Lazzaro Spallanzani and fossils: from a naturalist's travel observations to the teaching of natural history

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Abstract

This article analyzes opinions expressed by Italian naturalist Lazzaro Spallanzani on the origin and constitution of fossils on three of his travels, which punctuated three courses in mineralogy he gave in the natural history discipline at the University of Pavia. These trips to Portovenere, the island of Cerigo and the Two Sicilies enabled him to address important topics, such as the discovery of fossilized shells inside volcanic rocks, the discovery of human fossils, and the existence of fossils of species that had 'been lost', incorporating knowledge being developed at the time that drew on mineral chemistry. His concern with fossils is demonstrative of how Spallanzani, in true eighteenth century fashion, integrated studies from the three kingdoms of nature.

Keywords: history of paleontology; fossil; human fossil; extinction; Lazzaro Spallanzani (1729-1799).

Like many eighteenth century naturalists, Italian Lazzaro Spallanzani (1729-1799) devoted himself to the study of the origin and constitution of fossils. In 1755, upon graduating from the philosophy course at the Faculty of Physics and Mathematics of the University of Bologna, Spallanzani wrote a monograph entitled *Dissertazione sopra i corpi marino-montani* (Dissertation on marine-mountainous bodies). Even though he did not publish it, three years later he gave a public presentation of this work at a meeting of Accademia degli Ipocondriaci di Reggio Emilia. In this text, recently published by *Edizione nazionale delle opere di Lazzaro Spallanzani* (Spallanzani, 2001a), he examines controversial theories of his day and puts forward an alternative explanation for the formation and distribution of fossils. Although he set out from a widely held idea at the time that the Earth had been created by God, Spallanzani discussed a dynamic of forces responsible for creating and shaping the existing mountains and seas. His ideas are not so very different from those put forward by some previous thinkers, especially Italian naturalist Antonio Vallisneri (1661-1730; Faria, Prestes, 2010).

Around thirty years later, Spallanzani reviewed the topic in some of the travels he made to study and collect animal, plant and mineral species. We encountered passages where the author gives accounts of observations of fossils on travels to Portovenere in 1783, the Island of Cerigo in 1785 and Two Sicilies in 1788. He made these journeys during the holidays between the mineralogy courses he gave as part of the natural history course at the University of Pavia.

In this article, we analyze how Spallanzani integrated the empirical observations he made on his trips with the theoretical model that had been formulated previously, as well as how he combined this with the different knowledge available at the time that was presented to the students who did his course.

Upon investigating these different episodes, we were able to trace elements that were representative of the research work and lecturing work performed by the naturalist in the late eighteenth century.

The teaching of natural history and the travels of a naturalist

Spallanzani started teaching shortly after he obtained his degree, at the age of 26. He first taught Greek, logic, mathematics and French to high school pupils, then two years later he started lecturing in physics and mathematics at the University of Reggio Emilia. Between 1763 and 1769, he worked at the University of Modena, where he lectured in physics and philosophy. In a quest for better compensation and conditions that would enable him to devote his time exclusively to the study of living creatures, which he started in 1761, he was appointed to a position at the University of Pavia. At 40 years of age, Spallanzani created the discipline of natural history there, where he continued to work until the end of his life (Prestes, 2003, p.186-188).

For a given period, the discipline alternated yearly between zoology, botany and mineralogy. As such, as far as one can tell, Spallanzani gave the mineralogy course three times, in the academic years of 1784-1785, 1788-1789 and 1790-1791. The analysis of the lessons given over this seven-year period gives a picture of how his ideas on the topic

changed with time. This is possible thanks to the recent publication (Spallanzani, 2001a) of the transcripts of his lessons made by one of his students, probably from notes prepared or at least reviewed by Spallanzani himself (Di Pietro, 1994, p.196).

At the university, as well as lecturing, Spallanzani was responsible for creating and organizing the collections for its museum of natural history. For this task, he made numerous trips to collect animal, plant and mineral specimens. His interest in these collections is evidenced by the fact that parallel to this, he made a collection of his own in his house in Scandiano. This private collection, whose paleontological section contains 124 specimens, was transferred to the Civic Museum of Reggio Emilia, where it is still safeguarded.

The first of Spallanzani's many travels for his naturalist studies was in 1761, precisely at the beginning of his research into living creatures; his last was in 1792, at the age of 63. In the 1780's, he was making journeys almost every year. In all, he made 14 travels and trips to different parts of Italy and Switzerland, as well as one two-year voyage to the Orient as far as Constantinople.[1]

On these occasions, he would set up his 'laboratory' to make observations and do small experiments on different topics, such as the electricity of eels or the formation of corals. Many of these studies were recorded in letters to other naturalists and published in Italian periodicals at the time. Although he must have regularly made observations of fossils on his travels, amongst the accounts that have been published, there are at least three that contain important passages on the topic, as we will see below.

Journey to Portovenere as reported in a letter to Bonnet

One year before he gave his first course in mineralogy, Spallanzani set off on July 22, 1783, for Portovenere, the Apuan Alps and Garfagnana, returning to his home town, Scandiano, on October 25 of the same year. The aim of the trip was to resume his studies for the publication of a natural history of the sea. Spallanzani recorded his observations in letters to naturalist friends, especially to the Genevan Charles Bonnet (1720-1793).[2]

In his letter to Bonnet, alongside a large number of observations on the many natural treasures buried in the Gulf of Genoa, the Italian naturalist tells how he had fruitlessly sought fossils to the east of Genoa. He describes the marble formations in the Portovenere area – the already famous Carrara marble – comparing them with the region to the west of Genoa, in Riviera di Levante, where the limestone rocks reached great stratigraphic depths, and even enabled caves to be formed. As he had noted on a previous trip in 1781, the whole Riviera to the west of Genoa "to the Fort of Monaco, which corresponds to a stretch of seventy miles or more, all those mountains beside the sea, and those that stretch inland, contain testacea" (Spallanzani, 2001b, p.143).[3] Upon examining the rock of those mountains with a magnifying glass, along with the whole, preserved shells, he observed that it was almost entirely made up of fine grindings of these shells.

Spallanzani further noted that these shells were of a single species of *Pecten*.[4] As it was a "medium-sized" species, it was surprising how far the limestone rocks extended in the region: "how could one single species of shell, of marine origin, have accumulated in such great, such prodigious numbers that we can hardly imagine?" (Spallanzani, 2001b, p.143).

Without being able to explain this intriguing phenomenon, he went on to present another interesting fact about the distribution of these shells: "And your amazement will grow all the more when I tell you that this kind of living shell is known only by fishermen from the sea off Ligustico and Provence. I leave it to you to meditate on this very obscure phenomenon, which so far seems to be unique amongst so many referred to by naturalists about marine-mountainous bodies" (Spallanzani, 2001b, p.143).

The example of this fossil of a species not encountered living in the surrounding area, but just in a more distant region, was added to other similar cases noted in Spallanzani's later journeys. These observations show the importance the professor gave to research of the mineral kingdom.

Course in the academic year of 1784-5: elements of oryctology

In the academic year after his trip to Portovenere, 1784-1785, Spallanzani first gave a course on the mineral kingdom, naming it "Elements of oryctology" (1994c). The name derives from the Greek term *oryctòs*, which means 'dug', in the same way as the Latin term *fossum*, which is the root of 'fossil' (Di Pietro, 1994, p.195). Spallanzani said that this science was also called mineralogy at the time. The second time he gave the course, in 1788-1789, he called it *Regnum Lapideum*, or the mineral kingdom (1994b), a term used in Linnaeus's *Systema naturae* since the first edition of 1735. The third time he taught it, in 1790-1791, it was given the new name of "Supplement to the lessons on the fossil kingdom and new lessons on said kingdom" (1994a).

What strikes one most about this terminology is the meaning of the term fossil, which at that time designated any body encountered by digging. It could be derived from living creatures or bodies of mineral origin – in other words, it did not solely designate remains of biological activities preserved in natural systems, as it is understood today. Parallel to this, the term 'petrification' was used to refer to materials which, while looking like minerals, were of a different origin – vegetable or animal. Their mineral-like appearance was attributed to a transformation process. Thus, albeit in different terms, Spallanzani and his peers perfectly differentiated materials that were actually paleontological ('petrifications') from mineral materials ('fossils'). To make it easier to read this article, we have used 'fossil' in the same way it is used today, but being careful to refer to it in Spallanzani's work only when he alluded to animal or vegetable 'petrifications'.

Interestingly, the distinction Spallanzani makes is related directly to living creatures. While "fossils" - i.e. minerals – "grow by addition and conjunction of the outer part, and not by an inner force, more specifically by outer mechanics" "petrifications" corresponded to bodies of vegetable or animal origin that "grow by developing through an inner mechanism and are reproduced by seeds, eggs, fetuses, etc." (Spallanzani, 1994c, p.207).

In the oryctology course he started in 1784, Spallanzani presented minerals in nine different classes: earth, sand, hard rocks, salts, pyrites, semi-metals, metals, sulfur and the last, made up exclusively of "petrifications". He defined them thus: "Petrifications are shaped rock or mineral bodies, which are always foreign to the primitive land, which come from the animal or vegetable kingdom, and which by some accident of water or sea,

after having been deposited in the extracts of earth, undergo different transformations" (Spallanzani, 1994c, p.208).

In other words, by this definition the naturalist defines three elements as being constitutive of 'petrifications': they are exotic, meaning they do not come from the land where they are found; they are of animal or vegetable origin; and they undergo transformations that can be explained by the action of water, which is responsible for combining the earthy molecules. Later in the course, Spallanzani defined them again, this time referring not to the bodies but to the way they were formed, incorporating a different element to the definition: the conservation of the primitive form: "By petrification, one means an operation of nature whereby a body from the vegetable kingdom or the animal kingdom is converted into stone, always preserving the form it had before" (Spallanzani, 1994c, p.228).

When describing animal fossils, Spallanzani presented them in six classes, starting with worms and insects (worms, corals and testacea, like seashells, univalves, bivalves and multivalves), fish, 'amphibians' (including frogs and crocodiles), birds, quadrupeds and anthropolites, meaning the petrifications of some parts of the human body.

His anthropolites were cause for special attention. When mentioning the case of a fossil described by Johann Jakob Scheuchzer (1672-1733), Spallanzani showed a certain disinclination to accept its human origin. *Homo diluvii testis*, as Scheuchzer's fossil became known, seemed to have a skull and a backbone, which he interpreted as belonging to a human being from the time of the great biblical flood. Although the fossil had these parts, its lack of similarity to human anatomy was questioned by naturalists of the time, a fact that was recalled by Spallanzani, who indicated uncertainty as to whether the skulls that had been found were indeed human or of other animals (Spallanzani, 1994c, p.230). This topic was brought up again during the 1790 course, as we will see later, with a more decided interpretation.

When discussing petrifications of plants, Spallanzani distinguished those that had been totally or partially transformed into stone from those that had just "left their form on the earth or rock" (Spallanzani, 1994c, p.231). He split plant petrifications into five genera. The first included "perfectly petrified vegetables", which covered different kinds, such as "harder and less succulent plants, such as grasses"; trees, both whole, with roots and branches (rarer) and tree trunks "turned into limestone, but preserving their organic texture with the fibers and rings and other indications of their previously having been wood" (Spallanzani, 1994c, p.231); roots, parts of grains, leaves and drier fruits of nature, on which petrification acts more easily. Spallanzani had encountered whole petrified trees years before he gave this course. As he writes in a letter of July 26, 1778, to a student of natural history, the Milanese count Luigi Bossi Visconti (1758-1835), he was keen to see and fetch for the Pavia Museum "a thick, whole tree trunk turned to stone" that he had been told existed in hills near Reggio Emilia (Spallanzani, 1985, p.56).

The second genus was made up just of the "genuine figure and form imprinted on the rock along with other remains of the body of the vegetable not turned into stone, but very degraded" (Spallanzani, 1994c, p.231). Spallanzani went so far as to state that this kind of petrified body should not be confused with shaped or dendritic rocks, where no vestiges of any plant is observed, and which are of mineral origin.

The third and fourth genera were characterized by the state of conservation of the organic structure, which was whole, having been penetrated or imbibed with "limestone or clay earth" in one case, and with "mineral or metal particles" in the other (Spallanzani, 1994c, p.232).

The fifth genus included "plants that have undergone little or no transformation, are buried underground and are often called fossilized wood" (Spallanzani, 1994c, p.232). This classification is clearly less consistent than the classification of animals, since the groups are not formed by the same criteria, but alternate between anatomical features and the state of fossilization.

Journey to the Island of Cerigo reported in a letter to Lorgna

Having finished giving his course, Spallanzani set off on August 22, 1785 from the port of Venice in a warship for a two-year journey to the Orient, destination Constantinople. In early October, bad weather forced the ship to spend eight days anchored in the archipelago of which the Island of Cerigo is part, or the ancient island of Citera, between Peloponnesus and Crete.

Spallanzani took advantage of the enforced stop to make some observations, especially of a geological nature, which he reported in a letter to Antonio Maria Lorgna (1735-1796). In 1782, this Italian mathematician and physicist had founded Società Italiana delle Scienze detta dei XL, which garnered great prestige in eighteenth century Italy, and still exists to this day under the name of Accademia Nazionale delle Scienze detta dei XL.[5] Lorgna published Spallanzani's letter (2001a) under the title of "Osservazioni fisiche istitutte nell'isola di Citera oggidi detta Cerigo" (Physical observations made at the Island of Cítera, today called Cerigo) in the society's periodical, *Memorie di Matematica e Fisica della Società Italiana*, in 1786. An extract of the same text was republished in French in 1798 (Spallanzani, 1798, p.278-283).

Cerigo is almost entirely covered with volcanic rock. Spallanzani stated it was full of petrified human and animal bones. He said he had found two kinds of whole, preserved shells, pectens and oysters, the latter in large number and of considerable size. Spallanzani considered the finding of intact, fossilized shells inside volcanic rocks a "new discovery" (Spallanzani, 2001a, p.173).

He also framed his observations within an ongoing discussion about the origin of the island. Asking why the lava had not "calcified or reduced these testacea to powder," he put forward two hypotheses about the Citera volcanoes: "either these volcanoes exerted their action on an existing island, or it is they that produced it" (Spallanzani, 2001a, p.173). For the first hypothesis to be true, these shells must already have been on the island before the lava flowed over it, although it was hard to imagine how they would have remained intact. As such, he believed the second hypothesis – that the island of Citera had emerged in the middle of the sea by the action of a volcano – to be more likely. This action had steadily raised the level of the seabed, upon which there must have been both kinds of shells, which had emerged from the sea together with the island. Contact with the water had cooled the lava, whose effect on the shells was thereby reduced. Although he believed that the remains of extinct volcanoes at Citera indicated they flowed for some

time over the surface of the island after it had been formed, Spallanzani noted that near the volcanoes' craters, these shells were not to be found, but were found at more distant places. Another observation supported the hypothesis that the volcano itself had formed the island: bordering the island, one could see that "the mounts that extend into the sea continue to be of the same nature inside the water, and they form a continuous mass with the external parts" (Spallanzani, 2001a, p.176). Finally, he mentioned that maybe this was the island the Greek philosopher Strabo (63/64 BC-24 AD) had claimed had emerged from 'underground fires' between the islands of Therasia and Thera.

As in his report on his trip to Portovenere, Spallanzani drew attention to the absence of these two shell genera amongst those that existed in the sea around Citera. He therefore considered the possibility that the sea may have carried these fossils from foreign parts, but decided that "a more natural hypothesis" was that in the past, these species had been abundant on the seabed and that the "race had been lost" (Spallanzani, 2001a, p.174). As to why this may have happened: "Either because they were destroyed by man or because they ran out of food, or for some other reason that we do not yet know. If one consults traveling philosophers and historians of greatest repute, there is no shortage of cases of similar occurrences" (Spallanzani, 2001a, p.174).

This disappearance of a species was discussed at the time and considered highly controversial. We have seen in the reports of the two journeys discussed so far that Spallanzani himself, despite mentioning these shells, did not fail to consider the possibility that the living specimens of these fossils could still be encountered on some unexplored part of the ocean floor. In fact, the potential discovery of living representatives of the organisms only known by their fossils was the most widely used argument to counteract the claim that species did in fact become extinct. The argument was particularly good for refuting the extinction of sea creatures, because the oceans had been little studied and these creatures could be living in deep waters that were completely unknown.

Shortly afterwards, Georges Cuvier (1769-1832) got round this objection to extinction, at least in the case of a land-living species (Faria, 2010, p.45). In *Mémoire sur les espèces d'éléphans vivantes e fossiles* (Memoir on the species of elephants, both living and fossil) of 1796, he strategically chose to analyze the fossils of a group of animals, quadrupeds, which, due to their size, would be hard not to be seen anywhere, should there still be any living specimens. In this case, some naturalist or some inhabitant even of the most far-flung parts would have described them, as it was believed that every part of the globe was already known (Cuvier, 1801, p.256).

Another topic of importance to Spallanzani's observations about the island of Cerigo concerns what was called *montagna dell'ossa*, a mount of fossilized bones which he believed were mostly human, despite also containing fossils of quadrupeds. However, as already noted in the literature, the only print in *Osservazioni fisiche istitutte nell'isola di Citera oggidì detta Cerigo* portrays oysters and bone fragments, which would be hard to identify as human (Rudwick, 2005, p.279).

Some of the bones from *montagna dell'ossa* that Spallanzani collected and identified as human were analyzed in 1812 by Georges Cuvier, during his time at Pavia. The French naturalist made the following statement: "Despite the assertion of this renowned observer,

I state that there is none that one can affirm is human" (Cuvier, 1812, p.120). In his courses at Collège de France, Cuvier claimed that Spallanzani himself later admitted his mistake (Cuvier, Saint-Agy, 1843, p.271-272).

Journey to Two Sicilies, published in a six-volume work

Of all his travels, his trip to Two Sicilies in 1788 was the one that most involved Spallanzani in producing a work, whose publication stretched from 1792 to 1797. He also worked hard to have *Viaggi alle Due Sicilie e in alcune parti dell' Appennino* (Voyage to Two Sicilies and some parts of the Apennines) published in the scholarly lingua franca of the time, French, for which he counted on his long-time collaborator and translator, the Genevan Jean Senebier (1742-1809).[6]

Spallanzani set off on his trip on June 25, 1788, which meant he had to bring forward the end of his course in natural history that year, which he was authorized to do upon his guaranteeing that "the students would not miss all their lessons" (Di Pietro, 1979, p.64). He resumed classes soon after he returned in mid December, having collected 36 boxes of 'natural products' for the university museum.

On this trip, Spallanzani continued searching for petrified human bones. In Messina, he learnt about the existence of three human skeletons that had been unearthed by miners and removed from the sandstone rocks near the town. According to the miners' reports, the fossils had been acquired by a doctor from Messina, who now had them. Spallanzani managed to track down this doctor: "He told me that his parents, in fear of the bones of a dead person, had thrown them out of the window" (Spallanzani, 1797, p.175). The most reliable account Spallanzani managed to obtain was from his companion on some trips to the areas surrounding Messina, Abbot Gaetano Grano (1754-1828), who assured him they were human bones, having even identified one of them as a femur. However, he also reported that they showed no signs of being petrified. Spallanzani raised a few hypotheses about the case: the bones could be recent, thus not having had time to be petrified, or the surrounding rock was not of the right kind for this process to take place. He even conjectured that these skeletons could have been of some of the Saracens who had ruled Messina for a time (Spallanzani, 1797, p.175).

–It is important to stress that the discovery of human fossils would not just contribute to the debate about whether the prophesied Mosaic deluge had taken place, but were also valued for being new, given that until that time, no human bones had been found that were unequivocally petrified, even in old rock strata. Only in 1856 was the first hominid fossil encountered, of a *Neanderthal*, and only in 1868 did Louis Lartet (1840-1899) encounter the first fossil of a *Homo sapien* in the Cro-Magnon caves in south-western France.

In *Viaggi alle Due Sicilie* Spallanzani also discussed the issue of the distribution of fossils, including the occurrence of "testacea" and "other marine products" in the mountains near Messina. When he was still in Naples, he wrote, a "man versed in natural history" had assured him that he would find "petrified marine bodies" in the Messina granite (Spallanzani, 1797, p.162). However, Spallanzani only encountered fossils at the surface of some granite that was the baserock for the foundations of a monastery. Having examined

this rock, he concluded that there was a thin layer of sedimentary rock there, which he described as "a crust of limestone of an irregular thickness that was full of large madrepores" (p.163).[7] Even in thin layers, this limestone covered the granite, which meant that these madrepores were "unrelated to the granite" (p.163), or, as we would say today, were contained in a secondary rock covering a primary rock. Amongst the madrepores, Spallanzani recognized two species, "*m. turbinata*" and "*m. trochiformis*" (sic; p.166), described respectively by the Swedish naturalist Carl von Linné (1707-1778) and the Prussian naturalist Peter Simon Pallas (1741-1811). Alongside these organisms, other marine bodies, like testacea, starfish, gastropods, etc. were embedded in the Messina limestone. About a hill near Mount Cateratte, in the Catania region, wrote Spallanzani (1797, p.168):

> Even if the madrepores were not devoured by time and maybe by other destructive agents that dispersed the means for the species to be uncovered, one cannot be mistaken about their genera … If we examine the land around them carefully, we see that it is mostly formed of remains of these madrepores, and such observation can be repeated at different places on this hill: as such we may conclude that all or almost all these mounts were produced by the decomposition of these living beings, which are no longer found in the seas, or so state the fishermen, just as the other madrepores from the limestone that covers the granite.

As in the report on the trip to Cerigo, Spallanzani confirms the disappearance of these organisms from the wildlife in the Messina region. "This is the surprising phenomenon noted by different authors, who teach us that the original testacea and marine animals now scarcely exist in the seas where we discovered them petrified and fossilized" (Spallanzani, 1797, p.168-169).

To further pursue this matter, Spallanzani sought to obtain data from the material collected in an activity he called 'coral fishing' done six miles to the north of Messina: "I closely examined the fragments of rock the net brought up from the bottom; some carried a few branches of coral, others had none. These fragments often have a collection of zoophytes and small testacea on the outside; inside, there is an accumulation of these types of organisms that survive and have been mixed with an earthy limestone" (Spallanzani, 1797, p.176).

However, according to Spallanzani, at other opportunities, these rock fragments taken from the bottom of the Strait of Messina were made up of sandstone (*pierre aréniere*), and the rarity of their collection was no surprise, "since its hardness and the strength of its grip does not enable it to be broken off easily with the instruments used in this kind of fishing" (Spallanzani, 1797, p.177). In these sandstone rocks, always arranged in layers, he found "testacea" that indicated the action of a "mineralizing principle" that was very active in that strait (p.177).

Course in 1788-1789: lessons from the mineral kingdom

During the academic year of 1788-9, Spallanzani's course was named "Lessons from the mineral kingdom" (1994b). At the beginning of the lessons, when he was explaining the difference between living and non-living, he added the new characteristics to the distinction

he had made in the previous course: "Plants and animals grow by the development of all the mass and volume, and minerals by the addition or conjunction of parts. The difference between an organized body and a crystal: systems of vessels and humors that are encountered in organized bodies do not occur in minerals" (Spallanzani, 1994b, p.233).

In the third lesson of this course, Spallanzani covered the topic of the fossilized sea shells encountered in the mountains, describing the geological processes the Earth's surface underwent which resulted in the distribution of these fossils at sites far from the sea and at great altitudes, on the surface and at depths. In this description, he established a temporal dimension of approximately two to three thousand years as the duration of these processes. Alongside these events, Spallanzani (1994b, p.235) added that:

> It is very easy to demonstrate that, as all terrestrial matter acquired its solidness by the continual action of gravity and other forces that brought together and combined the parts of the material, the surface of the Earth must first have been less solid than it became later, and as a consequence of the same cause, which presently only renders almost imperceptible changes over the space of centuries, must at that time have produced great revolutions in a few years: in fact it seems certain that the earth today, dry and inhabited, was previously under sea water and that this waster was higher than the peak of the highest mountains, because in them and at their peaks there are marine products which, compared with the living beings in the sea, are identically of the same species. It also seems that this sea water traveled over the earth for some time, since the aggregates of these marine bodies are in many parts of the globe, for it is not possible that such a great number of these animals should have lived in the same place at the same time.

To confirm that fossilized shells were not the playthings of nature, nor that their origin was due to eggs of marine animals, Spallanzani cited a few authors and subjects that the students would have to study. Along with Antonio Vallisneri, he noted the observations made by René-Antoine Ferchault de Réaumur (1683-1757) on the sea shells found in Amsterdam; the observations by astronomer Antonio de Ulloa (1716-1795) on a geographical expedition to Peru, reported by Georges-Louis Leclerc, count of Buffon (1707-1788)[8]; and his own observations on *ictioli* (fossilized fish) and other marine products, based on his own travels and the examination of specimens at museums in Switzerland.

The fourth lesson on the "mineral kingdom" was entirely devoted to the old controversy, and was entitled emphatically, "Shell fossils are not from the universal flood" (Spallanzani, 1994b, p. 236). Spallanzani listed the authors who had put forward different hypotheses, picking up the discussions that had been pursued two decades before. He reproduced John Woodward's (1665-1728) idea that the fossils of sea organisms encountered on mountain tops had been taken from the seabed to the heights by the action of great storms and associated flooding, counteracting it with explanations that were "more in keeping with the laws of nature" by Vallisneri, for whom the distribution of these marine-mountainous bodies resulted from the movement of waters and multiple floods (p. 236). Spallanzani mentioned the observations made by Robert Boyle (1627-1691), Réaumur and Johann Georg Adam Forster (1754-1794), and the opinions of Girolamo Fracastoro (1478-1553), Gottfried W. Leibniz (1646-1716) and Buffon, again offsetting them against those of Vallisneri. In the last lessons of the course, Spallanzani resumed the classification of plant and animal petrifications.

Course in the academic year of 1790-1791: lessons on the fossil kingdom

In his third course, Spallanzani addressed mineralogy in broader terms, revisiting subjects he had covered in his *Dissertazione* of 1758. He had dropped the term oryctology, but still used 'fossil' in the sense of an excavated object, and 'petrification' for something more like what we today understand as a fossil, as one can see from the following passage: "Here we begin the Treatise on Mineralogy *per se*. We give the name of mineral kingdom to fossil substances that are encountered in the earth, which have no organic structure, or which have lost it, such as petrifications" (Spallanzani, 1994a, p.318).

One important novelty in this course is the addition of knowledge from the field of chemical mineralogy which was being developed at the time. This also reflects Spallanzani's new interest, in the 1790s, in physiological research related to Lavoisier's new chemistry, amongst which his investigation into the respiration of animals and plants is highlighted (Prestes, 2006, p.260).

In this course, Spallanzani also indicated the mineralogy system by Swede Axel Fredrik Cronstedt (1722-1765), which was entirely founded on chemical characteristics and "approved throughout Europe" (Spallanzani, 1994a, p.318). He was undoubtedly referring to Cronstedt's book from 1758, translated into English under the title of *An essay toward a system of mineralogy*. He also made mention on several occasions of Irish chemist and geologist Richard Kirwan (1733-1812), author of *Elements of mineralogy* (1784), the memoirs of French chemist Antoine François, count of Fourcroy (1755-1809), and the work of Swedish chemical mineralogist Torbern Olof Bergman (1735-1784). The adoption by morphological mineralogy of these methods of studying chemical constituents triggered a change in the way Spallanzani characterized 'petrifications' in this third version of the course, as can be seen in the following passage: "It is concluded, from Bergman, that we have established the classes, genera and species of the mineral world based on the internal composition and characteristics, and [we have established] the varieties based on their outer form. Thus, we bring together the advantages of both methods" (Spallanzani, 1994a, p.319).

By this time, Spallanzani had already made a large number of empirical observations of fossils on his travels, as we have seen. He added his own observations to citations of different fossil samples and the places they were found in Italy and other countries by other naturalists. This mass of data caused him to alter the way he discussed the topics compared with the previous courses he had given and his *Dissertazione* of 1758. Then, he had speculated on the transformations of the surface of the globe to explain the origin, constitution and distribution of fossils. In this course, they were taken as evidence of the occurrence of those transformations, characterizing the "advantages that naturalists derive from petrifications" thus listed by the naturalist:

> First, they enable one to understand the revolutions of the globe, in relation to the land and the sea. Such are the testacea and crustaceans in the mountains; stronger proof that the sea has been at these places: and for this reason the world was higher than it is today. These sea shells exist at great depths: so the earth went through a sudden and great change; this also gave rise to whole mountains. So the sea was not just there, but it was there for many centuries.

> Bones of elephants and rhinoceroses in Siberia that exist in large numbers and prove that once that place was inhabited by these animals: and consequently that the earth underwent great transformations (Spallanzani, 1994a, p.340).

Another change Spallanzani introduced to this course in 1790 was about the fossils of creatures that could not be found living in the same region where the fossils were encountered. The first example mentioned is that of fishes from Mount Bolca, in Veronese.[9] Their presence at the top of this mountain was taken as proof that in the past its strata were at the bottom of an ocean, thereby bearing witness to the occurrence of a great revolution of the seas. Another example he mentioned was that of marine fossils encountered on Mount Etna, which had been calculated to be over 3,500 years old. In this case, Spallanzani made direct mention of 'extinguished' species: "Through these marine petrifications we are introduced to animals from the past: and we find that many of the current animals existed at that time; *but many exist no more*: from which one may infer either that the races have been lost or that they only exist in the depths of the seas" (Spallanzani, 1994a, p.340, italics added).

In a different passage, we see that at least from a logical viewpoint, Spallanzani also seemed to cogitate the appearance of new species: "Many of these animals are not native to our seas, but exotic, be they testacea or fish. Such as those from Mount Bolca, near Verona. Thus, either these animals existed or they did not exist, or they were transported: which proves the great revolution of the seas" (Spallanzani, 1994a, p.340).

The last topic covered was that of human fossils. Several examples on this topic had been recorded, especially inside mines – although Spallanzani said that one could be sure of the origin of very few of them. He returned to the example of Scheuchzer's *Homo diluvii testis*, this time stating that it was known not to be the skeleton of a man, but the "upper part of a seal" (Spallanzani, 1994a, p.347). This fossil was finally identified by Georges Cuvier as being a giant pre-historic salamander (Faria, 2010, p.88).

Meanwhile, he mentioned finds of "some, albeit few, human bones turned to stone, mostly not transformed or but slightly hardened and still calcified" or as human bones found by Abbot Alberto Fortis (1741-1803) on Cherso island, and his own observations at Cerigo, and the specimens from Libya, "where whole caravans are sometimes buried in the sand, and one finds men who, if not turned to stone, are at least dissected, and embalmed like mummies" (Spallanzani, 1994a, p.347).os:[10]

Combined in a broader approach in the third course, these facts also confirmed, according to Spallanzani, the revolutions of the globe and the changes undergone by the Earth, concepts present in the geological discussions of different authors from the period and expressed by him in *Dissertazione* in 1758.

As announced in the beginning of the course, at the end Spallanzani again mentions a "Treatise on Mineralogy". Although this was never published, the notes compiled from these lessons and the records of the sources that guided him seem to leave no doubt that this was in the Italian naturalist's plans: "And the Treatise on Mineralogy reaches an end, covering salts, earth, rocks, bitumens, metals and petrifications. The author by whom I was guided was the illustrious Bergman, who, being restricted, I took care to comment on, develop, expand and exemplify at length, adding observations by others and my own concerning that part of Natural History" (Spallanzani, 1994a, p.348).

Final considerations

The different, ongoing observations made by Spallanzani on his travels seem to us to be clearly indicative of his real interest in fossils, and not just the fulfillment of the duty of collecting samples for the university museum or giving lessons in mineralogy. His large personal collection and his constant recourse to the topic whenever he was able to make empirical observations leave no doubt as to the nature of his research, which we would today call multidisciplinary, covering as it did studies into the three kingdoms of nature, in keeping with the prevailing trends in the eighteenth century.

Part of a strong natural history tradition in the 1700's which gave precedence to observations of the natural environment, Spallanzani helped boost the importance of field studies in the earth sciences and therefore in the study of fossils. Towards the end of the century, such studies started to be pursued by scholars themselves, and not just by collectors, who were mostly students or assistants of these scholars.

According to Martin Rudwick (2005, p.72-74), with the development of the study of the spatial distribution of geological formations – i.e. physical geography – these on-site observations became necessary, because that kind of object of study could not be moved into a museum, as, for instance, could objects from a different area of the earth sciences at that time, mineralogy. This science included the study of fossils, which also benefited from these scholars' excursions to the sites where they were encountered, as there they ended up detecting different properties of the fossils which enabled them to be better understood.

Interest in the origin and constitution of fossils, above and beyond their characterization into different kinds (animal and vegetable) demonstrates the epistemological commitment so often reiterated by Spallanzani. It can be seen in this passage from an essay sent to Malaspina, in which he refers to Buffon's method of making a "good portrayal" of the objects of nature as "what characterizes the philosopher naturalist and sets him apart from the simple name-giver, who is happy to trace the lines without caring to color it in" (Spallanzani, 1986, p.62).

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NOTES

[1] Appennino Reggiano and lake Ventasso (1761); Lombardy Alps and Switzerland (1772); Switzerland (1779); Genoa and Riviera di Levante (1780); Marseilles and the Gulf of Genoa (1781); islands in the Adriatic (1782); Portovenere, Apuan Alps and Garfagnana (1783); Chioggia and Montegibbio (1784); Genoa and Genovesato (1785); Constantinople (1785-1786); Two Sicilies (1788); the Modena Apennines and Euganei hills (1789); the Modena Apennines (1790); Veneto and Comacchio valley (1792).

[2] This letter was published in 1784 and 1785 in two Italian periodicals: *Memorie di Matematica e Fisica della Società Italiana* and *Opuscoli scelti sulle Scienze e sulle Arti*. It was later translated and published in France (1786) and Germany (1788 and 1789).

[3] This and the other quotations of texts from other languages have been rendered in a free translation.

[4] Genus of a bivalve mollusc which has one concave valve and one flat valve, both made of calcium carbonate ($CaCO_3$), a material that makes up limestone. It is a living genus that emerged in the Eocene (54 to 33 million year ago; Foucault, Raoult, 2005, p.258-259).

[5] It was called Società dei XL because it comprised 40 scholars, including Lorgna, Spallanzani, Alessandro Volta (1745-1827), Luigi Lagrange (1736-1813), Rugero Boscovich (1711-1787).

[6] Senebier's translation, published in Bern in five volumes between 1795 and 1797, was not to Spallanzani's liking, and was ultimately redone by Georges Toscan and Amaury Duval. This was published almost simultaneously, between 1795 and 1800, in six volumes, by Imprimerie des Sciences et Arts, in Paris.

[7] Madrepores are cnidarians of the class *Anthozoa* (Foucault, Raoult, 2005, p.203). Spallanzani referred to fragments of coral reefs formed of these organisms.

[8] Antonio de Ulloa's accounts, just as those by Charles Marie de La Condamine (1701-1774) and Louis Antoine de Bougainville (1729-1811) on fossils encountered in South America, are also mentioned by Spallanzani in a letter of April 13, 1789, to Alessandro Malaspina (1754-1818). Malaspina was preparing for voyages on the Atlantic and the Pacific with the Spanish royal navy, making geographical and natural history explorations, between 1789 and 1794. Spallanzani wrote him an "essay on the two kingdoms, animal and mineral, which may contribute to the furtherment of natural history" (Spallanzani, 1986, p.64).

[9] We know that Spallanzani was very familiar with the fish fossils of Mount Bolca, samples of which he obtained for his private collection, which are today kept at the Civic Museum of Reggio Emilia, which contains 21 such examples (Di Pietro, 1979, p.157). These fossils, described in 1555 by Andrea Mattioli (in *Discorsi sopra Dioscoride*), were discussed by different eighteenth century authors: Scheuchzer (1709, *Herbarium diluviannum collectum*); Antonio Valisneri (1721, *De' corpi Marini su' monti si trovano*); Gian Jacopo Zannichelli (1736, *Enumeratio rerum naturalium quae in Museo Zannichelliano asservantur*); Anton Lazzaro Moro (1740, *De' crostacei e degli altri Marini corpi che si truovano su' monti*); Domenico Testa (1743, *Lettera su i pesci fossili del Monte Bolca al Signor Abate D. Francesco Venini*); Alberto Fortis (1778, *Della Valle vulcanico-marina di Roncà nel territorio veronese*); Giovanni Serafino Volta (1796, *Ittiolitologia veronese del Museo Bozziano ora annesso a quello del Conte Giovanbattista Gazola*).

[10] It is impossible to be sure of Spallanzani's opinion on whether there were human fossils or not, as one can see from the quotations in this article. Considering potential religious constraints on Spallanzani's publishing a more clearly enunciated opinion on the topic, we checked his correspondence using the index that accompanies the 12th volume of the letters published in *Edizione nazionale delle opere di Lazzaro Spallanzani*. We found no mention of human fossils, just of fossils of different animal and plant species.

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