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ORIGINAL SCIENTIFIC ARTICLE

# Brocchi's Subapennine Fossil Conchology

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**Abstract** The Italian geologist Giambattista Brocchi (1771–1826) is presented as a key figure in the historical period preceding young Charles Darwin's first work on transmutational theory while on the Beagle. The brief biographical account focuses on Brocchi's writings related to his analogy that species have births and deaths like individuals, and culminates in his most important work, *Subapennine Fossil Conchology* of 1814. Brocchi's analogy as an original and fertile way to approach the fossil record was to influence Darwin's first evolutionary thinking. Relevant passages of the book are presented for the first time in an English translation.

**Keywords** Brocchi · History · Paleontology · Stepwise extinction · Speciation

> Man is invited by nature itself to study its productions. How could he refrain from investigating the property of bodies, when he tries to penetrate the mystery of creation? (Brocchi 1796)

> Brocchi proposed a fourth, original solution to the species problem, different from those previously advanced by Linnaeus, Cuvier, and Lamarck. (Pancaldi 1991)

The reappraisal of the role of geology in the history of science is the enduring legacy of the British paleontologist and historian Martin Rudwick, a legacy taking the form of a long series of books and papers, celebrated by the History of Science Society with the awarding of the 2007 Sarton Medal (Mayer 2008). Since his work was achieved thanks to a life-long study of primary sources—leading to conclusions that at times saw him swimming against the tide of standing historical paradigms—it is no wonder that his most acclaimed work is ponderous and written late in his career. Published in 2005 and 2008, the two volumes *Bursting the Limits of Time* and *Worlds Before Adam* are thick and challenging, starting from their subtitles aimed at "reconstructing historical geology in the ages of Revolution and Reform" (Rudwick 2005, 2008). What can be concluded from their careful reading, however, is not just that the layman has to re-learn the history of geology (Baker 2008; Gohau et al. 2007), but that he must reconsider the history of evolutionary theory as well. A central figure emerging from Rudwick's narrative, one that stands side by side with the likes of George Cuvier, Jean-Baptiste Lamarck, and Charles Lyell, is the Italian Giambattista Brocchi, discussed in relation to his role in the history of geology. Brocchi had also proposed a novel approach to the study of the natural history of species: how species originate, spread, and eventually become extinct. Since this approach was later exploited by the young Charles Darwin while considering the South American fossil record, Brocchi has also clearly influenced the history of evolutionary theory. This is shown by the recent study of Darwin's previously unpublished geological notes (Eldredge 2009) and other writings (Dominici and Eldredge, this issue). Brocchi's approach to the search for natural causes to the species problem, like that of the young Darwin and most others natural philosophers of their time, was consistent with the morphological stability of species in the fossil record, hence more modern than the gradual-

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istic view adopted by Charles Darwin after the discovery of natural selection in 1838. What has been aptly termed "Brocchi's analogy" (Pancaldi 1991), together with Brocchi's wider contribution to science, is contained in *Subapennine Fossil Conchology* published in 1814, a book instantly well received by key figures in the history of geology (Pancaldi 1991; Rudwick 2005, 2008). The historical role of Brocchi is yet only insufficiently appreciated because his work was never translated into French or English, the two languages of geology of the first half of the nineteenth century. Even if today we more fully recognize the relevant role played by *Subapennine Fossil Conchology* in the early development of geological thinking (Rudwick 2005), and Brocchi's analogy in relation to Darwin's approach with the fossil record (Pancaldi 1991; Rudwick 2008; Eldredge 2009), no such translation exists yet, apart from citations scattered in papers and books (Pancaldi 1991; Rudwick 2005, 2008), some of which do not concern Brocchi's analogy (Horner 1816; McCartney 1976). Here we give an extended and fairly continuous English translation of those chapters we deem most relevant to the birth of evolutionary theory (Appendix). This is done in the hope to foster a renewed discussion on the work of Brocchi.

## A Geologist and a Theorist

Born in 1772 in Bassano del Grappa, amidst one of the most interesting regions for fossils, one known to philosophers and naturalists for centuries, Giambattista Brocchi made contact with the geological avant-garde of his time, such as the geognost Pietro Arduino and the eminent Paduan naturalist Alberto Fortis (Berti 1988). These were in their turn tied to Giovanni Targioni Tozzetti and the school that had pioneered in Tuscany the reconstruction of earth history and deeply influenced Brocchi (Dominici 2009). A man of vast interests ranging from literature to civil and natural history and an active member of society at times of deep political change (Berti 1988), the young Bassanese produced a very interesting early predecessor of *Subapennine Fossil Conchology* in 1792, when he was only 20 years old. In the paper "Research on Egyptian Sculpture," devising a history of Egyptian sculpture following the lesson of the German antiquarian Johann Winckelmann, Brocchi sees each cultural phase as an individual: "Arts at their birth are like men. Weak and imperfect at first, they gradually gather strength and perfection; they have their periods of infancy, they become old and then they die like them" (see Berti 1988). Analogous thinking was therefore there from the start, mingled with an attitude of applying antiquarian techniques to the history of natural productions. Some time after writing a "Treatise on Odiferous Plants" in 1796 (he remained interested in botany for the rest of his life), Brocchi focused on geology in 1802, when he wrote a mineralogical account on a sector of Lombardy. In the same year, he was appointed to teach mineralogy at the Brescia Lyceum, presenting in his *Mineralogical Lectures* the first comparison of fossil and living invertebrates. Thanks to his acquaintance with the work of early marine zoologists like the young Giuseppe Olivi (1769–1795), he could access existing reports on the Mediterranean fauna. In the "Mineralogical Lectures," he could thus come to propose that "many species of petrified crustaceans are not met with alive in modern seas." This was a first argument against one general belief of his time, championed first by Carl Linneaus and then Jean Guillaume Bruguière, that all fossil species unknown in the modern biota are living in some remote part of the globe. By 1802, Brocchi was discovering on his own ground the reality of extinction of marine species, as Georges Cuvier was doing for Tertiary terrestrial mammals of the Paris Basin (Rudwick 2005). He could also be influenced by Lamarck's teachings in Paris, if not by his monograph on Tertiary mollusks, which appeared between 1802 and 1809. In fact, if Brocchi was never in Paris, still he kept very good connections there through the naturalist Giuseppe Marzari-Pencati from Venice, one who attended Lamarck's lectures in 1803 and who regularly sent Brocchi materials and books from the capital of geology (Pancaldi 1991).

The *Mineralogical Treatise* published in 1807 contains the first edition of Brocchi's analogy between species and individuals, based on his understanding of the fossils of ammonites and focusing on the death of species: "A constant and general law of Nature [...] species die just like individuals do [...] this final term is marked by the lack of reproductive force and the inability to develop." When he was appointed curator of the Milan museum of natural history in 1808, Brocchi had at his disposal all the Tertiary collections that once belonged to Giuseppe Cortesi from Parma, one of the largest of his time (Rudwick 2005). The time for him was ripe to undertake the first extended geological tour across Italy, in 1811–1812 (Pancaldi 1991; Rudwick 2005), with which came the fruits of a work seeded decades and centuries before by his Italian predecessors (Dominici 2009). The knowledge Brocchi acquired on Italy's geology and its Tertiary shells are all contained in the two volumes of the *Subapennine Fossil Conchology*, published in 1814, a work that the few other fellow geologists in Europe were ready to receive.

The first volume contained an introductory note and some important essays, whereas the second volume was a systematic description of the Italian Tertiary molluscan faunas illustrated by several splendid copper engravings.

The latter volume clearly stood next to Lamarck's monograph on the Paris Basin mollusks, completed by 1809. The long introductory note of the first volume explains the general aim of the book, which is both geohistorical—that is, concerning the punctual reconstruction of historical events by the use of documents (or "monuments"; Rudwick 2005) such as fossils and stratal relationships—and also clearly addressing the emerging problem that geologists were facing, the secondary (i.e., natural) causes shaping the history of species. Essays of the first volume dealt with apparently separate issues that the author felt relevant to the general aim of the book. These topics were the history of conchology in Italy, the geology of the Italian peninsula, and an original theoretical work on the extinction of species. The history of conchology in Italy was greatly the history of geology in the widest sense, as distinct from geognosy (Rudwick 2005). A large part of the debate on the meaning of fossils had, in fact, taken place in Italy (Rudwick 1972; Dominici 2009), as clearly understood by the young Charles Lyell (McCartney 1976; Rudwick 2008). The *Conchology* was soon available at key places in the geological community, namely Scotland, England, and France. Its presence in Edinburgh is first attested by a long and enthusiastic account published in the *Edinburgh Review* in February 1816, authored by the geologist Leonard Horner, future father-in-law of Charles Lyell. Leonard Horner wrote to Brocchi on December 30, 1816 that the book is "one of the most interesting [works] that has appeared since Geology begun to be studied as a branch of true science" (Pancaldi 1991). At Oxford, the book was praised by William Buckland, who toured the continent with George Greenough, first president of the Geological Society, both meeting with Brocchi in Milan in the spring of 1817 (Rudwick 2005). High esteem came from Paris through the words that Cuvier and Bruguière wrote on March 22, 1819 in a letter to Joseph Antoiz, a malacologist active in Tuscany. They were looking for a collection of Tertiary shells such as those described by Brocchi (1991), for the Paris museum, after this institution had missed the chance to buy Cortesi's collection in 1806. Brocchi's role as a leading geologist was finally confirmed in 1820 with a visit to Rome by Alexandre Brongniart, founder of modern stratigraphy, who also toured Europe after the end of the Napoleonic era (Rudwick 2005). Unlike his colleagues, Brocchi never traveled Europe, yet he was appointed foreign member of the Wernerian Natural History Society in Edinburgh on March 3, 1817 (Stuart Wallace 2010, personal communication) and, in 1818, of the Geological Society in London (Pancaldi 1991).

Oddly, Brocchi published no further comment on the species-individual analogy, and his name disappears from chronologies. Notwithstanding, the analogy remained a fruitful line of research according to an anonymous essay dedicated to geology in 1826, published in the *New Philosophical Edinburgh Review*. The paper was probably authored by the journal's editor Robert Jameson, one advocate and translator of Cuvier's work and defender of the heuristic value of geology. The analogy was eventually picked up by Charles Lyell and dealt with in the second volume of his *Principles*, and by Darwin on the *Beagle* (Dominici and Eldredge, this volume). After the premature death of Brocchi in 1826, during a geological survey in Egypt, a brief necrology appeared in Jameson's journal in 1827. Brocchi's work was finally extensively cited in the same journal, in a paper concerned with the geology of the surroundings of Rome, showing that Brocchi was still read by contemporary geologists (Hoffman 1830).

## Notes on the Translation

The following translation, based on the first edition of Brocchi's *Conchology* available online at the Biodiversity Heritage library (www.biodiversitylibrary.org), expounds the first and the last chapter of the first volume of *Subapennine Fossil Conchology*. These are the introduction to the general work and the essay on the "loss of species," both already widely commented upon (Berti 1988; Pancaldi 1991; Rudwick 2005; Dominici and Eldredge, this volume). These two chapters are not, however, translated in their entirety, some missing passages being explained in square brackets. The text ends with some passages from the introduction of the second volume.

Brocchi uses the word *originale* when relating to living representatives of a given species found also in the fossil state. This word reads in English as "original," meaning "extant," "living," or "modern," a sense which becomes clear from the context. The word *testacea* instead has been variously translated into "mollusks" or "invertebrate" in order to streamline the relative sentence. Punctuation generally stands as in the original text, excepting rare instances where commas were ignored. Species names were italicized.

It is finally important to remember that when Brocchi refers to fossils from "mountains" and fossils from "hills," he means to contrast Secondary and Tertiary fossils, the first being utterly different from the extant fauna. Particularly in Tuscany, Secondary and Tertiary strata are easily separated on geometrical grounds and form two different types of landscape (Dominici 2009).

## Appendix

*Subapennine Fossil Conchology* with Geological Observations on the Apennines and the Adjoining Terrain [Excerpts]

[Conchiologia Fossile Subapennina con Osservazioni geologiche sugli Appennini e sul suolo adiacente]

By Giambattista Brocchi (1814)

Volume I

### Introduction

The aim of this book is to offer a series of documents that shed light on the ancient history of the globe. I take them from the organic remains that the sea has abandoned on our land when, running from the continent, it shrank to its present boundaries, and I expand them with some observations I made on the spatial relationships of those remains, on their state of preservation, the quality of the earth which bounds them, and all the sum of the circumstances that, according to my way of seeing and interpreting, are worthy of consideration. And since hearing of living beings that once populated the waters of the ancient sea raises curiosity to learn what correspondence they have with those from actual seas, and while our attention is eminently attracted if we can compare with the present what others tell about the past; so I resolved to reconcile to the matter I am about to deal with, the interest I could derive from the above-mentioned comparisons. Thenceforth by describing and classifying a large number of shells collected from the Italian lands, I have made all efforts to compare them with living species, mainly with those that dwell in the Adriatic and the Mediterranean and, whenever I could, I have always paralleled fossil and marine conchology.

Of such great importance are these comparisons, with such a tight connection to my subject that we could not neglect them without missing an essential part of this work: and I must add that I would not have even started my task had I seen that they cannot be sustained, and if the shells that we unearth had been wholly different from those that presently dwell in seas. In fact, even if we were to consider any research aimed at knowing Nature's worthy productions, it would be too sterile an occupation to finely revise a bunch of shells that have no analogs, that do not admit any comparison, and that teach nothing more as we progress in their discovery, something that would look more like busying ourselves to plot a distinct genealogy of some obscure descent long since gone.

But in another way, things proceed from those that I am about to describe. Many are the species whose originals are unknown; but also many are those so similar to the species of modern shores that no doubt arises that they are exactly the same. This occurrence is very important for the moment; but, among the shells whose prototypes are available, it deserves special attention that a good number are obvious in the seas washing our peninsula at the present time, and what I most like is that I have recovered within marls and sands of our hills many gastropods and bivalves discovered in our time by Olivi and Ranieri. By comparing the writings of such worthy men, particularly Ranieri, who has published an extended and finely described catalog of shells from that sea, frequent examples occur of what I am saying, and I will be solicitous in pointing them out wherever appropriate. This list includes, just to name a few, *Dentalium incurvatum*, *Patella squamatula*, *Trochus striatus* and *punctatus*, *Turbo fasciatus*, *Murex reticulatus*, *rostratus* and *politus*, *Voluta buccinata*, *Ostrea nivea*, *Mactra triangula*, *Cardium clodiense*, *Tellina muricata* and others that I won't name for the sake of brevity. So if my fossil conchology had seen the daylight a few years earlier, it would have anticipated many discoveries of the Adriatic conchology, just as I am firmly convinced that it will anticipate many more that will appear in the future.

I am thus confident that the work I now publish will offer in this regard many new facts that do not stem from all those that are presently available on the same subject. Nor is it my intention to speak of ancient studies, it being well known that fossil bodies were once considered individually, and with no application whatsoever; and if anybody ventured into comparing them with those from the sea, he did it in such a coarse manner and with such little insight that we cannot now fruitfully consider those authors' classifications. In more modern times, however, there is no lack of those who have pursued such investigations with great accuracy and fine criticism. Solander described in the best way fossil shells from Hampshire county in England, and Parkinson those in the London neighborhoods; but above all others stands Lamarck, who has skillfully depicted a large quantity of those remains that were collected around Paris. The land from which naturalists have established their observations are, geologically speaking, as young as those that I have walked; nevertheless species analogous to living ones occur there in such a small number that, among 500 and more species classified by Lamarck, we recognize few more than 20 within this number.

According thus to the information of these authors, we could argue that when the sea invaded the continent, it hosted creatures in its waters for the largest part different from those sustained today, which would give way, as in fact has happened, to some particular system. But whatever the reason for this fact is in the above countries (something we will somehow consider at the proper time), we certainly draw from what we see in our country opposite conclusions, since I can affirm without any doubt, as you will see in the course of

the work, that among the shells that I considered, more than half belong to known species, for the most part dwelling in nearby seas.

I realize that someone will wonder why some men spend their time walking down the strand and rummaging the bottom of the sea to investigate these shells and then start pondering the finest lineaments of these shells, comparing the slightest differences to differentiate this from that, and subdivide them into genera and species; much more, they shall wonder at spotting others making the same search atop mountains and hills, giving the highest importance to fossil remains that have lost all their appeal together with their colors: so why bother? But if we wanted to strictly consider physical studies and value them in order that the real advantage is gained, against how many sciences could we bring the same arguments with which we are judging this and other parts of natural history? In truth, do we believe that it is more important to stress the mind on an intricate and subtle problem of calculus or geometry than to spy out the structure and organization of an insect? To sharpen the eye across the telescope to see what's invisible on the sky than to spend hours observing atoms from a microscope? To inventory and name all the stars is maybe more important than cataloging all animals and plants on the face of the earth? If instead we want to leave aside frivolous and inconclusive objections of *cui bono*, and ridiculous contests on the primacy of this or that science; if we want to recognize that all which advances our knowledge of the work of creation is worth our attention; the entire matter is thus reduced to this: either all studies are in vain, or all must be appreciated. I agree that wanting to describe all the shells of the sea, to sort them by order, genera, and species, does not lead to great consequences, but if no one dared to treat marine conchology in an academic way, how could we usefully study fossil conchology, which gives units of measure in geology and paves the way to so many beautiful speculations? Anyone even slightly interested in the study of Nature understands how important it is to the physical history of our globe that we proceed with diligent and mature attention on these investigations, and I frankly declare that without those materials previously prepared from our naturalists that have explored the Adriatic and the Mediterranean, I would have gathered little advantage from my research.

From what we are claiming, it is not to conclude that fossil shells of Italy are to be referred only to local species. The largest part have their originals from this number, but others are today living under other climates and on a different hemisphere, inhabiting the Indian Ocean, the Atlantic, the Pacific. This is not the place to list their names, but wishing to give some examples, I can cite some species of genus *Murex*. *M. cancellinus* lives in the Austral Ocean, *M. lampas* in the Indies, *M. tripterus* close to Batavia, *M. cornutus* along the African coast, *M. ramosus* in the seas of Asia and America, and *M. magellanicus* in the strait bearing its name, and all are buried under our soil, some in large numbers. From this, we can derive that among the fossil shells which I will speak about, some lack analogs, others live in the Adriatic and in the Mediterranean, others still were never recovered in foreign seas. To be honest, such a heterogeneous consortium is of no little obstacle to anyone about to give an account of the provenance of these beings. In fact, if only species of the first of the three categories were dominant, we would have one hypothesis; other explanations would be appropriate had we found only species of the second, and we would have reasoned in yet another way had we only species of the third, or were they larger in number; but since indigenous species are mixed with exotic ones, and those which we deem lost are together with others that nevertheless exist, we want to produce a system to reconcile facts of such variety, and that by satisfying all concomitant circumstances, tries to explain them without outraging reason, and in consonance with physics.

These reflections often came to my mind, and induced by the importance of this subject, I have stepped unknowingly into so intricate a matter; but since I realized that I had gone too far to come back, I have proceeded the best I could and proposed the solution that I judged most probable. I claim I did this almost without intention, since I wanted to avoid controversy and limit myself to openly and candidly exposing what I had before my eyes: Arid but faithful chronicler, I wanted to announce the facts without drawing any conclusion whatsoever, and to present a compilation of isolated observations, leaving to others the burden of putting them together at their will. I wouldn't impose so strict rules to such studies, and I don't know what progress could be brought to science from their observation. Nothing is more familiar than hearing outcry against systems, and repetition of all the usual commonly mentioned in these cases: Of the small mass of positive knowledge we possess for the moment, the impossibility of establishing general axioms, and of the need to carefully observe phenomena, and record them with fidelity abstaining from comments and applications, all are things that may be true within certain limits; but altogether true is that many indulge in these principles and, while claiming against the use of hypothesis, they act as if ignoring their use.

Myself, I believe (and I have declared this feeling in another circumstance) that without geological systems, little would remain of the many things we know on the structure of the globe, and that to these more or less ingenious theories, provided that they are not too speculative or ideal, we own the debt of the large part of those factual notions that make up the true wealth of science. Many particularities concerning the nature and the differences of rocks,

their reciprocal relationships, the order of their superposition, the direction of strata, etc. would have escaped our attention, or many of us would have deemed them indifferent, were it not for the special interest in using them to defend or attack a system. Woodward's system, for example, however fallacious, has extensively treated the issue of petrifactions yet unresolved at that time and has pushed naturalists to observe, if I may use this expression, the organization of the soil with respect to the succession and the character of strata. Buffon's other system, notwithstanding that it may have caused surprise more than persuasion, taught how to recognize a certain regularity within the bulk of mountains that look like disordered masses, placed with no apparent pattern one beside the other, and gave a reason to look for connections among the various mountain chains. Lazarus Moro, who fancied substituting fire for water to explain the formation of continents, started to study the product of ancient volcanoes which before were little known or unknown. Lamétherie, ignoring the crystallization of the whole globe, draws attention to that of single rocks, and Breislak, who sees in the primitive period an epoch of generalized combustion, open the way to new and singular investigations on the effects of igneous fluids applied to sedimentary strata, regarding which, Hall's experiments reveal quite remarkable things. So Geology, which merges and combines so much, has facilitated the advancement of Geognosy from mere seeing and taking notes. This is, if you allow me, Alchemy educating Chemistry, which does not lead to blaming the cause when the effects are good. From this, you should not think that I want to indirectly justify myself, as if with no restraint I had completely given myself to hypothesizing and creating a world of my own, since I would not be capable of this, nor does the issue deserve this. I have done nothing more than from place to place adding my reflections to some wonderful facts that I had the chance to observe; since I could not remain a cold observer in Nature's theater, I showed those ideas that were moved by the observation of those objects that I had started to study.

One may ask how classifying and naming shells has opened the way to so much philosophy; as I said from the start, I have not limited myself to one occupation. While visiting the sites where I was recovering those fossil remains, I have also paid attention to the most important peculiarities of their orientation and to the physical nature of the soil. The exposition on this subject forms the subject of the first part of my work, as I will soon summarize.

But above all things I would like to affirm that even if I have traveled the greater part of Italy, I limited my conchological research to that portion which is crossed by the long chain of the Apennines, so that I have not ventured into the region surrounding the Alpine chain surrounding Lombardy. It is also necessary to say that among the fossil shells I wanted to describe, only those that we meet on hills appear, while I will not mention those belonging to the high Apennine mountains, which would belong to a completely different conchology. Shells that are found on hills are in their natural state and having lost only their animal substance, now have a chalky appearance or, as it is said, are calcined; many conform to existing species or if their originals are missing, they nonetheless have strong affinities with known shells. The soil in which they are dispersed consists of soft and incoherent matter, marl, clay, carbonate, or siliceous sand. None of these situations are encountered on mountains. Besides that, in the Apennine, marine bodies are in much smaller numbers, so that large tracts can be traveresed without meeting a single vestige, and those that we find are imbued with a cementing substance that has entered the pores, and shells are usually lost, so that only their inner cast is left. Extremely rare are the species identical to living ones, and many have such strange appearance that we would not be able to compare them with any genus of modern seas. Now, distinguishing between fossil shells from hills and those from mountains is much more than a gratuitous supposition, not just because it is founded on the above differences admitting little exception, but because a natural limit between one kind and the other is posed by the different epochs in which those terrains have originated. Mountains are more ancient, and the Appenines can all be referred to the secondary period, whereas the sandy and marly hills belong to a far more recent formation that I shall call tertiary, and have resulted from the last marine deposits. These deposits exhibit phenomena so instructive and singular that I am certain anyone aiming at ordering a rational system of geology should start from them, better than as we usually do, starting from epochs so obscure and remote that border on chaos. Since they are conveniently placed close to those forming in our time, they offer a good term of comparison for operations of the ancient sea with those of the modern, so that the geologist, by moving little by little to older terrains will be able to rightly discern and understand modifications and changes seen, as these move away from the first term. [...]

[On pages 22–29, Brocchi briefly explains the chapter on the geology of the peninsula, the types of distributions of shells, and other marine fossils in Tertiary strata, stressing the similarities with their distribution in bottoms of modern seas and moving from marine vertebrates to their terrestrial counterparts.]

And I should have limited myself only to the above incumbencies; but here is where I have expanded my hypotheses, trying to explain the existence of these skeletons; and since one proposition pulls another and we want to add secondary proofs to the principal ones, I have let myself gradually slide from conjecture to conjecture, until I reached a state in which a step further would have

caused a fall by the wayside. I let others judge if I have recognized dangers only too late. I have mentioned above that among fossil shells, some are no longer living in our or other seas. It has been long disputed among naturalists whether this is because their race has turned off, or because they live hidden in the deep abyss of the ocean from which they cannot be recovered by the force of the tempest nor by any human means. I will devote a whole chapter to this argument that I had raised by accident five years ago in another writing; and without claiming I can understand the logic followed by Nature in creating living beings, I thought I had enough inductions to venture to say that it is law established that species die like individuals, and that they are bound to make their appearance in the world for a fixed span of time. With this reasoning will end the first part. The classification of shells will be the subject of the second. [...]

## Reflections on the Losing of Species

Fossil osteology and conchology would be too sterile and ineffectual occupations if we did not wish to trace what relationship they bear one with zoology of the modern world, the other with conchology of modern seas. As we undertake this task with all the ponderation that it deserves, we are heavily impressed to see how high is the number of mollusks and quadrupeds that can't be referred to known and existing species. All we have to do is to understand what has happened to them. [...]

[On pages 219–220, Brocchi reviews the opinion held by Linnaeus and Bruguière, and its relevant evidence.]

Other quadrupeds have such profound differences, and they can be distinguished by characters so peculiar, that they cannot be likened to any living animal. Such are the three or four species of paleotheres discovered in gypsum strata at Montmartre near Paris, the four anoplothere species from the same site, the five species of mastodont (some of which were unearthed in Northern America), and others in many neighborhoods of Europe (the megatherium from Paraguay and the megalonix from Virginia). Many of these animals were of large volume and gigantic height, so that the mastodon whose remains were recovered in the North American countries in which the Ohio river flows must have been at least paired with those of the elephant. But not to dwell too long on details, it is enough to say that among 78 quadrupeds classified by Cuvier, 49 are no longer found anywhere in the two hemispheres, so we can reasonably conclude that we have lost their species. Nor is it to be concluded that those animals could live confined in some continent where Europeans have not set foot... [on pages 222–223, Brocchi revises evidence that the terrestrial mammals found only among fossils cannot reasonably remain undiscovered in the modern world].

Since all the available proofs on such logic concur to demonstrate that the species of those living beings no longer exist, in analogy, we can deduce that the same destiny is to be assigned to some marine mollusks whose originals are missing. But since this speculation is still far and away a mere opinion, I will confirm it with a circumstance that, if not strictly a direct proof, is yet provided with great momentum.

Among fossil shells of marine origin, many are in some countries, namely around Paris, that were without any doubt recognized as terrestrial and fluvial. Lamarck discovered more than 50 in Grignon; Cuvier, Brongniart, and Brard [sic] then recovered a good number of others that they began to classify with full accuracy. Very few species emerged from the research of these naturalists that are analogous to those living nowadays in rivers, pools, and on the surface of the earth, so in only two among those described by Brongnart (Ann. du Mus., tom. XV, pag. 357) may we envisage this correspondence. [...]

[On pages 224–225, Brocchi revises data on modern terrestrial and marine mollusks, recognizing that if not all regions have been explored, still it is highly unlikely that all missing species will be one day discovered alive].

Either I am wrong or the above splendid examples show that many molluscan species have been lost similarly to those of large animals. Given the truth of this fact, many have conjectured, and this is the most common opinion, that shells were often lost due to a general and disastrous catastrophe, and wishing to guess which, they revert to the one that has forced the seas to reduce within the bed they presently occupy. It is thus believed that this swift escape of the waters caused the destruction of many marine species because they were abandoned on the land, where they quickly perished, being out of their element. But this hypothesis is at most tenable if the species whose race has been lost were only found on top of the mountains or much within continents, since we could in that case imagine (but find hard to believe) that, after the wide space that the waters had to pass going from those points to the abysses that at once opened, had they remained on dry land, with not a single one having the chance to be dragged from the currents and sustain the durability of species. But we miss a lot to verify this circumstance: They are not just found in very low reliefs, but even in littorals, as we find in many occurrences in Italy that it is deemed boring to tell. Now who does not see that drawing back the sea from those lands to establish its place after a small distance, could have easily brought specimens of those animals with itself like it transported specimens of those many others that present themselves in the fossil state in the same places, and still live today in contiguous seas? If ruling out this hypothesis, we were to substitute the above catastrophe with any other, I cannot imagine which could be the one so general in its

effects as to strike both marine and terrestrial animals, and so partial on the other hand that while destroying some species, it spared others that were living in company of the first, since fossil shells that lack analogs, are, I repeat, mixed and confused with others still extant, and together with bones of lost quadrupeds, we have those that belong to the horse, the deer, the fallow deer, and other common animals.

As for myself, I believe it is superfluous to distress the mind so much and invoke accidental and extrinsic causes to explain a fact that we can judge to depend upon a general and constant law. Why don't we thus admit that species die like individuals, and that like them they have a fixed and determined period for their existence? This should not seem awkward, if we think that nothing is in a state of permanence in our globe, and that Nature is maintained active with a perpetual circle and a perennial succession of changes. But let me abandon vague and general statements to penetrate more intimately the idea that I herein expose. Let me stop and contemplate instead for a moment the behavior that Nature herself has observed while attending the construction of organized bodies. The first intention was to prescribe a certain end to their life, and the inner economy of these machines was devised thus with such an artifice that they cannot exercise their functions but for a given lapse of time, after which death must come. This span of time, for particular reasons we do not know nor wish to investigate, was dispensed to individuals of different species in different degrees: The mayfly lives but a few hours, whereas the deer is assumed to live for some centuries; among the vegetables, some are deemed to be born, grow, fructify, and perish in a few months; others can maintain for one year, others for two, and others still have the faculty to live even longer.

In the way that time span is circumscribed, so limits are posed to increment regarding the dimensions that bodies may attain, which is to say, the force of development was restricted to certain norms.

It is thus clear that when Nature created organic beings, it was conducted by counts of size and time, and that it regulated both at its will with a direct aim and intention. If she let some power to Chance in derogating her decrees, it was more to shorten than to lengthen those first limits set by her, as familiar examples show. Individuals that cannot complete the entire natural stage of life are greater in number than those that cross the limit, and many are those that stay below the height they could attain. We could finally say that Nature in some way more likely pleases herself in degrading and destroying her works, than in perfecting them and extending their conservation.

Now we believe that among all these calculations, it has been actually prescribed that vitality and force of development are maintained at the same degree from individual to individual, or what if on the other hand they deaden and disappear, going from generation to generation until disappearing? Would one find it extravagant if species were created under the condition that each must make its appearance on the globe for a given stretch of time, or wouldn't we laugh instead at the frankness with which someone warns us that their destruction cannot ever be while our planet lasts: "that it would be better, to make that happen, to have a comet hit or some similar disaster take place; and that only individuals are capable of destruction and renewal, but species are perpetual" (Necker, Phytozool. philosoph., pag. 21)? Which is to speak with much solemnity.

If all this is gratuitously supposed, and if we can believe, on the contrary, that these do not exist forever, nevertheless they do not perish at once, and the slow and gradual progression with which the destruction of individuals is conducted is observed in this very same circumstance. And since these do not pass at once from life's vigor to the state of death, but slowly come to this point by the gradual weakening of their physical faculties, so by imperceptible grades species come to their annihilation: Vitality disappears, the virtue to proliferate weakens, and less energetic developmental force is then from age to age always weaker; and the more feeble the complexions are, fecundity and multiplication become more limited, growth is labored until the fatal end is reached when the embryo, unable to stretch and develop, abandons the slender life principle from which it is slightly animated, and all dies in him.

There are still species that seem to be in this state of deterioration and decadence, so that the moment when they cease to exist must not be far. I don't know if we can include in this number the small nautilus of the Adriatic, the Mediterranean, and the Indies, so minute that they cannot be seen without the aid of a microscope. But it is certain that while this family once possessed gigantic species, it does not include today any but very small ones, almost imperceptible. We search with no success for those voluminous ammonite horns, once so numerous, and whose remains are so common not only on Europe's mountains, but also on those of Asia and Africa, that Gesner has no doubt in asserting they outnumber all other petrifactions. Some reach such a large size that they measure seven or eight feet in diameter, and one foot thick; whereas *Nautilus pompilius*, the largest known nowadays, barely reaches a diameter of one foot. [...]

[On pages 230–233, Brocchi corrects his early views of foraminifera, which he described in his 1807 Treatise as very small ammonites, and disagrees with Bruguiere, extensively cited together with Faujas, Linnaeus, and others, arguing that fossiliferous mountaintops are presently too high to be once covered by a deep sea].

If Bruguiere's arguments are considered unfounded, then we can study mountains under their zoological

aspect with some profit, since they furnish us with documents to know which species existed in the most ancient ages of the world, before continents were formed. These large masses of solid rocks, whose formation largely precedes that of sandy and marly hills which lie at their feet, bear the remains of the most ancient generations of those living beings that once inhabited the waters of the universal ocean; similar, if I may, to Egyptian obelisks that carry the chronological history of their country, the mountains present in some way the history of their organic creation, when we can interpret their characters in the proper sense.

[On page 234, he revises opinions on the progressive similarity of species to modern forms as one progresses from fossils of the mountains to those of the hills.]

It is evident to all naturalists that there is a relationship between the age of strata and the quality of the species, and that the older their origin, the greater the number of shells different from those we know. Cuvier supposes that there has been a change in the chemical nature of the fluid, and this matched a series of variations of animal nature. If you ask why in ancient strata species surviving nowadays are so rare, and in most recent strata on the other hand you have a large number identical to the modern, Cuvier would answer that the fluid where the first lived acquired qualities so contrary to their complexion that all died; that others raised behind, but that waters subsequently deteriorated once again, with this one difference that these resulted fatal only to some species. This famous man has a smart answer indeed, but this does not suffice to the generality of the phenomenon. It does not account for the loss of freshwater shells and, what is more important, it cannot be applied to the loss of terrestrial quadrupeds, a subject about which he himself has observed that all unknown species belong to the rocks older than those others that bear remains of known species or more similar to living ones (tom. 1, Disc., pag. 33 and 70; tom. II, Remarq. prél., pag. 5). We must thus imagine other causes from those that have brought marine animals to destruction.

Speaking of myself who does not adopt extrinsic causes, I claim just one, that all these facts reveal a progressive decline of species taking place as centuries go by. Many have naturally perished due to necessity of constitution, in the time interval passed from the formation of large mountains to that of small reliefs, as others have perished in the epoch when actual continents made their appearance up to the one we live in; and like others, still will finally perish in the future and what we know will be sought in vain by our descendants.

[On page 236, Brocchi deals with species extinguished in historical times, like the dodo, with a mention of the South American *Megatherium*, the Virginia *Megalonix* and bones from Italian karst fissures, returning in the end to a list of Tertiary marine species.]

These and many others, compared with their analogs, correspond in such a grade that no dissimilarity can be seen, notwithstanding that they lived thousands of years ago. So, these species have over such a long stretch of time continued and remain nowadays in the same state with no change whatsoever. But if you admit, as is natural, that different terms of duration have been assigned to different species, it is consequent that the longest-lived will show clear signs of deterioration later than the others, as old age shows up later in individuals of animals that live for a greater number of years, compared to those whose life is shorter.

Given this, it is no surprise that the ibis is embalmed together with Egyptian mummies, that beavers are buried in French ancient peat bogs, and that some other fossil herbivores and carnivores look much like the other prototypes living nowadays. For the rest, it is useless to argue that the alterations that take place in the animal machine and that are symptoms of the decline of the species do not produce a large change in structure, which would be a true metamorphosis. They can make the individuals smaller and weaker, but they also signally influence the organs of vitality and propagation.

Volume 2

On the Methodical Distribution of Fossil Shells

In the distribution of shells I am about to account for, I follow the classification of Linnaeus. I adopted this system partly because I don't find it as bad as some believe, partly because among those subsequently devised, none is perfectly accomplished in describing the species, which is most important.

[...]

The determination of species was the toughest task. If one must pay great attention while classifying natural shells, he must be much more scrupulous for the fossil—if you think of the consequences that this can cause to geology, not wanting to present as foreigners those that live in our seas, or vice versa, nor like lost species whose originals are with us. I have used museum collections to compare fossils with marine remains; I have consulted a large number of authors, used their descriptions and the accompanying figures, and I made engravings of all the shells that no one has pictured before, together with some which have only imperfect drawings.

[...]

If someone wishes to devote himself to this study and augment with new species the catalogue I'm presenting, he should not forget that I am describing only shells from tertiary sediments, marly and sandy, only slightly fossilized, and that I completely avoid those that are lithified and contained within the solid mountain strata. Those were

deposited in a much more antique epoch, when a different order of things prevailed, and they mostly belong to lost species. I warn that I did not consider microscopic ones.

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