Maurizio Mamiani

The Map of Knowledge in the Age of Volta

Aristotle had maintained that mixed mathematics, like optics, harmony and astronomy, are the "reverse of geometry",[1] because they study mathematical properties insofar as they are physical. They are therefore to be kept separate from the three theoretical sciences (mathematics, physics, and theology or metaphysics) whose sole object is the knowledge of substances and their kinds.[2] Despite Newton's work basically upsetting these distinctions,[3] Aristotle's matrix for classifying the sciences comes through like a karstic stream, as a result of the great good fortune of eighteenth-century encyclopaedic literature.

In the preface to the *Cyclopaedia* (1727), Ephraim Chambers drew up a complicated Map of Knowledge to support the cross-references from the alphabetical list of headwords in his dictionary. Chambers divided knowledge into two parts: the first, natural and scientific, the second, artificial and technical. He had major recourse to the works of Newton and Locke. This did not prevent Aristotle's three theoretical sciences from reappearing under natural and scientific knowledge, but in a significantly different order. Chambers put mathematics after physics and metaphysics, attributing to it the highest level of abstraction from the senses and therefore maximum power to the activity of reason.[4] Thus mathematics, in which objects and relations are the result of reason and not experience, was again and even more separated from physics. Physics, or natural philosophy, consisted in the study of the power or properties of sensible objects.

Mixed mathematics had a different fate: Chambers established them as belonging to technical knowledge. It was no coincidence that in the *Cyclopaedia* the difference between rational mathematics and mixed mathematics was the same as that between physics and chemistry. In the Aristotelian plan, physics and mathematics were conceived of as theoretical sciences; optics, mechanics and chemistry as technical knowledge applying physics and mathematics to further purposes dictated by the imagination.

In Chambers' encyclopaedic system, the sharpest distinction was between nature and art, with a far smaller part attributed to the tripartite Baconian division of human

[1] See *Phys.*, 194a9.
[2] See *Metaph.*, 1025b-1026a.
[3] See MAMIANI (1998).
[4] See MAMIANI (1983), pp. 104-5.

faculties (memory, imagination and reason). Diderot and d'Alembert's *Encyclopédie* adopted the latter scheme.

The external connections between Chambers' *Cyclopaedia* and the *Encyclopédie* are well known but, until now, nobody has directly and completely compared the headwords of the two lexica. Some entries, signed by d'Alembert, are simply translations, or minor expansions of those by Chambers. This is true particularly of Newtonian entries like "Newtonianisme", "Attraction", "Gravitation", etc. which were a primary part of the enlightened interpretation of Newtonian science.[5]

In the "Discours Préliminaire" to the *Encyclopédie*, Chambers' influence, as I have shown elsewhere,[6] is much more important than historians have so far admitted. Chambers popularised Newtonian science. At the same time he gave the Royal Society back its Baconian approach into which Cartesian mechanism had been incorporated. Newton's main innovation was his attempt to integrate all the various traditions brought together into the "new science", and primarily the mathematical and experimental ones. This was thwarted by the mass of concepts required to produce lexical descriptions.

Chambers' entry "Mechanics", translated entirely by d'Alembert, is a good example of how easily the previous century's ideas became distorted. Chambers (who was and remained an entirely unscrupulous lexicographer and journalist) superficially examined the preface to *Principia* (1686) and attributed to Newton what Newton had flung polemically in the face of the Ancients, i.e. the distinction between practical and rational mechanics. On the other hand, d'Alembert, by attaching to Chambers' text a new important entry taken from his own *Traité de Dynamique* (1743), in which mechanics is understood as a branch of mathematics, increased the confusion and uncertainty as to the borders between these two disciplines.

The methods used in the two encyclopaedic dictionaries of the eighteenth century had both a practical aim (to prevent alphabetical order from degenerating into a scattered inventory) and an epistemological one (to suggest a distinction between the grouping of objects in order to facilitate collective research, i.e. the development of science). Of course, these two aspects overlapped, even if the cross-references fulfilled the first aim more than the second. Both Chambers and Diderot and d'Alembert underlined the arbitrariness of subdivisions within disciplines,[7] but, from many points of view, the result was just the opposite. The cultural impact of the encyclopaedic system was largely ideological. Encyclopaedic presentation gave a much less critical picture of knowledge than the editors had intended, and than was given by the individual articles. Right at birth, the classifications of these two eighteenth-century encyclopaedias used the Baconian system, which was already over a century old, and through which the Aristotelian one could easily be discerned. As the prophet of a science which he had not helped construct, Bacon provided the encyclopaedists with

[5] See FARINELLA (1996), p. 152.
[6] MAMIANI (1983), pp. 24-6.
[7] *Ibid.*, p. 59.

the essential means to enclose and unify it in a new type of scholasticism. However, this framework did not at all correspond to the still uncertain development of science, nor to its historical development, especially in Italy.

In 1779, the *Prodromo della Nuova Enciclopedia Italiana,* an ambitious project by the ex-Jesuit Alessandro Zorzi, was published in Siena. Zorzi's death that same year put an end to the project, before ecclesiastical censorship, which was already on the alert, could finish preparing its attack.

Zorzi's planned encyclopaedia, for which he intended to make use of authoritative collaborators, thanks to the help of Spallanzani, Barotti and Malfatti,[8] was intended to be "new" in the same way as the French one was by comparison with the *Cyclopaedia*. In other words, he proposed both to publicise articles from the *Encyclopédie* – d'Alembert's "Discours préliminaire" was to be reprinted in full at the start of the work – and to reduce, expand or rewrite them completely. Zorzi naturally intended also to cut articles out or add new ones.[9]

As has been noted, what was interesting about the *Prodromo* went beyond the "mere ordering and systemising of acquired knowledge",[10] since it was planned to include original contributions, especially "philosophical" and mathematical ones. The Appendix of the *Prodromo* gave, amongst other things, two examples of these: mathematician Giordano Riccati's article on "False Sound" and Lazzaro Spallanzani's on "Artificial Fecundation".

Despite the epigraph from Bacon at the start of the *Prodromo* and Zorzi's expressed intention to put a general "Tree of Knowledge", in the first volume of the planned work, "largely following the Paris one",[11] the real arrangement was different. It was reduced to distinguishing eight classes: "in which division much larger consideration has been given to economic criteria than to encyclopaedic ordering".[12] In the *Prodromo* Zorzi manifestly followed, by analogy, the subdivisions of knowledge then current in the major academies:

Mathematics Class,
Physics Class,
Medicine Class,
Metaphysics Class,
Jurisprudence Class,
Fine Arts Class,
History Class,
Mechanics and Crafts Class.

Sebastiano Canterzani, the Secretary of the *Accademia delle Scienze* of Bologna, was allotted the programming of studies in the Mathematics and Physics Classes. Of

[8] See INGEGNO (1989), p. 21.
[9] ZORZI (1779), p. XV.
[10] INGEGNO (1989), p. 21.
[11] ZORZI (1779), p. XXII.
[12] *Ibid.*, p. XVIII.

the two syllabuses produced only that for the Mathematics Class (see the subdivisions on next page) bore any resemblance to the mathematics section in the *Encyclopédie*, although with some differences from d'Alembert's.[13] Yet, what is surprising about both Canterzani's study plans is how pragmatic they were. They recalled actual scientific practice:

> It is not easy to establish the limits of mathematics and physics, but that doesn't matter. What is important is that the subjects are dealt with, even if it is not yet decided as to which faculty which subject belongs.[14]

The decision about which subject belonged in which sphere was decided each time. Canterzani adopted only one criterion regularly: physics had to deal solely with concrete bodies, leaving everything else to mathematics. Consequently, he classified as mathematical the general laws of motion, of the equilibrium of solids and fluids, the explanation of tides, etc.

On the other hand, Canterzani thought that physics extended to the vegetable and animal realms, the production and growth of plants and the feeding of animals. He had no doubt that physical chemistry existed, but:

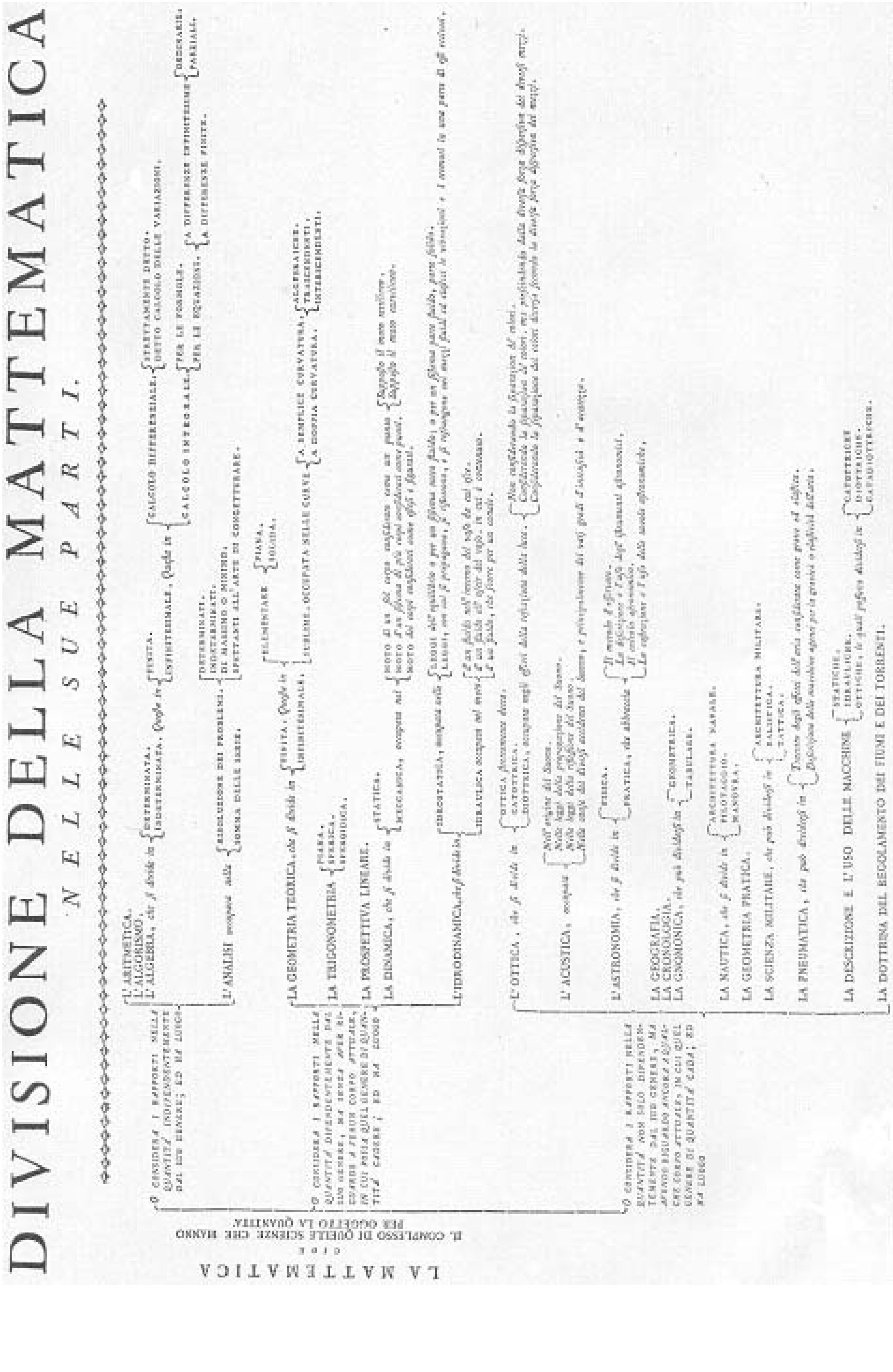
> it is equally true that a sort of different science has been developed, which is treated by Chemists in their way and which, insofar as it is of use in Physics, is to be treated in the manner of Physicists and not as Chemists do.[15]

This eclectic picture of physics was common in the *Istituto* and in the *Accademia delle Scienze* of Bologna, as pointed by the fact that the *Commentarii* report the majority of the chemical memoirs (e.g. on phosphors) in the Physics section.[16] Although the distinction between physics, physiology, and chemistry was not clear, demarcation was clearly demanded only for mathematics. Canterzani never doubted when a mathematician should take the floor. Moreover, right from when Galileo was convicted, one of the main characteristics of Italian science academies was the separation between mathematical and experimental research.

Giordano Riccati, one of the authors chosen for the new Italian encyclopaedia project (although he was over seventy) had written an essay in 1747, which remained unpublished, on the usefulness of mathematics for the other sciences. This essay usefully indicates how very ambiguous the relation between mathematics and physics was in Italy. His remarks show the uncertainty of the situation within which experimental physics developed in the second half of the eighteenth century:

> the small number of gifted men with whom Italy is at present blessed, comes from the unfortunately common prejudice that mathematics is, so to speak, a separate science,

[13] See SPALLANZANI (1989), p. 33.
[14] Biblioteca Universitaria di Bologna, Manoscritti di Sebastiano Canterzani, Ms. Caps. XXVII (4158), fasc. 10, c. 40. Quoted in SPALLANZANI (1989), p. 33.
[15] CANTERZANI (1779), p. 20.
[16] See TAGLIANINI (1987).


DIVISIONE DELLA MATTEMATICA
NELLE SUE PARTI.
LA MATTEMATICA

> having nothing to do with the others. As long as this mistake exists, although Italy has an abundance of extremely brilliant minds, we will have to swallow our shame and let other nations, previously barbarous and taught by Italy, hold supremacy. On the other side of the mountains, the situation isn't like that because there many people really apply themselves to studying and who are not short on mathematics. This is shown in the Acts from Paris, London, Leipzig, Berlin and St. Petersburg, which are full of mathematical dissertations.[17]

Riccati's essay – written before the *Encyclopédie* was published – gave a complete picture of the mathematical sciences. Canterzani's mathematics syllabus, drawn up over thirty years later, was almost *verbatim* Riccati's. There are more similarities. Canterzani seemed convinced that physics, when it managed to give adequate explanations of its true theoretical principles, should be left "entirely to Mathematicians".[18] In other words, experimental physics had a solely "historical" not "theoretical" function. Giordano Riccati had also written:

> What is physics other than the mathematical faculties I have just mentioned? Mechanics, statics, dynamics, hydrostatics, hydrodynamics, optics, dioptrics, etc. are certainly nothing but physics to which firm demonstration methods are applied. No one should expect to be able to explain any point of physics without resort to mathematics.[19]

The result was just what Canterzani claimed: experimental physics, as long as it had no firm demonstration methods, could not "enter into theory in depth and detail".[20] Hence the temporariness of experimental results. Bound, as they were, to the specific real bodies, they finished up in a temporary file of the natural sciences, i.e. in physics, because physics could be enlarged or restricted at will, as it dealt with a variable, mobile area. It is therefore not surprising that Canterzani did not produce an illustrated scheme for physics, but restricted himself to summarising the headings under which physical matters, thus understood, could be distributed:

I. Essence, common qualities, real qualities, apparent qualities of bodies, and their principles both elemental and chemical,
II. Mechanical Physics,
III. Chemical Physics,
IV. Electricity,
V. Magnetism,
VI. Phosphors,
VII. Affections of apparent qualities; anomalies and effects proceeding therefrom,
VIII. Phenomena appearing in the atmosphere,
IX. Hydrology and Geology,

[17] Biblioteca Civica di Udine, MS. 1029, f. 291.
[18] CANTERZANI (1779), p. 18.
[19] Biblioteca Civica di Udine, MS. 1029, f. 294.
[20] CANTERZANI (1779), p. 19.

X. Physics of vegetables and animals,
XI. Physics of fossils,
XII. History of Physics.

As can be noted, electricity was considered by Canterzani to be only a part of physics. Its boundaries were yet to be fixed but it was separate from mechanical physics and chemical physics. The distinction was not made, as one might think, for didactic purposes. The headings under which Canterzani divided physics had to follow different principles and therefore different forms of theory. Giordano Riccati, thirty years previously, had concluded expressing faith in mathematics and in its ability to take upon itself every aspect of reality:

> Only now, everywhere here in Italy, are experiments being performed with the electrical forces. Let those who are not geometers explain things by miracles. It can be said with certainty that the electrical matter is light and that the marvellous effects experienced are dependent on the artifice of condensing it in the bodies we want to electrify, preventing it from spreading to other neighbouring bodies like the floor and through that to the whole house, because, with such spreading, the electrical matter would be so thinned out as to produce no visible effect. Moreover, it can be observed that electrical matter first attracts then repels certain light bodies, gold leaf, for example. This phenomenon was noted in minute detail, particularly the curve traced by the gold leaf as it was attracted and repelled. It is up to geometricians to work out the rule governing such forces of attraction and repulsion. From the pattern of iron filings around a magnet, Count Jacob, my father, deduced that the magnet's power of attraction follows the inverse quadruplicate proportion of the distance.[21]

Riccati also widened the confines of physics, though for him it was mathematics that benefited from the situation:

> Let us make anatomy and medicine come after physics, given that they are after all only different parts of that physics. The aim of anatomy as a science is to understand the marvellous structure of living bodies, especially of animals. This is where mathematics is needed. What has elucidated the highly perfect structure of the eye, if not dioptrics? Gianalfonso Borelli's treatise on animal movement will be famous forever. Messrs. Giovanni Bernoulli and Marchese Poleni have treated of the expansion and strength of muscles.[22]

Giordano Riccati's mathematism was followed by Canterzani's empirical pragmatism. What, if anything, is surprising is that both currents stemmed from the same motivation. The scientific status of physics was uncertain, as was the range of phenomena covered by physics. Neither in Riccati nor in Canterzani was there any further trace of the Aristotelian concept of physics as a theoretical science, the science that dealt with a particular type of being, one which had within itself the principle of movement and stillness.[23]

[21] Biblioteca Civica di Udine, MS. 1029, ff. 294-5.
[22] *Ibid.*, f. 295.
[23] See *Metaph.*, 1025b.

Research into electrical phenomena in Italy was performed against this background of non-unified conceptions of physics and of uncertainty as to its frontiers with mathematics and its encounters with vegetable and animal life. Between 1790 and 1792 three different theories came into being in Italy: Luigi Galvani's on animal electricity, Alessandro Volta's on heterogeneous contact, and Giovanni Fabbroni's on the chemical action which should precede the electrical.

I do not intend here to investigate the historical development of all these theories, which overlapped and conflicted with each other for much of the nineteenth century. Neither shall I consider the interpretations advanced by philosophers of science on the opposition between rival theories. The present view reflects Kuhn's ideas that two contrasting scientific models become incommensurable. I shall merely observe that it has been preferable to simplify the controversy between Galvani and Volta – which is entirely permissible – crystallising the opposing explanations and reducing them to two: animal electricity, which for Galvani is *unbalanced naturally* and for Volta *unbalanced artificially*.[24]

So, as already mentioned, it is precisely the contrast between natural and artificial which is the main axis of the *Cyclopaedia*'s classification system, going back to Aristotle's distinction between science and art. For the Galvani-Volta dispute, instead of referring to the metaphor of "concealed metaphysics", it is probably more useful to reflect on the eighteenth-century situation, just outlined, of classifying disciplines.

In this framework, physical science has two connotations: as knowledge of the general properties of bodies as such, and as knowledge of their specific properties. This dualism seemed to run parallel with the natural-artificial contrast, even though there was no evident correspondence between these distinctions. Since different cognitive values were given to the natural and the artificial, in the eighteenth-century classification of subjects, it was possible to consider as natural sometimes what was specific and at other times what was general. Consequently, there were various ways of defining the areas to which natural phenomena belonged.

In the *Prodromo della Nuova Enciclopedia Italiana* it is the tension between mathematics and physics which is raised. Physics refers to mathematics every time it can use a general demonstration method. Otherwise it sticks to the particular, such as the physics of plants and animals.

In the first of his *Memoirs on Animal Electricity* (1797) Galvani, referring to Volta, wrote "he wants this electricity to be the same as that common to all other bodies; I consider it particular and proper to the animal".[25] Galvani seemed here to be repeating the view prevailing in the *Istituto* and the *Accademia delle Scienze* of Bologna. But he immediately added that, as regarded the reason for electrical imbalance, Volta "established that the cause was accidental and extrinsic; I, natural and internal".[26]

[24] See PERA (1986), p. XVII.
[25] GALVANI (1797), p. 303.
[26] *Ibid*., p. 304.

Galvani's use of the terms "common", "particular", "accidental" and "natural" suggests curious intertwinings. Evidently these terms relate to each other indicating cognitive values. Electricity "common to all bodies" meant for Galvani that it was also "accidental" or "artificial". On the other hand, "particular" meant "proper" and "natural".

The dispute therefore concerned what distinguished the "natural" from the "artificial" and, for Galvani, the former should be given cognitive prominence. The object of physical knowledge was, at one time, natural, particular and proper, whereas what was common but accidental was a product of art, i.e. artificial, and could have no theoretical value.

This explains why the dispute could not be settled by compromise. For Galvani, physics concerned mainly what was natural, particular, and proper. Galvani's view echoed – and this was hardly by chance – the ideas on which encyclopaedic classifications were based. In his syllabus for the Physics Class, Canterzani had underlined the distinction which was also in the *Encyclopédie*:

> They normally divide Physics into general and particular. The former concerns bodies in general and their primary qualities; the latter goes down to specific bodies which exist in the world, reduces them to certain classes and examines their nature.[27]

To deal with qualities common to all bodies, their primary qualities, meant referring to their essence, as Descartes had shown. This type of knowledge could not be obtained through art, which has to do with accidental causes. Then with particular bodies it was a case of underlining the specific nature of the phenomenon being studied. Also in this case mere generalisation of the results artificially obtained could not be given theoretical value.

Volta's defence of artificial electricity, excited by external motors, acquired for him the value of an epistemological choice. Volta chose to give theoretical value to the results obtained artificially. An artificial object, like the battery, became an instrument for establishing a theoretical principle: that of the contact between conductors. But the battery (in the same way as the telescope for Galileo or the pneumatic machine for Boyle) became a machine for knowing that the old distinctions between disciplines, presented as the "modern way of thinking" by Canterzani,[28] but which really went back to Aristotle, were set aside together with the distinction in cognitive value between natural and artificial.

In this sense, Volta's work, whether intentionally or not, helped give physics some status. This status provided the language of experiments with authority and autonomy which it had not had until then, as it had been considered devoid of firm demonstrative methods.

[27] CANTERZANI (1779), p. 17.
[28] *Ibid.*

BIBLIOGRAPHY

ACCADEMIA DELLE SCIENZE DELL'ISTITUTO DI BOLOGNA ed. (1841-42), *Opere edite ed inedite del professore Luigi Galvani*, Bologna: Tipografia di Emidio Dall'Olmo, 1841-42.

CANTERZANI, SEBASTIANO (1779), "Piano della Classe Fisica", in ZORZI et al. (1779), pp. 17-22.

FARINELLA, CALOGERO (1996), "Le traduzioni italiane della *Cyclopaedia* di Ephraim Chambers", *Studi Settecenteschi*, 16 (1996), pp. 97-160.

GALVANI, LUIGI (1797), "Memorie sull'elettricità animale al celebre abate Lazzaro Spallanzani" [1797], in ACCADEMIA DELLE SCIENZE DELL'ISTITUTO DI BOLOGNA ed. (1841-42), 2nd part, pp. 229-434.

INGEGNO, ALFONSO (1989), "Tra teologia e lumi: L'Enciclopedia di A. Zorzi", in PRODROMO (1989), pp. 19-27.

MAMIANI, MAURIZIO (1983), *La mappa del sapere: La classificazione delle scienze nella Cyclopaedia di E. Chambers*, Milano: Franco Angeli, 1983.

ID. (1998), "La rivoluzione incompiuta: I confini tra matematica e fisica da Newton a d'Alembert", in SANTUCCI ed. (1998), pp. 39-48.

PERA, MARCELLO (1986), *La rana ambigua: La controversia sull'elettricità animale tra Galvani e Volta*, Torino: G. Einaudi, 1986.

PRODROMO (1989), *Prodromo della Nuova Enciclopedia Italiana*, Siena: Monte dei Paschi di Siena, 1989 [with text by Catoni, Giuliano and Ingegno, Alfonso and Spallanzani, Mariafranca; contains facsimile of ZORZI et al. (1779)].

SANTUCCI, ANTONIO ed. (1998), *L'età dei Lumi: Saggi sulla cultura settecentesca*, Bologna: Il Mulino, 1998.

SPALLANZANI, MARIAFRANCA (1989), "Un mappamondo scientifico", in PRODROMO (1989), pp. 29-46.

TAGLIANINI, SILVANA (1987), "Chymica", in TEGA ed. (1987), pp. 87-121.

TEGA, WALTER ed. (1986-87), *Anatomie accademiche*, Bologna: Il Mulino, 1986-87, 3 parts.

ID. ed. (1987), *L'enciclopedia scientifica dell'Accademia delle scienze di Bologna*, 2nd part of TEGA ed. (1986-87).

ZORZI, ALESSANDRO et al. (1779), *Prodromo della Nuova Enciclopedia Italiana*, Siena: Vincenzo Pazzini Carli e figli e Luigi e Benedetto Bindi, 1779.

ZORZI, ALESSANDRO (1779), "Piano Generale dell'Opera", in ZORZI et al. (1779), pp. XI-XXII.