructions at MUSE Museo di Scienze (Trento), including life-sized representations of *Rhynchocyon udzungwensis* (grey-faced sengi), *Zaglossus bartoni* (eastern long-beaked echidna), and several hominids. More recent is the installation of the new Museo Darwin-Dohrn in Naples, which has made extensive use of life-size models of fish, cetaceans and sharks, accompanied by Italy's only whale fall diorama featuring an authentic sperm whale skeleton as support for a model carcass reproducing this peculiar ecosystem (Boero, 2022). Finally, we emphasize the use of replicas for amphibians and reptiles, particularly for extinct species like *Chioninia coctei*. The recently created replica of this Cape Verde giant skink was based on an ethanol-preserved specimen in MRSN Torino (Andreone & Gavetti, 1998).

These examples underscore how replicas bridge gaps in collections, enabling Nhms to: (1) display species that cannot be preserved traditionally (delicate or extinct animals); (2) enhance public engagement with hyper-realistic, visually striking exhibits; (3) Support educational narratives where original specimens are lacking. By merging artistic skill with scientific rigor, replicas have become indispensable in modern museology, offering solutions where taxidermy or wet preservation fall short.

Exposition and didactic use of historical artefacts as a potential cause of deterioration

It is well-known that there is a tendency to exhibit hunted/collected animals, believing that their authenticity is crucial and inescapable and, therefore, particularly appreciated and/or demanded by the visiting public. However, the results of exhibiting original specimens are not always accompanied by a high degree of naturalisation. Moreover, the use of taxidermied animals still presents some objective constraints, connected both to the use of scientific and historical materials, and to the difficult retrieval of study skins, which are unavoidable to proceed with taxidermy.

In the "Victorian age" (1837-1901), the use of natural specimens was likely primarily favoured to surprise and to expose the beauty and variety of nature and living things to the public. With the passage of time, however, it was easily realised that their continuous display could cause quite a few preservation problems for historical and scientific artefacts. In fact, exhibition can cause degradation due to light and atmospheric aggression, parasites, and also because acts of unintentional damage and/or vandalism are by no means uncommon, especially when zoological exhibits are accessible to a heterogeneous and disrespectful public of visitors. In our opinion, the use of historical specimens in public exhibition finds its justification and "raison d'être" primarily when it is intended to show their origin and, indeed, their history, with evident clarity. But, overall, it should be increasingly limited.

Not infrequently then, historical artefacts are (and have been) used in practical teaching. This applies both to laboratory activities preparatory to specific degree courses and to the teaching offered to schools and the general public. It should also be remembered

that since the end of the 19th century (and for much of the mid-20th century) natural history collections with this purpose have been particularly encouraged in schools (Pizzigoni, 2015). These "school collections" have acquired considerable value over time, although their very original didactic destination has not always allowed for an effective preservation.

Current difficulties of obtaining zoological specimens

A further, important aspect when considering the long-term use of taxidermied specimens concerns the increasing difficulties in obtaining freshly dead animals, particularly from tropical areas (if we exclude from these considerations animals obtained by professional hunters). In the past, the collection of zoological specimens was also intended for museological display or contextual display. It was important to show to the public the results of scientific expeditions and collecting campaigns, mainly to show the variety of nature in ages when other communication systems such as video recording or the internet were not available.

Nowadays it is quite rare that the exhibition aspect is conceived as the first purpose of field studies; thus birds and mammals are seldom collected for this purpose. Currently, the tendency is that survey activities are mainly - if not primarily - aimed to collect voucher specimens for scientific collections. Although taxidermied specimens are still exposed today, this opportunity becomes rarer. In many cases, authorisations for their collection are not provided, or are limited to exceptional cases. More realistic and feasible, and still regularly carried out, are the sampling of voucher specimens of fish, amphibians and reptiles (among vertebrates) as well as many categories of invertebrates. However, as already said, it is not implied that these specimens are regularly used for exhibition, as they are difficult to display. Amphibians, reptiles and fish, as well as invertebrates, were sometimes exhibited as 'dry specimens', more often as liquid specimens.

Currently, naturalised specimens of mammals and birds can be obtained mainly through the recovery of private collections, mostly from hunting activities held in the past, or through the recovery of animals that have died in zoos and bioparks and/or recovered animals that have died in the wild (e.g. died due to road traffic).

Is it still reasonable to exhibit taxidermied specimens?

A further aspect to be considered for the possible choice of synthetic exhibits with regard to the realization of an exhibition tour also concerns the different ethical perception that exists today. In fact, it is increasingly difficult to justify the killing of animals for mere exhibition purposes. Therefore, the use of 'new' taxidermied animals is essentially based on specimens found dead in the wild (e.g., roadkills) or casualties from centers for the recovery of wild animals, zoos or bioparks. Private collections, put together by hunting enthusiasts, deserve special mention. The recovery of these finds and collections is in itself very important, as they often constitute important collections, even if they often refer to animals hunted on commission, and therefore with exclusively (or mainly) taxonomic/exhibition value.

In a situation in which the purpose and ostensive vocation in natural history museums and other public structures has increasingly become a priority, exhibits kept in storage and not on display are often seen as underused and/or inadequately valued. Thus,

one can ask whether in modern natural history museums a massive or even exclusive use of taxidermied animals (and other specimens) still makes sense. On the one hand, it is also evident that the zoological specimens of large Nhms are nowadays becoming very historical, as they largely consist of specimens collected in periods when Nhms sent their own conservators to make ad hoc collections or guaranteed the purchase from naturalist-collectors.

In the past, many naturalists (and even some institutions, such as the Zoological Station Anton Dohrn in Naples) made a business out of selling specimens to natural history museums, a practice that enabled the creation of important collections. Their finds still make a fine impression today in the exhibitions of major Nhms, such as in London, Paris, Vienna and, in Italy, e.g., in Genova, Torino and Firenze. While the use of these specimens further bears witness of the travels and work of naturalists of the past, it is also rather problematic because they are often very valuable specimens that can easily deteriorate if exposed. On the other hand, contemporary collections are increasingly aimed at obtaining voucher specimens for faunistic, phylogenetic and descriptive use, mostly intended for scientific collections rather than display parts.

The work of artists makes it possible to obtain hyper-realistic replicas of great ostensive value. The use of these exhibits provides clear indications of what should or could be the development of exhibition practices in natural history museums. Not being able to easily find specimens that have become rare in their natural environment, or included in CITES, suggests that the creation of ever more faithful replicas may be one potential way to integrate ancient finds and new forms of communication. Obviously, the recovery of animals that have died in the wild or in zoos will continue to be common practice.

As mentioned above, we believe that the recovery and collection of animals in the field is mostly justifiable when the primary objective is the study and extension of scientific collections. This does not detract from the fact that in some cases, even specimens taken in the wild and thus accompanied by complete data (coordinates, time of capture/collection, altitude, etc.) can be used for exhibition purposes. The use of synthetic models represents therefore an effective possibility to supplement exhibition routes. The high degree of fidelity of these artefacts, made with the most advanced methods of using different materials, makes the use of models a unique and irreplaceable way of presenting taxa that would be difficult to recover nowadays. Especially when contextualized (i.e., naturalized) specimens of mammals and birds are required, the realization of artificial replica specimen constitutes a major advance, even more when their reconstruction achieves exceptional degrees of fidelity. Of course, this is very valuable when there is a need to recover a specific taxon, as in the case of reconstructing an ecosystem fragment, etc.

Modelling techniques have become particularly refined over time, especially with the use of 3D scanning and printing and new resin products. They have been widely used since the early 20th century especially in paleontology, to obtain realistic reconstructions to place alongside fossils in exhibitions, especially in the great American Nhms where the work of zoologists and paleontologists was assisted by real artists. In Italy, one of the very first examples of a model being used for educational purposes was the *Triceratops prorsus* made in the late 1960s at the Museo Civico di Storia Naturale in Milano. This model has the distinction of being the first realistic (for the time) life-size reconstruction of this dinosaur species (Pinna, 1970). Henceforth, we strongly believe that the collection of animals and plants for scientific purposes must first and foremost be justified by the need to collect voucher specimens, and by no mean by the need to display specimens in exhibitions.

We believe that the use of synthetic specimens will have to go hand in hand with the use of new ostensive and narrative methods, including the use of video stations, soundscapes, and the use of artificial intelligence. By incorporating synthetic artefacts and appropriately narrating their uniqueness one can, in our opinion, achieve much better exhibition feedback.

Are replicas a threat for natural history museums persistence?

During the drafting of this article, the result of an extensive development process and opinion exchanges, we had the opportunity to engage in repeated discussions with colleagues, museologists and fellow naturalists, preliminarily sharing our key conclusions. These reflections support the notion that, in the future, Nhms may - and in some ways must - increasingly adopt hyper-realistic replicas for the narration of exhibition pathways. The objective difficulty of sourcing deceased natural specimens, necessary to illustrate specific themes - such as evolution, climate change, environmental alterations, or degradation processes - represents a significant challenge. As we have noted, obtaining such specimens, whether from the wild or captivity, is complex, not to mention the restrictions imposed by permitting regulations.

We also feel obliged to respond to criticisms that have been moved to us recently by some colleagues, insofar as they are not very keen on the use of synthetic finds. One of the objections levied against the use of replicas concerns the low fidelity of synthetic specimens and, therefore, their immediate recognizability as artificial articles. The most advanced methods of creating such artifacts make indeed possible to obtain results that are almost indistinguishable from (and often even superior to) those obtained by artistic taxidermy (e.g., the jellyfish models by 10 Tons). A second criticism concerns the fact that the public would demand and/or be loyal to taxidermied specimens. Finally, some have also pointed to the fact that, by disconnecting the collection of specimens from their display, one would lose a 'lever' to be able to proceed with collections.

As an illustrative example, we consider the case of *Cryptoprocta ferox* in MRSN (Torino), for which we had the fortunate discovery of an individual that died in captivity to integrate a section dedicated to Madagascar. In the absence of such an opportunity, we would have opted for an ultra-realistic replica to integrate and complete the exhibition. Nevertheless, significant resistance persists regarding the full replacement of taxidermied specimens with artificial models. In many cases, if a public preference for natural specimens is observed we believe it is influenced by superficial conservatism. A further concern is that the extensive use of replicas could lead to a gradual decline in collection activities.

We do not believe that this corresponds to reality, barring some very specific cases. Collection activities, at least in Italian Nhms, is already quite reduced, for a series of reasons. Curators, which in the last decades of last centuries were allowed to organize field surveys not only in Italy, but even abroad, are far more limited in their logistic abilities. Since many Nhms depend on public administrations (municipalities, regions) the curatorial personnel is often equipared to administrative one, and for this reason they are very rarely allowed (let alone encouraged) to carry out field activity. Therefore, the use or non-use of taxidermied specimen and ultra-realistic replicas does not seem, in our opinion, to depend directly from personnel field work.

Although in the past specimen collection also served exhibition purposes, this approach is no longer sustainable today. The justification of display cannot and should not form the basis for maintaining scientific collections. On the contrary, we argue that museum research should be independent of exhibition needs: the acquisition of specimens for scientific purposes should not be tied to their potential display, while exhibitions, in turn, should employ updated and alternative methodologies. Unfortunately, this autonomy is not always achievable, particularly in small-scale natural history museums, where staff - often limited and primarily dedicated to education and exhibit design - can rarely support research activities. In such contexts, the use of artificial replicas could resolve logistical challenges while ensuring both the accessibility of exhibitions and the preservation of historically or scientifically significant specimens. If implemented judiciously, this solution could thus strike a balance between innovation, sustainability, and scientific rigor.

Replicas and museums: a road to the future?

Nhms have long served dual roles as both research institutions and centers for public education. Historically, their exhibitions relied heavily on authentic specimens - taxidermied animals, skeletons, and preserved specimens - to showcase bio- and geodiversity. However, growing ethical, logistical, and conservation challenges have prompted a shift toward a growing and complementary use of ultra-faithful replicas and models in exhibition design.

One of the primary advantages of replicas is their ability to mitigate the degradation of irreplaceable historical and scientific specimens. Continuous display of original specimens, especially in suboptimal conditions, may accelerate their deterioration due to light exposure, humidity, and even vandalism. Replicas offer a sustainable alternative, allowing museums to preserve voucher specimens - critical for taxonomic research - while still engaging the public with visually compelling exhibits.

Technological advancements, such as 3D scanning and printing, and artistic craftsmanship now enable the creation of hyper-realistic replicas that may rival and often exceed traditional taxidermy in both accuracy and aesthetic appeal. These replicas are particularly valuable for displaying species that are already extinct, difficult to preserve (e.g., delicate invertebrates, amphibians, and fish) or ethically contentious to collect (e.g., endangered or protected species). Moreover, they allow for dynamic and immersive dioramas that enhance storytelling, such as reconstructions of extinct ecosystems or rarely visible wildlife behaviours.

Despite their benefits, replicas have faced skepticism from some museum professionals and visitors who perceive them as inauthentic or inferior to "real" specimens. However, public preference for natural specimens often stems from tradition rather than an informed critique of their scientific or educational value. Clear labeling and contextualization can help audiences appreciate the role of replicas in conservation and research. A critical consideration is the decoupling of exhibition needs from scientific collection practices. While historical Nhms often collected specimens explicitly for display, modern conservation ethics and legal restrictions make this approach unsustainable. Instead, specimen acquisition should prioritize research, while exhibitions increasingly rely on replicas, digital media, and interactive technologies. This separation ensures that collections remain intact for future study while allowing museums to adapt to contemporary educational demands.

Ultimately, the strategic integration of replicas does not threaten the authenticity of Nhms but rather enhances their ability to fulfill their missions. By combining ultra-faithful models with innovative storytelling techniques, museums can continue to inspire curiosity and attention about the natural world without compromising scientific integrity or ethical standards. The future of museum exhibitions lies in a balanced approach - one that respects the past while embracing the possibilities of modern technology.

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RIASSUNTO

Una biodiversità sintetica? I musei di storia naturale e l'uso di repliche artificiali come integrazione agli esemplari tassidermizzati.

I musei di storia naturale sono istituzioni dedicate principalmente alla ricerca, alla divulgazione e all'esposizione della natura. Nel corso del tempo, hanno sviluppato il rigore scientifico nella raccolta di serie di esemplari, campioni di tessuto, fotografie e registrazioni sonore, contribuendo a studi tassonomici, ecologici e biogeografici. Nel 20° Secolo, i musei sono diventati centri di educazione e divulgazione delle scienze naturali, utilizzando le collezioni storiche per coinvolgere il pubblico. L'uso di esemplari originali per scopi educativi e di divulgazione scientifica pone sfide significative, tra cui la conservazione a lungo termine, la perdita di dati e l'acquisizione di valori storici. Inoltre, gli esemplari zoologici diventano sempre più difficili da acquistare a causa delle limitazioni etiche e legislative. Qui proponiamo un uso integrativo di repliche di alta qualità, associate alla grafica computerizzata, all'intelligenza artificiale e alla stampa 3D. L'uso combinato di vecchi materiali e di questa biodiversità sintetica può fornire nuove opportunità ai musei di storia naturale senza compromettere le collezioni storiche e scientifiche.

Parole chiave: Biodiversità, Calchi, Attività educative, Modelli, Musei di storia naturale, Repliche, Collezioni scientifiche, Innovazioni tecnologiche.

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