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MUSEUMS AND EVOLUTION

Evolutionary Theory and the Florence Paleontological Collections

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Abstract Florence has a tradition of Natural Philosophy, and since as early as the sixteenth century fossils were collected by the Granduke. The Museum of Natural History of the University of Florence houses today collections that belonged to Nicolas Steno, when fossils were for the first time used as documents to reconstruct Earth history. Natural philosophers and geologists, both Italian and foreigners, continued to study fossils collected in Tertiary strata of Tuscany until the nineteenth century, when the first speculations on the origin of species were proposed. Charles Darwin himself mentions fossil vertebrates that are today on show in our museum. In the last years, this part of the history of science has been proposed to the public. The aim was to foster an understanding of the centrality of fossils in two cultural revolutions, the discovery of deep time and the birth of evolutionary theory–connected among themselves and with the emergence of geology. Dedicated volumes, public conferences, guided visits to the collections, and field trips to paleontological sites have attracted an attentive and responsive public, showing that the history of science can help deliver modern evolutionary thinking. Other activities aimed at students of all ages have also shown that the interaction between schools, university teachers, and museum personnel is vital to form the mind of future generations on the reality of the evolution of natural systems.

Keywords History of science · Geohistory · Tuscany · Nicolas Steno · Charles Darwin

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Introduction

Collections of fossils existed and were exhibited as separate objects of natural history already some decades before the theory of transmutation by natural selection formulated by Charles Darwin was published in 1859. As a matter of fact, starting with Lamarck and well into Darwin's early work, fossils were the main source of evolutionary thinking (Rudwick 2005, 2008; Dominici and Eldredge 2010). Yet, paleontological exhibits do not inherently speak about the evolution of one species into another, as the majority of late eighteenth and early nineteenth century geologists daily dealt with fossils without feeling pushed to conceive evolution. As a further proof, in creationist hands, fossils are used today to exactly the opposite effect (Princehouse 2009). What the public can learn about evolution when walking through a paleontological exhibit thus comes from the way fossils are arranged and from the words and graphics mounted to explain them. In addition to this, historical European collections have a particular story of their own to tell about the precursors of modern evolutionary thinking. This is the case with fossils housed in the Museum of Natural History of the University of Florence, including seventeenth to nineteenth century collections and fossils mentioned by natural philosophers like Steno and Buffon, and geologists like Cuvier and Darwin (Rudwick 2005, 2008; Dominici 2010; Cioppi and Dominici 2010). In Florence, as in Paris or London, paleontological exhibitions can be thus walked along two tracks, one focusing on taxonomy or stratigraphy, another considering that some of these very same objects represent the history of geology. Florence fossils were used (1) to discover and explore the depths of geological time, (2) to realize that some species have become extinct, and—last in historical order, but not least, given the title of this paper—(3) to conceive that species have had origins within the realm of natural phenomena. This added

value of historical collections facilitates the process of learning, inasmuch as the visitor is brought to empathize with those who, starting from scratch and in a stepwise fashion, discovered the geological and paleontological facts that were directly seminal to Darwin's theory of natural selection, finally leading to modern evolutionary theory.

The Rediscovery of Deep Time

The multifaceted nature of time, both cyclical and irreversible, and the many ways time regulates natural phenomena were approached in our museum during the exhibition "Time of nature," from October 4, 2003 to March 7, 2004. A conference held on the 9th of February, 2009 with the title "Deep Time: From Steno to Darwin" was expressly dedicated to connecting time with evolutionary theory and to celebrating Charles Darwin's bicentennial (1809–1877). This aimed at establishing a historical connection between the Tuscan geological and paleontological heritage, a large part of which is stored in Florence, with the emergence of the British school of geology in which young Charles Darwin was trained. At the time Darwin published *The Origin of Species*, the Florence paleontological collections, albeit not central to his theory, were still well known to some of his peer geologists. The conference, mainly aimed at a public of high school students and their teachers, was less a celebration than a debate among philosophers and geologists committed to reconstructing and understanding precise passages in the history of geology. Since the latter is a sector of the history of science that has only recently started to loosen the fetters of traditional Anglocentric accounts (Baker 2008), the conference turned out to be a lively meeting, full of discoveries for the conveners themselves.

To Nicolas Steno (1638–1686), who enriched and ordered the granducal collection of those objects today we call fossils, then called petrifactions, and wrote in Florence his seminal works of 1667 and 1669, the history of our planet was limited to little more than 6,000 years. In Tuscany, Steno saw how to use sedimentary strata to reconstruct history by geometric relationships, freeing it from textual accounts (Cutler 2003). Steno's stratigraphic principles ("the lowest is the oldest" and others) and his role in demonstrating the organic origin of fossils are still taught today in Earth science courses (Cutler 2003), but what a thrill to come out of the books and face the outcrops where those principles were first conceived! Leading teachers and students along Steno's footsteps during the fieldtrip connected with the conference and again the following spring, moreover, adds a much-needed connection between the objects closed in a museum and the territory, helping to imaginarily bring fossils out of the drawers and showcases, into the open space of the outcrops where they were collected. For many participants, this resulted in a lasting impression of what geology is and proved a powerful approach to gaining personal experience with the reconstruction of time through fossils and strata. All the participants were "wearing the shoes" of one—Steno—who had not obviously learned from the manuals how to make an anatomy of the earth.

To celebrate the Darwin bicentennial, it was necessary to explain how the measure of prehuman time had been increased by at least three orders of magnitude by Darwin's immediate predecessors, four orders by the man himself. Without deep time he would have not conceived the slow transition of one life form into another, so deep time has also been presented as the "lost ingredient" of evolutionary theory. Lost because geological time is seldom mentioned in school books as a prerequisite of evolution by natural selection, and also referring to the fact that the importance of Darwin's geological training has been overly simplified by scholars, until very recently (Herbert 2005; Eldredge 2006; Rudwick 1974, 2008; Dominici and Eldredge 2010). Darwin was the first to devise a practical way to calculate absolute geological time, measuring the Tertiary in tens of millions of years (actually exaggerating it by five times). Telling what happened between the two centuries that separate Steno's from Darwin's writings, and how Florentine fossils were instrumental for understanding the vast stretches of time before the advent of man on earth, catalyzed the attention of the public. Some of our fossils were collected in Tuscany and ordered by Giovanni Targioni Tozzetti (1712–1783), the man of trust of the Granduke, one century after Steno, and one who gave a fundamental impulse to the birth of our museum, in 1775 (Cioppi and Dominici 2010). Targioni conceived a system of classification by merging zoological and paleontological collections, presenting fossils as documents that have traveled "innumerable centuries," bringing us evidences of former life forms. The remains of fossil proboscideans of the Targioni and granducal collections are today presented to the visitors not just for their systematic and stratigraphic value, but also as instrumental to the history of geology (Monechi and Rook 2010). Among these, the remains of Valdarno proboscideans, first interpreted as remains of "giants," then as Hannibal's elephants, were interpreted by Targioni and a few of his contemporaries as prehuman animals, opening the way to the work of George Cuvier (1769–1832), who duly came to visit Targioni's collections and all other paleontological treasures of Tuscany (Rudwick 2005; Cioppi and Dominici 2010). When confronting one of Targioni's fossils, the visitor is presented with the discovery of prehuman history, and the anatomically grounded evidence that once upon a

time large animals had lived here but are now extinct (Rudwick 2005). In this as in other European museums, each specimen tells two stories, history of science and history of the earth (Fig. 1; Cioppi and Dominici 2011).

From Extinction to Origination

The proof that extinction is a natural phenomenon that punctuated prehuman history was one further step toward evolutionary theory (Rudwick 2008). This proof was grounded in the method of comparative anatomy conceived at the turn of the century by George Cuvier in Paris and repeatedly tested in museum collections throughout Europe, including Florence (Rudwick 2005; Cioppi and Dominici 2010). The articulated, complete, and mounted skeletons of large proboscideans like *Anancus arvernensis* and *Mammuthus meridionalis*, present the visitor with animals that belonged to species similar to, but distinct from living elephants (Fig. 2). When correctly guided, this is a larger-than-life approach to a fact of history, one that sticks in the mind, a proof not solely of climate change (as timidly claimed by Giovanni Targioni Tozzetti), but that some species have gone extinct (as shown by George Cuvier). The same experience can happen with skeletons of rhinos and hippos, horses and giant deer, and skulls of local saber-tooth tigers and giant hyenas. Modern scientists know well how to compare Tertiary terrestrial fossils with extant animals. Today we can show from our collections of Miocene, Pliocene, and Pleistocene vertebrates that species appear in geologically ordered strata in a piecemeal fashion and that species become more and more similar to those today inhabiting the face of the earth. The same can be done with fossil mollusks, many Pliocene, and some Miocene species that are morphologically indistinguishable from bivalves and gastropods still thriving in modern Mediterranean bottoms. The latter

Fig. 1 The scapula of *Anancus arvernensis* from the Targioni collection. Fossils such as this were mentioned in his correspondence with Georges-Louis Leclerc, Comte de Buffon

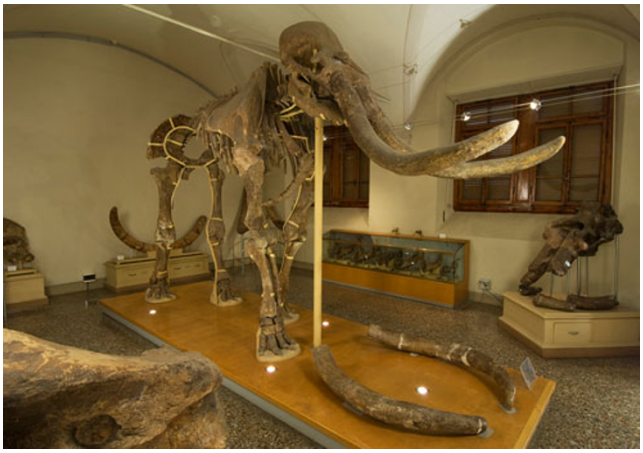

Fig. 2 An articulated specimen of *Mammuthus meridionalis*, surrounded by other proboscideans remains

discovery authored by Giambattista Brocchi (1772–1823) in 1814 was the first step toward the ordering of Tertiary strata by percent of extant species by Gérard Paul Deshayes (1795–1875) in 1824 and Charles Lyell (1797–1875) in 1833 (Rudwick 2005, 2008; Dominici and Eldredge 2010). Giambattista Brocchi studied Tertiary mollusks of our collections in 1811, after collecting his own lot from the nearby hills. From this and other evidence, he first speculated that species like individuals have a birth and a death, the same concept explored by young Charles Darwin during the *Beagle* voyage, in his first attempt to work out facts for a theory of transmutation (Eldredge 2009; Dominici and Eldredge 2010). Darwin himself had direct contact with the Florence collections at a later stage of his scientific activity, thanks to one of his correspondents, the vertebrate paleontologist Charles Immanuel Forsyth Major (1843–1923). Forsyth Major pointed out to him a female skull of a fossil *Bos* without horns, as mentioned by Darwin in the 17th chapter of *The Descent of Man* (1871) as an example of the transmission of secondary sexual characters, a specimen today on display. Darwin also had contact with the young geologist Igino Cocchi (1827–1913; Cioppi and Dominici 2010). On the second floor of the building, the invertebrate collections are stored in early twentieth century showcases, ordered according to geological period, provenance, and taxonomy. This huge exhibition makes a large impact on visitors as massive evidence of the hundreds of species that have originated and gone extinct through the 541 million of years of the Phanerozoic (Fig. 3). Here, one can walk past fossils from oldest to youngest, experiencing a progression from odd life forms to a more familiar universe, from showcases packed with trilobites or brachiopods, to those with clams and crabs. A new exhibition on the ground floor synthetically conveys this stratigraphic and geographic order using the standard colors and absolute time estimates of the Geological Time Table, side by side with the modern

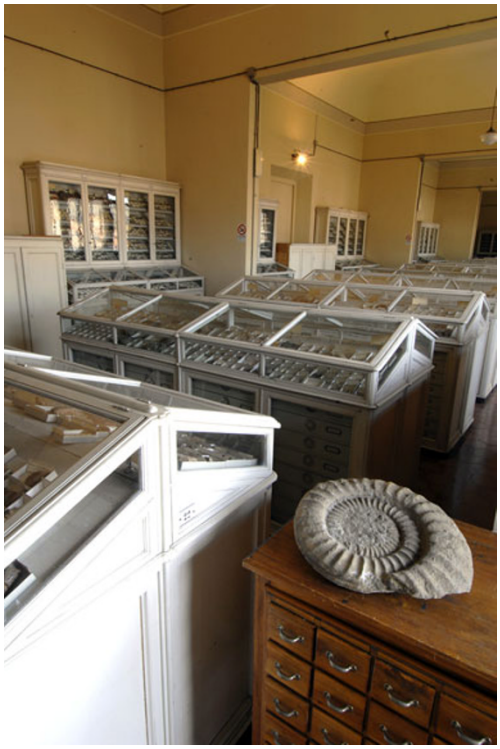

Fig. 3 Invertebrate exhibition, ordered by stratigraphic, systematic and geographic criteria

version of the Darwinian theory of evolution by natural selection and the allopatric model (Eldredge 1971), or "punctuated equilibria" (Eldredge and Gould 1972).

School Activities and Impact on Visitors

Students, from elementary grades to high school, make up the largest part of our public. One of the educational activities, entitled "From the origins of the universe to the origin of man," running from 2006 to 2010, was designed and proposed by a team of three institutions, comprising Florence Museum of Natural History, the Museum of Prehistory in Florence and the Museum of Planetary Sciences in Prato. The subject dealt with the three key origins: the universe and the solar system, of life, and of man, connected by the concept of the continuous transformation of all natural systems. The activity included a guided visit to the three museums and field trips to important prehistoric and geological sites of Tuscany. Each year ended with a public show of the work created by the students during the previous months of activity, as a response to the effort spent by our educators and their teachers. In 2007–2008, students of all ages were asked to study, eventually design, and act in theatrical performances. These were offered to the public during an exciting open-air evening meeting in front of the Planetary Science Museum—a moment of creativity which left lasting impressions on us all. Interestingly, the acts were performed by high school students, at times guided by a team of teachers of different disciplines. This made the experience of particular value if we consider that in our experience high school students are very difficult to attract to visiting museums (Cioppi et al. 2010). Another educational activity aimed at high school students took place during the school year 2005–2006, inspired by the work of Howard Gardner and the idea that the theory of evolution is one of the best to "illuminate the nature of truth, beauty, and morality" in the mind of a student (Gardner 1999). The activity was designed by a team of teachers and museum curators, sponsored by the Regional Institution for Educational Research under the title "Science in schools and museums" and included lectures by museum personnel and university teachers, a visit to paleontological and anthropological collections, and the final production of a hypertext by the students. A strong point of our educational projects was the involvement of the academic world, well acquainted with the collections used in teaching. Lectures included (1) the paleontological documents of evolution, (2) the evolution of primates, (3) the comparison of primates skulls, and (4) the contribution of molecular biology to reconstructing human history. The course had a historical dimension, including an introduction on the discovery of deep time and Darwin's *Beagle* voyage (Lachina et al. 2007). One constructive segment was the handling of casts of the skulls of australopithecine and humans to learn about the place of *Homo sapiens* in the tree of life. Casts from all over the world and real fossils were shown. The latter included the articulated skeleton of the miocene ape *Oreopitecus bambolii* recovered in Southern Tuscany (Rook 2009) and an early human skull found in 1995 in Eritrea, both fossils studied by Lorenzo Rook of the Florence University (Abbate et al. 2004), who presented

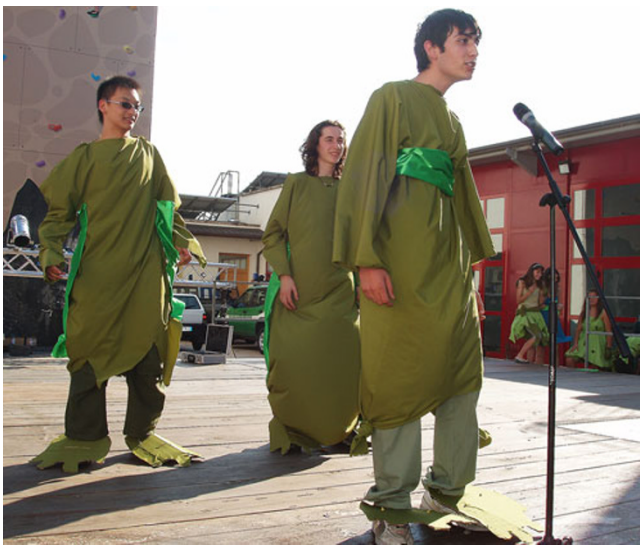

Fig. 4 Amphibians conquer the land: high school students as authors and performers at the end of the project "From the origin of the universe to the origin of man"

his fieldwork and studies. The activity proved that a synergy between academic teaching and museum curatorship is a way to bring scientific work in the framework of evolutionary theory to high school students, and to help them to raise their consciousness of the place of man in nature. This is, in most cases, their last chance to face some evidence of evolution before growing up to adulthood (Lachina et al. 2007). A second chance to interact with teachers and students of Earth science in the Florence University was a project in collaboration with Simonetta Monechi. Students of her paleontology course were asked to design and make an exhibition on mass extinctions and the main biotic turnovers of Earth history. The exhibit was on show for several months in 2001, with rewarding results for the public and the young organizers of the show (Fig. 4).

Concluding Remarks

The general public of the Florence Museum of Natural History is attracted by paleontological collections and is willing to be told what lies behind the face value of fossils. Most of the fossils on show, be they remains of large vertebrate animals or small marine shells, were recovered in the territory of Tuscany. Florence and Tuscany played an important role in the history of European science in the 17th and 18th century, and some of these fossils were those used by natural philosophers such as Steno to prove that remains of ancient animals are now enclosed in rocks, or by Targioni Tozzetti to explore prehuman geohistory. The discovery of the organic nature of fossils and of deep time, a true pan-European cultural revolution, prepared the way to Darwin's theory of evolution in the nineteenth century. In our experience, connecting the fossils to the territory and connecting both to the history of science wins the favor of the public and leads to a more natural, less theoretical way to learn about evolution.

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