Alessandro Minelli

DARWIN'S BICENTENARY AND NATURAL HISTORY MUSEUMS

BICENTENARIO DI DARWIN E MUSEI DI STORIA NATURALE

Collections

Natural history museums are the repositories of collections whose materials are used for both educational and research purposes. It is certainly not a chance that natural history collections had such a large importance in the life and work of people like Lamarck, Darwin and Wallace, not to mention a huge number of more recent scientists like Ernst Mayr, Berhard Rensch, Willi Hennig and George Gaylord Simpson.

In 1793, a middle-aged Jean-Baptiste Monet de Lamarck, formerly a soldier, a meteorologist and a botanist, was abruptly put in charge of the invertebrate collections of the newly founded Muséum d'Histoire Naturelle in Paris, and it took him little more than ten year work with these museum's collections, especially those of Recent and Tertiary shells, to realize that living beings are subject to change, and also to reject the traditional "descending order" listing animals from mammals to fishes to insects to polyps. Eventually, Lamarck presented his evolutionary views in his *Philosophie Zoologique* whose bicentenary of publication (1809) has been completely obscured by the Darwinian celebrations, while his multi-volume *Histoire naturelle des animaux sans vertèbres* (1815-22) materialized the ideal arrangement of a zoological collection in agreement with his theoretical views.

As a country gentlemen, Charles Darwin did not work in a museum, but collecting natural history items was one of his main jobs during the long voyage on the *Beagle*, and the specimens he eventually brought home contributed significantly to the development of his idea of evolution. The best known example, in this respect, are the geospizines (the well-known "Darwin's finches" of the Galapagos Islands), to whose diversity - in terms both of species and adaptations - his attention was called by the ornithologist John Gould, whom Darwin had entrusted with the study of his bird collection.

An extraordinary collector of museum specimens - of butterflies and birds, for example - was Alfred Russell Wallace, in Amazonia first, and later in that "Malay Archipelago" where he eventually developed a theory of evolution by natural selection, very close to Darwin's at the time still unpublished model.

In more recent times, evolutionary biology has so extensively ramified that a very large fraction of its research effort has been devoted to objects and tools very different from those that represent the traditional and characteristic resources of a natural history museum. Genetics first, and molecular biology later, have contributed very extensively to our current appreciation of evolution and additional fields spanning from ecology and ethology to developmental biology have progressively gained prominence in evolutionary studies. Nevertheless, the importance of the collections of natural history has never diminished and the result of taxonomic and phylogenetic studies has always contributed its great share to the common pool of evolutionary knowledge.

Many leading figures of the so-called Modern Synthesis of Evolutionary Biology were museum scientists. Among these are the palaeontologist George Gaylord Simpson and the zoologist (ornithologist) Ernst Mayr, whose books have trained in evolutionary biology whole generations of scientists. Far from being mere generalists or speculative theorists interested in evolution, both Simpson and Mayr produced major monographs in the respective fields (fossil mammals and living birds), based on the painstaking study of extensive museum materials, inclusive of major collections each of them gathered personally in the field.

Among many other important evolutionary biologists of the twentieth century, a museum scientist was also Willi Hennig, an entomologist specialising in Diptera, to whom we owe the foundation of cladistics, i.e. the modern approach to the reconstruction of phylogeny. Following the publication of Hennig's seminal book *Phylogenetic Systematics* (1966), a couple of large natural history museums (in particular, the American Museum of Natural History in New York, and the British Museum (Natural History) - as it was called at the time - in London) were the theatre of the most lively debates on cladistics. Along the '70s and the '80s, the most important conceptual development of cladistics and the most vigorous campaigns in favour of this approach to systematics were also largely in the hands of museum scientists, such as the fish palaeontologists

Colin Patterson and Peter Forey and the botanist Chris Humphreys in London, or the ichthyologist Gareth Nelson in New York.

A first-rate acquaintance with the many dimensions of animal diversity, such as only a daily perusal of zoological collections can grant, is also evident in the works of Bernhard Rensch, himself a university professor rather than a museum curator, another giant of last century's evolutionary biology, whose works are perhaps not so popular as those of Mayr and Simpson, but still deserve respectful reading, especially his *Evolution above the species level* (Rensch 1959).

Ecological time vs. geological time

Evolution being change of populations with time, there is no difficulty realizing the strict dependence on museum collections of the study of macroevolution, especially when based on fossils, where the gaps between forms worth comparison are measured at the scale of geological time. Less obvious is perhaps the relevance of museum collections to the study of microevolutionary dynamics. The latter studies are quite often performed, indeed, on wild populations, or on selected strains kept in laboratory cages, but those studies represent only a part of the picture. Complementary to them are the studies of materials preserved in the natural history museums, as the following examples will show.

The birch moth *Biston betularia* is often cited in textbooks as a species on which it has been possible to record the effects of natural selection in the field. In the simple terms in which it is generally told, the history runs this way. Like many thousand other species of moths, the birch moths are active during the night, while during the day they remain motionless, with the wings characteristically spread flat against the ground. In natural to quasi-natural conditions, the adults of *Biston betularia* rest very often on the trunks of birches. Their wings are usually whitish, with black mottling, such that a resting moth is hardly distinguishable from the surrounding birch bark. This is regarded as advantageous, as during the day these moths are exposed to predation by insectivorous birds. Here and there, some rare specimens of *Biston betularia* have been recorded, whose wings are not whitish with dark mottling, but uniformly coal black. These specimens are obviously very conspicuous when resting on the bark of a birch. This might explain why the dark form is usually so rare. But this is right the point where natural history museum enter the stage. Their collections preserve the record of times and places where the dark form of *Biston betularia* became, for a while, abundant, perhaps even more than the "normal" white form. This happened, as reported in textbooks, during the Industrial Revolution, in regions where persistent clouds of smog caused the bark of trees to become dark as the smoke of the chimneys, or the lungs of people living in industrial areas (cf. Kettlewell 1955; 1956; 1973). Years ago, strong objections were raised against the current interpretation of this story as an example of natural selection (Hooper 2002), but this does not lower at all the precious value of the historical record preserved in the museums; rather, any critical discussion may only ask for more detailed and geographically and temporally distributed vouchers.

Museum specimens are obviously a unique source of information in the case of critically endangered species. Extensive record from past decades may document the trends in reduction of range and specifically point to areas where conservation measures should be primarily implemented. But the specimens of endangered species preserved in the museums may offer information of much higher scientific content, at the critical juncture between population studies of relevance for conservation and targeted studies of microevolutionary dynamics. A nice example is the study performed by Harper et al. (2006) on a lycaenid butterfly, the Adonis blue *Polyommatus bellargus*. The authors extracted DNA from museum specimens more than 100 years old and compared it with specimens of the same species collected at the same site in Southern England some 200 generations later. This comparison revealed dramatic changes in allele frequencies, something they interpreted as the effect of genetic drift or of recolonization following local extinction. More important, one allele present at high frequency in 1896 was not found any more in extant UK populations, suggesting that it may have been lost.

Evolutionary developmental biology

Evolutionary developmental biology is one of the most actively growing fields within the life sciences. As indicated by the discipline's name, its research program has double roots, in evolutionary biology and developmental biology, respectively. However, far from being a mere melting pot of the two parent sciences, evolutionary developmental biology is developing a core set of original problems, the most important of which is arguably "evolvability" (Hendrikse et al. 2007). This neologism has been introduced to indicate the whole scenario of possible avenues of evolution that are within reach starting from an organism's current organization. This is something we cannot address in terms of natural selection, that is, of differential survival and reproductive success of alternative phenotypes. Focus is shifted instead towards the "production" of phenotypes, especially towards the identification of pathways of change we should likely expect, from the point of view of selective advantage, which are nonetheless missing, or nearly so, due to developmental constraints. A popular example is provided by the number of the cervical vertebrae supporting the neck of mammals, whose number is nearly universally fixed at seven, even in the case of the giraffe, where the extreme elongation of the neck was accomplished under a long-lasting selective pressure that favoured individuals with longer cervical vertebrae, but could not favour individual with higher number of vertebrae, simply because no variation for this trait was ever available during the evolutionary transition from giraffe ancestors with short neck to modern giraffes with long neck.

Interestingly, the collections of natural history museums have provided materials of the highest value to evolutionary developmental biology. This is perhaps unexpected, as developmental biology, as such, is hardly a science to be primarily cultivated in a museum. Three recent examples will demonstrate that such an expectation is misplaced.

Evolutionary trends, generalized constraints and lineage-specific variation in the vertebral numbers of mammals have been investigated by Narita & Kuratani (2005) in a well-researched paper that literally exploited two centuries of zoological research. On the one hand, their analysis of evolutionary trends was performed against the current views of mammal phylogeny, which are mainly based on extensive comparisons of molecular sequences. On the other hand, the data base on vertebral numbers analysed by the two Japanese authors was derived, necessarily, from museum collections. But they did not need to examine skeletons by themselves: they found what they wanted in the *Descriptive catalogue of the osteological series contained in the museum of the Royal College of Surgeons of England* published in 1853 by the well-known comparative anatomist and palaeontologist Richard Owen. This is clearly a unique demonstration of the long-lasting value of the information stored in the natural history collections, and of the careful descriptive work that good museum curators are able to perform on it.

A second example of the role of museum collections in providing data for research in evolutionary developmental biology concerns the fossils. Of course, development of extinct animals can only be studied when abundant series of specimens of different developmental age have been preserved, something that does not occur too frequently, even for numerically abundant fossils, mostly represented by individuals of the same developmental stage. Sampling problems notwithstanding, museum collections have sometimes provided uniquely precious information about the development of extinct animals and these data, despite their fragmentary nature, has sometimes provided extremely valuable insight on the evolution of developmental schedules. Extraordinary interest, because of their age, have elicited the 580 million years old eggs and embryos from the Late Precambrian Doushantuo Formation of Southwest China (Li et al. 1998; Xiao et al. 1998; 2000; Chen et al. 2000; 2006; Xiao & Knoll 2000) and the slightly younger Cambrian fossil eggs and embryos found in China, Siberia, Australia and North America (e.g., Pyle et al. 2006; Lin et al. 2006; Steiner et al. 2004). Much younger but not less interesting is a wonderful series of Cretaceous tadpoles studied by Chipman & Tchernov (2002).

Of the many other examples of "developmental fossils" I could add to this list, I will only mention the Lower Silurian trilobite *Aulacopleura konincki*, represented in museum collections, especially in those of the Natural History Museum in Prague, by thousands of specimens out of which it has been possible to reconstruct not only the whole sequence of post-embryonic stages, but also its individual variation. As a consequence, the development of this fossil arthropod has became critically important in improving our understanding of the evolution of arthropod developmental schedules (Minelli et al. 2003; Fusco et al. 2004; Hughes et al. 2006).

As a final example of the unique value of museum collections for the progress of research in evolutionary biology, I want to mention a case involving my favourite group, the centipedes. More than three thousand species of these arthropods are known to date. Descriptive work based on museum specimens has shown that all adult centipeds have an odd number of leg pairs (Minelli & Bortoletto 1988). This is clearly suggestive of a developmental constraint that opens a question about the evolvability of segment number in these arthropods. As number variation, in this case, is not continuous, the smallest change from a given condition to the nearest one is apparently two segments, but a recent discovery suggests otherwise. The story involves, in particular, the Scolopendromorpha, one of the five major lineages within the centipedes. Most scolopendromorphs have 21 pairs of legs, the others have 23. Until recent, only one species was known to be dimorphic, including specimens with 21 and specimens with 23 pairs of legs.

Last year, however, a scolopender with higher segment number was found among the materials collected in a Brazilian forest and preserved in the collections of the National Museum in Rio de Janeiro. The new species is a very close relative of the scolopender with 21 or 23 pairs of legs, the main difference form it being its segment number. There are specimens with 39 and specimens with 43 pairs of legs, that is, nearly twice as many as in its shorter relative (Chagas et al. 2008). No scolopender with intermediate number of segments is known and none is likely to be found. Within the genus *Scolopendropsis*, evolution has arguably changed an animal with about twenty leg-bearing segments into a "double" animal - a single jump, i.e. an unprecedented case of "saltational evolution" (Minelli et al. 2009).

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Indirizzo dell'Autore - Author's address:
- Prof. Alessandro Minelli
Dipartimento di Biologia
dell'Università degli Studi
Via Ugo Bassi 58 B, I-35131 PADOVA