The Meaning of Fossils

Episodes in the History of Palaeontology

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There has long been a distinction between the celestial and the terrestrial world. The former is much simpler and was the first to yield to scientific inquiry triumphantly effected by Newton's celestial mechanics, which then became the ideal towards which all scientific ambition strove to emulate. Astronomy taught us that space was vast indeed and that mans place within was peripheral. The systematic study of the terrestrial world started with Aristotle, and was both classificatory in nature as well as speculatively philosophical, where the former took more and more precedence. That by itself was a philosophical choice, as enunciated by Francis Bacon, emphasizing the empirical at the expense of the speculative. To read the book of Nature with an open mind free from preconceptions. Naturalists such as Linnaeus and Buffon were out to systematically classify the world, the organic as well as the inorganic, bringing to it patient and untiring attention to detail in description, and elaborating on it encyclopedically. What general laws did they formulate? What real insights did they bring? Compared to the intellectual achievement of a Newton they seem pedestrian, mere stamp collectors as later scientists would disparage them and their activities.

Fossils were part of the natural world, but what were they? Organic entities or rocks? They came in a great variety form the barely differentiated to the fully articulated, showing such an intricacy of form as to show a great affinity to the organic world, while yet being made of rocks. Were they of organic provenience or did they manifest a parallel growth in situ? The question was not yet resolved during the 16th and 17th century. To hypothesize an organic origin was natural, on the other hand it presented some difficult problems of logistics. How come that obviously marine organisms were to be found on top of mountains? One obvious explanation was that they had been carried there by a great flood. The Scripture was an ancient text and it was natural to use it as a document to try and elucidate ancient history. Bishop Ussher found a precise date for the beginning of time using the Bible as source. The estimated age of a mere 6000 years is of course now an object of scorn, but at the time one should not think of the poor bishop as a religious zealot, he simply used standard humanistic scholarship of the day, exploring its possibilities. The scripture turned out to be a dead end, which was recognized even by pious people who had no problems with compartimentalization. God may be the ultimate creator, but he obviously chose not to meddle in affairs directly but instead prefer to do it through secondary means, namely through the agent of natural causes, which could be understood and appreciated by mortals.

The first stirrings of serious geology were presented by the Danish anatomist Steno. He pointed out that the layers of a sedimentation were laid down sequentially, with the youngest uppermost, and hence gave a historical record, a record that might be broken because of subsequent disturbances. His ideas were taken up by Hooke and also later by the ever busy Leibniz. It was fairly soon realized that different layers had different kinds of fossils, which were turned into a method of dating which did not really depend on having an understanding of what was the real origin of fossils, but a purely empirical observation. Eventually as the acquaintance with different fossils became more intimate it became clear that fossils must be traces of organisms. But as most if not all fossils had no real living counterpart the idea of extinction inevitably took root, although as with many of the fossils were of marine creatures it seemed reasonable to assume that they did exist, only being so far undetected[1].

One of the foremost French naturalists of the late 18th and early 19th century was Cuvier. He pioneered the discipline of comparative anatomy with an emphasis on the functional aspects, and hence not just a matter of some mindless description. This led to a deeply held belief that an organism was a very intricate machine in which all parts were dependent upon all others. It was perfectly adopted for its task. This had two major consequences. First that extinction must be brought about by some kind of catastrophe, otherwise why should species die out? being so perfectly in match with their environment. And secondly and most importantly, it showed that species were discrete entities which could not be deformed lest the intricate construction would no longer operate and thus species were natural entities. Against that view Lamarck argued, claiming that there is no such thing as species, they all fused into each other over time. In mathematical parlance, one cannot define a species relation which is reflexive, symmetric and transitive and hence there is no relevant partition of organisms. In other words Lamarck was one of the first proponents of evolution. Now Cuvier's position was perfectly reasonable. After all in chemistry there is a discretization, compounds are real entities and they do not blend into each other. Change a compound ever so little and its properties may be radically different. In short they possess rigidity, just as computer programs, where the change of single character may spell havoc. Cuvier and other naturalists had of course observed that populations changed over time as testified by fossils, but it is one thing to speak about evolution of populations, and another thing on the individual level. He also noted that there seemed to be a direction in evolution from more primitive organisms to more complex, and that this was brought about by so called inheritance of acquired characteristics. This is what we usually associate with Lamarck, but in fact this is something of a reconstruction of his thought, and which according to Rudwick is not highlighted in his works. Cuvier considered Lamarck to be a mere dreamer, whose speculations were not anchored in empirical reality. As to the changes of species, Cuvier could triumphantly announce that the mummified cats brought home from the Napoleonic campaign in Egypt showed no sign of being different from those living in Paris today. Lamarck may argue that huge time-scales needed to be involved in effecting the changes, but if one could not produce any extrapolation from shorter time-scales, not even those as comparatively long as those separating us from the ancient Egyptians, one was left in the land of pure speculation. Also, Cuvier as many paleontologists after him saw no direction in the fossil record. The earliest Trilobites appeared just as complicated and well-adapted to their conditions as

[1] The most spectacular of the so called living fossils was that of the Coelacanth discovered outside South Africa, assumed to have been extinct for a couple of hundred of million years.

modern arthropods, and no discernible complications could be found in modern fishes as opposed to the earliest fossil finds. Cuvier's contribution was to painstakingly and systematically reconstruct the various mammalian appearing during the Tertiary era. As a comparative anatomist he was unsurpassed in his time and would later be succeeded by Owen in England as a master practitioner. In a sense although both Cuvier and Owen saw themselves as scientists, they should also revealingly be seen as artists, in the sense that they possessed unique and non-transferable skills, and would if they were brought to life in the present easily stand their ground, just as a resurrected Mozart or a Tizian would find no one to rival them. People do not get smarter as time goes on, although of course the collective knowledge accumulates as opposed to individual skill. To Cuvier there was an opposition between extinction and evolution. Species did go extinct but they were replaced by immigration. However, as the empirical material grew and the same epoch showed the same kind of animals, the notion of immigration became more and more untenable, the earth was finite after all, thus bringing up the thorny question of creation.

During the first half of the 19th century geology made great strides. The rough tripartite division of the history of the earth in the Primary, Secondary and the Tertiary was proposed already in the 18th century, but a finer and more orderly division was brought about especially as it related to the confusing transitional period between Primary and Secondary. A division basically made possible through a definite adherence to the use of fossil fingerprinting in the identification of rock strata[2]. The dominant paradigm was uniformitarianism, or as Rudwick prefers, actualism. A principle already suggested in the 18th century by Hutton, who envisioned a steady-state Earth with no beginning and no end, going through endless cycles of mountain upheavals (orogeny) and erosions. His successor Lyell championed them in his three volume work -'The Principles of Geology' which due to its readable prose-style reached an audience way beyond that of the professionals. The principle was based on sound methodology and intended to do away with all scriptural influence, especially that of the great flood[3]. Lyell scorned all efforts of trying to reconcile the Bible with the facts, and the Oxford geologist Buckland was a particular target. The earth had been molded by nothing supernatural, all the forces involved had been ones which were still visible, and geology would proceed by extrapolation of those. He thus argued against the catastrophe theory of a Cuvier, even if that was a fairly mild one. He denied any direction in the evolution of life, in fact he denied the very existence of evolution as conflicting with his steady-state vision of the history of the earth. In particular he did not think of life having a beginning, as was suggested by the relative paucity of fossils before the Silurian epochs, and the total absence in the primary rocks. Lyell though of the lack of fossils in old rocks as a consequence of metamorphisms which had destroyed all the evidence. In fact he emphasized the spottiness of the fossil record, still it did not stop him from using the change of fossils to get an accurate time-scale. The idea being that

[2] The Devonian controversy was brought about by a challenge to the idea that fossils were markers of time, and the main actor Murchison was eventually able to vindicate the principle, which then reigned as unassailable, and can be seen as a general law of evolution, namely in the sense o Popper to restrict what is possible. It is not possible to find human remains among undisturbed dinosaurian.

[3] In classical geology and well into the 19th century one spoke of the ante-diluvean era reflecting the great watershed the flood was supposed to have constituted.

the change was constant, and hence statistical measures could be used to gauge it. Where there were gaps, i.e. where there was an abrupt change, he simply hypothesized missing stratification, and he was often proved right by posterity. Incidentally his statistical idea for dating is in principle not that different from the modern one that tries to gauge the timescale of evolution from the drift in genetic difference among peripheral genes, a kind of fossil not yet available to the 19th century paleontologist.

But as the century went on the idea of evolution became more and more often proposed although there were of course powerful arguments against it. The lack of missing links for one thing. If evolution was true certainly it would make an imprint in the record.

And then Darwin finally entered into the fray. A cautious man who hesitated for decades to get out of the closet. Evolution was thus seen as speculation and empirically unfounded and Darwin was at pain to present a carefully reasoned argument for which he needed to do continual research to buttress. He may very well have deliberated for another twenty years had not Wallace stepped on the scene, and urged by his mentor Lyell his hurried to get something in print. The book made a splash for a variety of reasons. First its time had come and he was able to persuade most of his peers, even the recalcitrant Lyell finally gave in, although rivals such as Owen opposed him bitterly. Secondly by only presenting an abstract of the great work he had planned to write and which was never finished and published he was able to reach a much larger public. The time was ripe because the problem of creation had become a most pressing one, and by that is not meant creation in the divine sense, there were theories around to account for a natural kind of creation. Owen had another vision, not based on an inferior knowledge of the natural world, as an anatomist Owen had no equal, but from another temperament. To Owen the different organisms were variations on some archetypical plans, which may not ever have been manifested and certainly should not be seen as founding fathers or groups of organisms, rather a more Platonic sense was meant. Owen's opposition to Darwin was not religious per se, in fact he came to accept evolution as a historical fact, but he was bitterly opposed to the mechanism of natural selection that Darwin proposed. Such a mechanism would make life contingent upon mere chance going against the grain of the beautiful design (not necessarily divinely orchestrated) that a master naturalist such as Owen saw manifest everywhere. The arguments against evolution still prevailed of course and Darwin blamed the spotty and incomplete record, a position which would turn out to be less and less tenable as more fossils were brought into the open. In fact being convinced of the fact of evolution, people started looking for evidence in the fossil record for it, and they found plenty, if not necessarily anything that pertained to men and his forefathers[4] Among the success stories of the late 19th century, instigated by Huxley and brought to fruition by Marsh on the rich remnants in North America, was the genealogy of the horse. Other inveiglements against natural selection of a more principled kind, were in addition to the moral and aesthetic one proposed by Owen, was the possibility of gradual change still keeping a well adapted organism, which of course goes back to Cuvier and his opposition to deformation. This argument has held sway until our days, presented with

[4] Man has for most of his history been a sparse animal and among the huge debris of animal remnants, one has to sift carefully for the stray human remain, an entire skeleton being such a spectacular find that it grabs worldwide attention.

puzzles such as the eye. How could an eye develop unless every partial stage imparted some reproductive advantage. Organisms are not designed, by created by small steps of trial and error. One speaks metaphorically about an adaptation landscape in which one has to blindly follow gradients with no possibility of foresight. But probably the most devastating attack against Darwin came from physics. It was generally accepted that any theory had to comply with the basic physical facts. One such which had already been introduced by the mathematician Fourier was the cooling of the earth, which gave to natural history a definite direction. This fact had previously been invoked when one argued that the climate in the past was warmer than today and that there were less variation[5]. Thompson calculated the rate of cooling and on this alone gave an upper bound of some 300 million years since the forming of the solid crust. He also made some even more restrictive bounds based on the energy available to fuel the sun. This struck a devastating blow to the theory of Darwin and after his death natural selection fell in disfavor among naturalists, although the philosophical principle became very fashionable and applied in all kinds of situations. In particular Spencer was very active in developing this side of Darwinism, and Darwin brought up in a very empirical tradition dismissed him as a mere windbag. But then came the turn of the century and with that the fortuitous discovery of radioactivity, which not only invalidated Thompson's estimates but also gave a reliable way of measuring the age of rocks and thus finally give an absolute gauge of the geological time-scale. That it was vast had been understood, if not for any other reason that the spectacular changes brought in the landscape would have needed a lot of time given the slow processes familiar to man. Radioactive dating confirmed those hunches, and actually showed that the best guesses had not been so far off the mark. The great gap in Darwin's mechanism was of course the question of how inheritance worked, the work of Mendel and the gene supplied the missing link for a grand synthesis of the 18920's which led to the great revolution in biology of the 20th century. But that is of course beyond the scope of the book, by that time fossil collection and its applications had had its heyday, as well as had the interest of the general public in geology particular and the natural world in general, never to fully revive.

The moral of the book, if any, is that such a supposedly empirical science based on so called incontestable facts, nevertheless is driven by principles and hidden assumptions. Patient collecting may have its worth, but never by itself. It is also interesting to observe the professionalization of science during the 19th century. In the past science did not really exist as a truly collective enterprise. The scientists of the past were basically polymath philosophers who had full command of their work and thus could conceive of things in an idealistic and rational way. Of course they were not isolated as much as self-sufficient, and did correspond between themselves. As science became more specialized, you needed supporting staff. A man trained in geology was not equipped to identify fossils to the point that they could be used to support his geological arguments, The gentleman scientist soon became an anomaly, Darwin being one of the last to hold on, what was needed was now a full time commitment. Then travel became a necessity, especially in geology, where the empirical material was spread world-wide[6], and after 1815 travel became once again in the

[5] This does to some extent hold true, at least intermittently, but due to a totally different mechanism, namely the carbondioxide rate in the atmosphere and the greenhouse effect

[6] Murchison was not able to clinch his arguments until he traveled to Russia

post-Napoleonic age, easy. International co-operation became an obvious necessity, and in spite of the nationalist tendencies developing at large, scientists went out of their way to award prizes and recognitions across national boundaries. And in fact Darwin became more readily accepted and appreciated in France and Germany than in his home-country.

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