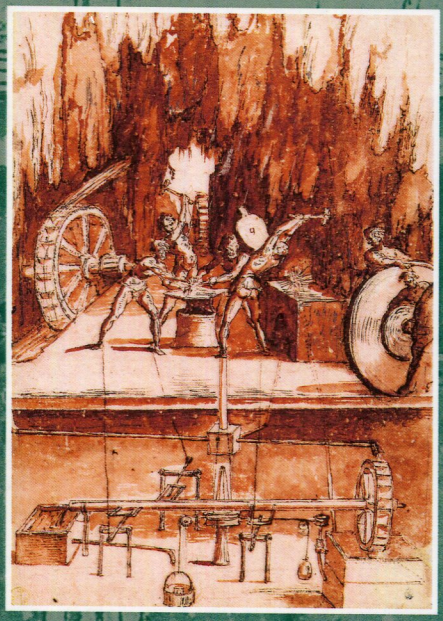
PATRIZIO BARBIERI

HYDRAULIC MUSICAL AUTOMATA



IN ITALIAN VILLAS AND OTHER *INGENIA* 1400-2000

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Musical Instrument History

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Patrizio Barbieri

Hydraulic Musical Automata in Italian Villas and Other *Ingenia* 1400-2000

GANGEMI EDITORE
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Contents

Preface

Scope and structure of the volume

In the past few years, there has been a notable reawakening of interest in the hydraulic musical automata installed, from the Late Renaissance onwards, in the gardens of noble mansions, first in Italy and subsequently in other European nations. This is evidenced by the recent monograph in German by Alexander Ditsche (2017, the first published on the subject), and the equally recent restorations-reconstructions of two Italian water organs (Rome, Quirinal Gardens, 1995; Tivoli, Villa d'Este, 2003) and another at Seville (Real Alcázar, 2006). Specifically, this volume aims at documenting the evolution of such automata, together with other kinds of *ingenia*, in Italy, placing them in their European context and investigating both their mechanism and their symbolism. The volume comprises 17 chapters, based partly on articles already published by the Author (mostly in Italian), and partly on new lines of research. The titles of the said articles, which have appeared between 1981 and 2007, are listed in the Section of "Works cited". They have all however been revised, restructured, expanded (in some cases radically) and – those in Italian – translated.

With regard to the overall organization of the book, it may be considered ideally divided into two parts. The first, comprising ten chapters, deals with water organs (including the musical compositions with which they were provided) and with a few automata in some way derived from those of Hero of Alexandria, such as the Faun and the nymph Echo, the Fountain of the Owl, the androids of the Farnese court, those left to us by Giovanni Battista Aleotti in his *Spiritali* and other manuscripts, as well as the hydraulic imitation of the explosion of the Catherine Wheel. Furthermore, the various systems producing the pressurised air needed for their operation are examined from the technical-scientific point of view, and we shall see that they were shortly afterwards adopted in the industrial field, in forges and melting furnaces. The seven chapters of the second part, on the other hand, deal with other sorts of *ingenia*, which – unlike water organs – are not always hydraulically activated or have programmable functions. Such devices include fountains and statues provided with curious acoustic effects, as well as sounding automatisms activated by thermal energy (as, for example, sunlight) or by counter-weights. To these are added those once included in the Roman museum of Athanasius Kircher, those produced for the Imperial Court at Peking (including an ingenious harpsichord-organ-viol invented by Kircher), several reconstructions of Vulcan's forge and the creation of various sounding monsters, once very fashionable. It closes with Michele Todini's "Galleria armonica" and with a special type of hydraulis built in Naples during the Late Renaissance.

Each chapter is preceded by a brief summary of the subject matter, and – when necessary – by a final conclusion, recapitulating the results achieved. For the reader desirous of more concise information, the following is a short abstract of the content of each chapter.

Hydraulic automata in Italian villas

Chapter A deals in detail with devices producing the pressurised air needed to feed the instruments. Until the Late Renaissance, we find solely the feed type already indicated in

Chapter A

Technical evolution of the 'aeolian chamber' for water organs and metalworks

A water organ is a musical instrument in which water alone produces (1) pressurised air to feed the pipes and (2) the driving force to rotate the barrel, i.e. the pinned cylinder that activates the instrument's pallets and enables it to perform the desired composition.

This chapter deals only with the structure and development of devices relating to point (1), i.e. to the production of pressurised air. We shall see that they were also employed in the industrial sector, especially for metalworking. Such devices can be divided into the following two types.

1. *Compression type*. Entering a particular chamber, the water progressively compresses the air it contains which, being higher than atmospheric pressure, emerges naturally through a dedicated pipe into the organ's pallet box. In order to ensure continuous air feed, such devices included a pair of chambers, functioning alternately. Early evidence of this latter solution goes back to the 9th century, and concerns an automatic flute designed by the Banū Mūsā brothers, who worked at Baghdad. It was also applied in the industrial sector to produce the air flow needed by smelting kilns and forges. The first certain evidence of this is much later, however, and dates to 1589, with reference to the Nettuno plant, near Rome.

2. *Emulsion type*. The practical realisation of the compression-type device was very complicated: its sole advantage was that it would work even without an adequate head of water. Much simpler and more functional, on the other hand, was a blower invented centuries later, which we shall call 'emulsion type'. This device was universally adopted for water organs starting at least from the Renaissance and, from the mid-17th century up to the mid-19th, by almost all the metalworks located in Italy, the Alps and Pyrenees. In this case, the water fell through a downpipe several metres long, at the top of which an appropriate device mixed it with air. The emulsion was collected in a container (which Athanasius Kircher styles an 'aeolian chamber'), in which the pressurised air is naturally separated from the water and is conveyed to the user, which in this case could also be an organ, the ventilation system of a mine, or the various pieces of equipment at a metalworks. Its first historically documented practical use is on the automatic water organ at Villa d'Este (Tivoli, 1567-72), by a fountain-maker who came for the purpose from an undisclosed location somewhere in France. The earliest information about its application in the metal production and processing sector, on the other hand, goes back to 1629, again in the Roman area, where further testimony leads to the conclusion that it became widespread in other regions.

In 1958, in a well-documented article on the employment of such devices in the metalwork sector, Bruno Boni mentions numerous unanswered questions concerning the date of the first appearance of these hydro-aeolian blowers, with the hope that further light might one day be cast by research on their employment in the field of music.[1] In the light of this prophetic hope, it is curious to ascertain that an invention which had for centuries such an important impact in the industrial – and hence socio-economic – sector, had unexpectedly been triggered by a simple toy invented for the amusement of wealthy aristocrats, who used it to increase the amenities of the gardens of their sumptuous mansions.

Chapter B

Hydro-aeolian blowers: early proposals for a quantitative theory and technical data

At a purely qualitative level, in Section A.2 we saw that the first correct explanation of the phenomenon on which the hydro-aeolian blower is based had appeared in 1601, in the *Pneumaticorum libri tres* by Giovanni Battista Della Porta. After this, two centuries passed before other researchers went on to seek – a far more complex matter – a quantitative theory concerning their air flow rate, to which this chapter is devoted. Together with the air flow rate will be provided technical data from existing 19th century plants.

The subject matter is divided into the following four sections:

B.1. 17th-century hypotheses

B.2. 18th-century theoretical developments: Giovanni Battista Venturi (1797)

B.3. Theoretical quantification of the air-flow rate: Jean-François d'Aubuisson (1815-1834)

B.4. Experimental data

B.1. 17th-century hypotheses

In Section A.2 we saw that, as early as 1601, Della Porta had ascertained that the air provided by emulsion-type hydro-aeolian blowers was drawn from outside by the mixing device located on top of them. The same conclusion appears in Athanasius Kircher's *Magnes*, published in 1641 (Section A.3.1). Nine years later, in his *Musurgia universalis*, Kircher inserted an illustration showing an aeolian chamber for an organ, in which however he forgot to show the mentioned air-water mixing device (Fig. A.2.8/*Fig. I* above; see also Fig. G.2.1 below): it was this very illustration, which had become famous due to the popularity of the treatise, that raised questions as to the real provenance of the air provided by this device. It was on this basis that Robert Boyle – in 1660, two years before formulating his famous law on ideal gases which bears his name – asked himself the same question; rejecting the hypothesis that it was the same air that was naturally dissolved in the water, since it would clearly be insufficient to feed an organ, he suggested that it was the same water, nebulised to the point of becoming vapour: "motion alone, if vehement enough, may, without sensible heat, suffice to break water into very minute parts, and make them ascend upwards".[1] Two years earlier, the Jesuit *fisico-matematico* Francesco Eschinardi (1623-1703) – in his *Microcosmi physicomathematici*, also with regard to Kircher's famous illustration – had asked himself the same question and had come to the same conclusion:[2]

[1] Boyle 1660, 217-8 ("Experiment 22").

[2] Eschinardi 1658, 80. A rather risky affirmation, recalling the already obsolete Aristotelean theory of 'rarefaction', postulating that water is transformed into air by means of heat: see Section L.3, fn 27. Robert Boyle, on the other hand, avoided this misunderstanding: in *New experiments*, mentioned above, he states clearly that water may fragment into the tiniest particles, without transforming itself into air (Reti 1956, 38).

Chapter C

Villa d'Este, Tivoli: the prototype of late-Renaissance European water organs

The present chapter aims to examine documentary evidence concerning the water organ at the "Fontana dell'organo", which recently aroused lively interest owing to its 1998-2003 reconstruction.[1] Its importance lies more particularly in the fact that – together with the automata of the Heronian 'Fontana della Civetta', also located at the Villa – during the late Renaissance it led to the creation of similar works at other princely mansions in the whole of Europe. This latter subject will be dealt with in Sections D.2-3-4 below, while Section D.1 will seek to cast a little light on the origin, still rather nebulous, and the motives of this innovation in the design of gardens.

It should be observed however that, unfortunately, the archival documentation for all the fountains of the villa is particularly scarce and fragmentary. Even the published evidence left by travellers on the 'Grand Tour', who through the centuries visited the villa, is as a rule lacking in details of a technical nature. An attempt will be made, however, to collate with care the surviving sources, so as to reconstruct the history of the said automata as far as possible. On a practical level, a few rare facts have also emerged from on-the-spot surveys during the said works for the reconstruction of the organ.

The subject matter is divided into the following four sections:

C.1. The Este's music patronage and the automata at Tivoli
C.2. The first version of Tivoli's water organ, the work of two French *fontanieri* (1567-71)
C.3. The *Fontana del Diluvio*, later *dell'Organo*: chronology of historical developments
C.4. Conclusion: the 'music of the waters' and the *inganni*

C.1. The Este's music patronage and the automata at Tivoli

C.1.1. The Este's music patronage: an outline

The House of Este was renowned for its propensity to experiment in the musical field, especially with regard to the construction of new instruments. Cardinal Ippolito II (1509-1572), in particular, was highly susceptible to the fascination of instruments belonging to the ancient Greeks and Romans. Not only did he provide his Villa at Tivoli with the first hydraulic musical

[1] The general restoration works of the Villa, directed by Isabella Barisi, were performed also thanks to the new archival documents provided by the Centro Studi sulla Cultura e l'Immagine di Roma (Marcello Fagiolo and Maria Luisa Madonna). As far as the automata are concerned, June 2003 saw the inauguration of the restoration-reconstruction of the "Civetta" (Owl) and the "Fontana dell'organo", by the organ-maker Rodney Briscoe (at Diss, Norfolk, England): see Chapter E below. The fame of the Tivoli automata rose to European level as soon as they had been built: for the first time described by Michel de Montaigne in his *Journal de voyage* (1580-81), they were subsequently cited as examples in numerous printed works, including the dictionary by Covarrubias Orozco 1611, f. 570v.

Chapter D

Automata evolution, before and after Villa d'Este

In Section C.1.2 we mentioned the enigma of the sudden appearance, in 1567-71, of hydraulic musical automata in the gardens of an Italian villa, the one belonging to Cardinal Ippolito II d'Este, at Tivoli. To help dispel the thick fog that still covers the background of these achievements, this chapter gathers testimonies concerning the presence of automata in the Western world prior to the fateful year 1567. We shall then analyse evidence regarding the impact of these automata, together with the ones created immediately afterwards at the Medici residences at Pratolino and Florence, throughout Italy, including the Kingdom of Naples, and in other European countries.

The subject matter will be divided into the following seven sections:

D.1. Early Western World *ingenia*

In the previous chapter we saw that the construction of the water organ at Villa d'Este was entrusted to two French fountain designers and makers. The fact that Cardinal Ippolito II had recourse to foreign workmen was not however due solely to his already-mentioned close political ties with France. Indeed, in this section we shall see that in the Western World – after the pioneering proposals of Hero of Alexandria, presumably in the 1st century CE, and the radical developments by the Arabs several centuries later – the first realisations of automatic mechanisms are reported from France, starting from the 13th century.[1] It should be said however that the question of the first appearance of automatisms in the Western World is still far from settled. Here we shall merely provide a rapid summary aimed at contextualising the history of the Tivoli water organ.

It should first be noted that, although sounding automata are documented at least starting from the 1st century CE, none has so far appeared among the furnishings of the mansions and gardens of Ancient Rome. Only in the Eastern Roman Empire, in the throne-room at Constantinople, in

[1] A similar motivation has already been suggested by Coffin 1991, 55.

Chapter E

The new water organ at the Villa d'Este, Tivoli, 1999-2003

Chapter C described the vicissitudes of the Villa d'Este water organ: at the end of the 20th century, there remained only the masonry structures relating to the makeover at the beginning of the 17th century, under Cardinal Alessandro d'Este. In 1999, after a general restoration of the villa, the director of the same – the architect Isabella Barisi – planned the construction of a totally new instrument, inspired by the conventions for such organs in the Roman late Renaissance, in the same place as the former one: the *Fontana dell'organo*. The new instrument, together with the related automatism, was built by Rodney Briscoe (in Diss, Norfolk, England), with the assistance of Leonardo Lombardi (a Roman specialist in hydraulic archaeology, who also directed the works) and Patrizio Barbieri. It was inaugurated on 18 June 2003, in the presence of the Minister of Cultural Affairs, Sandro Urbani.[1]

The aim of this chapter is to illustrate the various stages of this intervention, with the addition of an appendix illustrating the various causes, historically mentioned, for the deterioration of such instruments and their far shorter lifespan than ordinary organs. Technical data will also be provided on the reconstruction of the water organ at Granada (Spain), also made by Rodney Briscoe: this is the third instrument of its kind to be rebuilt in modern times.

The subject matter will be divided into the following five Sections:

E.1. Design criteria for the new instrument
E.2. Measurements of the reverberation time of the *tempietto*
E.3. The new organ
E.4. Appendix 1: Historically documented technical problems with water organs
E.5. Appendix 2: The new water organ at the Real Alcàzar, Seville

E.1. Design criteria for the new instrument

A few decades ago, all that survived of the fountain was the masonry and decorations.[2] In the absence of specific documentary research, the major problem at the time concerned the original structure of the instrument.[3] Around 1985, the engineer Girolamo Bardi inspected

[1] The present chapter, beside notes taken during the works, is largely based on two articles that appeared immediately after its inauguration, in which the restoration is described in detail: Barbieri and Lombardi 2004; Barbieri 2004. See also Fagiolo and Madonna 2003 (this article, on p. 107, contains statements by Leonardo Lombardi, *La Fontana dell'Organo e gli automi musicali idraulici*).

[2] Limenta 1940, 140 states that in 1940 the "remains of a wind-chest" of the water organ were still on the site, but later sadly vanished.

[3] In this connexion, a hypothesis were published in Ord-Hume 1987, 2-13. On the subject, see also two letters by Antonio Latanza, again published in *Music & automata* n° 10 (September 1987) p. 120 and n° 11 (March 1988) pp. 175-76.

Chapter F

Hero's heritage: the 'Fountain of the Owl' and other automata for the Este family

For a water organ of the kind built at Villa d'Este, examined in Chapter C, we would search in vain among the devices mentioned by Hero of Alexandria; its most ancient predecessor may be identified in the automatic flute of the Banū Mūsā brothers, one of the best-known automata designed during the Abbasid caliphate (758-1258). At Villa d'Este, on the other hand, as early as 1566, an authentic Heronian automaton was created: the 'Fountain of the Owl', with which we shall deal in this chapter; it was once more the work of Luc Leclerc, the builder of the water organ in the same villa. Authors describing it include Aleotti who, in one of his manuscripts, has left an unpublished solution for the mechanism activating the device. Inspired by the so-called 'Fontana della Civetta', Aleotti proposed to create, at Ferrara, a 'Fontana dell'Aquila', replacing the owl by this other bird of prey, indicated on the Este coat-of-arms. The novelty of Hero's mechanism lay particularly in the fact that, unlike the water organ, beside the sound effects it also included a moving figure. In the same manuscript, clearly taking inspiration from similar animated statues at the Medicean villa of Pratolino, Aleotti goes still further, proposing the creation of real "statues that play", provided with autonomous movement.

This subject matter will be dealt with in the following nine sections:

F.1. The Fountain of the Owl: its origin and meaning

Although the water organ examined in the previous chapters has nothing to do with the ancient Graeco-Roman hydraulos, this cannot be said of the "Civetta" (owl), whose movement is fully illustrated in Hero of Alexandria's *Pneumatica*. It is actually an elaboration of the well-known bird device already seen in Figs A.2.3 and A.2.11, also illustrated in Salomon de Caus's version, in which the chirping is provided by a pinned barrel (Fig. F.1.1).

Chapter G

The *organo ad acqua* in the Pontifical Quirinal Gardens, 1596-2013

An initial study on the *Fontana dell'organo* in the Quirinal gardens was published in 1961, focusing almost exclusively on the architectural structure of the large niche housing the organ and on the ornamental waterworks.[1] A second article on this complex appeared about twenty years later, this time focusing on the instrument and related archival documentation.[2] New data from on-the-spot surveys and fresh documentary research then emerged around 1990, at the time of the restoration of the instrument and the niche that houses it: this was the first thorough intervention after the radical remake-restoration under Gregory XVI in 1844, after which – also owing to the political events that saw Rome's annexation to the Kingdom of Italy – the instrument deteriorated progressively.[3]

In the present chapter, the main task is to provide an overview as complete as possible of historical and technical events concerning this water organ. Along the same lines as the 1981 article, construction details – corroborated by documentary evidence, which will be included in the text – will be given in chronological succession. In order to apprise the reader of the still unpublished archive material that has recently emerged, this will be provided in Section G.11. I am perfectly aware that all these details, while useful for any future restauration works, may disorientate the reader: by way of a partial apology, a rapid overview of the vicissitudes of the instrument can be found in Section G.10. Furthermore, the basic operational design – albeit already illustrated in Chapter A – will be summarised in Section G.2.

The text fully confirms the extreme vulnerability of automatic instruments of this kind, subject to the most challenging operating conditions, at a time, moreover, when technology had not reached its present level. As proof of this, it suffices to remember that, after the instrument was first built (in 1596, by Luca Biagi), the wind-chest alone – which continued to possess just 4-6 stops, limited to the pipe rows of the Ripieno and a Flauto – was subject to a series of interventions with a frequency decidedly higher than for ordinary organs at that time. Indeed, this occurred in 1647-48 (a complete remake, directed by Athanasius Kircher), 1704, 1728 (complete remake), 1732, 1742, 1779, 1833, 1844 (complete remake). The remakes in 1728 and 1844 were unknown until now, the former being the only one to provide us with a complete list of stops and the instrument's sound texture. The new documents related to the radical intervention in 1844, on the other hand, are important owing to the great detail provided in describing the new pinning of the barrel – another weak point of these automata, owing especially to the poor durability of the solderings fixing the pins to the copper sheet of the barrel – and the regulation of the hydraulic motor that activated its turning.

[1] Salerno 1961.
[2] Barbieri 1981
[3] Latanza 1995.

Chapter H

The *statue che suonano* at Villa Aldobrandini, Frascati: Mount Parnassus, Cyclops, and Centaur

The automatic hydraulic devices dealt with in this chapter are three in all, built in 1617-19 and housed at Villa Aldobrandini, Frascati: Mount Parnassus, Cyclops, and Centaur. Initially belonging to the Aldobrandini family, for whom the automatisms were created, in 1683 the villa passed to the Pamphlilj family, who owned it up to 1769.[1] After several previous maintenance operations, in 1759 all these automatic devices were radically restored, the task entrusted to Celestino Testa, the same organ-maker who was responsible for the final works on the Faun, a similar automaton, also made for the Pamphilj family – and again in 1759 – at another of their residences: Villa Belrespiro, in Rome (as we shall see in Chapter I below).

Such devices represent a development over previous Roman water organs – the ones at Villa d'Este and the Quirinal, already examined above –, since all three are connected to statues portrayed in the act of playing a musical instrument, statues that – uniquely – are located in a *Teatro*, i.e. an *esedra*, a semicircular architectural display.[2]

On-the-spot inspections show no trace of any of the automatisms connected with the statues, so that the present reconstruction is based mainly on the abundant surviving original documents (almost entirely preserved in the Doria Pamphilj Archive) and on those few travellers' accounts deemed reliable. This material has been divided into seven sections:

H.1. General layout of the "Teatro delle acque"
H.2. The automatic devices of Frascati in the Renaissance context of *musica hydraulica*
H.3. The automatisms, up to 1758.
H.4. The radical reconstruction of 1759.
H.5. The Villa's decline
H.6. The music
H.7. Appendix: archival documents

Further abbreviation:
Doc. = Document, followed by related serial number, cited in Section H.7.

Weights & Measures:
When cited in the text of the article, the original units of measurement found in the documents have been converted into present-day metric values.[3]

[1] D'Onofrio 1963, 150.
[2] Also the great *esedra* (semicircle) in the "Giardino del Teatro" at Villa Pamphilj was "inspired, even in its architectural details, by the one at Villa Aldobrandini at Frascati": Schiavo 1942, 95, 101.
[3] On the basis of the *Tavole di ragguaglio dei pesi e delle misure* 1877, 625-8 ("Circondario di Roma"): Canna architettonica [architectural rod] = 10 palmi romani [Roman spans] = 120 once [inches] = 2.234218 m; Libbra romana [Roman pound] = 12 once [ounces] = 0.339072 kg.

Chapter I

The myth of Faun and the nymph Echo: a mid-18th century revival at Villa Pamphilj, Rome

In Chapter H we have already described three hydraulic devices – Mount Parnassus, Cyclops, and Centaur – created in 1617-19 at Villa Aldobrandini at Frascati, known as il Belvedere. In 1683 the villa changed hands to the Pamphilj, who owned it until 1769 and, in 1759, undertook a radical restoration of all those devices. In those same years (1758-60) the Pamphilj also created – at their Roman villa at Porta San Pancrazio, known as the Belrespiro – another automaton, the Faun, which may be deemed an epigone of the Frascati Cyclops, since it was also portrayed in the act of playing the pan-pipes (so that it is sometimes also called "Dio Pan"). Furthermore, it was accompanied by an 'echo organ', to render the device similar to that of the God Pan and the nymph Echo, described, in the first half of the 17th century, by the French engineer Salomon de Caus and by Athanasius Kircher, authors who were in turn inspired by another then-famous automatism of the same name at the Medici villa of Pratolino. The final stages of creating the Faun were entrusted to Celestino Testa, the same organ-maker who was responsible, in those very same years, for the restoration of the Frascati devices.

As we have already seen, for the latter, on-the-spot inspections show that no trace remains of any of the automatisms once connected with the statue, so that the present reconstruction of events is based mainly on the abundant surviving documents (almost entirely preserved in the Doria Pamphilj Archive) and on those few travellers' accounts deemed reliable.

This material has been divided into five sections:

I.1. The idea of a water organ provided with an 'echo'
I.2. The Faun: features of its construction
I.3. The three tormented construction phases
I.4. Appendix: archival documents

Further abbreviations:

Doc. = Document, followed by related serial number, cited in Section I.4.
Ben. = Document published by Benocci 1988.

Weights & Measures: When cited in the text of the article, the original units of measurement found in the documents have been converted into present-day metric values.[1]

[1] On the basis of the *Tavole di ragguaglio dei pesi e delle misure* 1877, 625-8 ("Circondario di Roma"): Canna architettonica [architectural rod] = 10 palmi romani [Roman spans] = 120 once =2.234218 m; Libbra romana [Roman pound] = 12 once [ounces] = 0.339072 kg.

Chapter J

The androids of the Farnese court and other *ingenia* devised by Jean Baillou, alias Giovanni Baillioni

After providing brief documentary information about the hydraulic musical automata designed for the Farnese Court at Parma around 1619, the rest of this chapter is devoted to the automata made by Jean Baillou about a century later for the same Court and, as documents will prove, for the Villa Visconti-Borromeo at Lainate. Also known as Giovanni Bailleul or Giovanni Baillioni, his multi-facetted activities, carried out mostly in Italy from 1712 to 1745, have only recently been adequately reconstructed and assessed from a historical point of view. Engineer, physicist and naturalist – he is largely known nowadays for an important collection of his, with which he founded what would later become the Natural History Museum in Vienna –, he was also an ingenious and innovative constructor of musical automata, some of which were hydraulic.

The subject matter is divided into the following four sections:

J.1. A water organ "from Nuremberg" for the Farnese Royal Palace at Parma (1619)
J.2. Jean Baillou's "Grotta incantata" at the Farnese Summer Palace, Colorno (1718-24)
J.3. On the multi-facetted activities of Chevalier Jean Baillou (1683/4-1758)
J.4. The hydraulically-operated *corni da caccia* at the Lainate's Villa Visconti-Borromeo, and other barrel organs at Milan

J.1. A water organ "from Nuremberg" for the Farnese Royal Palace at Parma (1619)

In this section, we will deal with the fountain and related "grotta" of the "Palazzo del Giardino", remodelled in 1611-19, of the Farnese palace at Parma. About this item, we have an interesting contract dated 28 September 1619, envisaging the installation – by a fountain specialist from Innsbruck – of four figures simulating the performance of a "musical motet", besides a water-driven "organino" from Nuremberg and sundry musical devices, imitating the sounds of trumpets, flutes, birds and other unspecified animals:[1]

[1] ASP, *Raccolta storica*, b. 18, fasc. "Fontana del Giardino", at that date (n° 470). The shelf-mark of the said document, together with a summary description of its contents, had already been indicated in Adorni 1990, 519. I wish to thank Marzio Dall'Acqua (ASP) and Christine Streubühr (Istituto Storico Germanico, Rome) for their help during this research.

Chapter K

The *Giardino matematico*: new proposals for *fontane armoniche* and statues based on ingenious acoustical effects

The gardens examined in this chapter contain fountains that may be defined as 'harmonic', since their waters played an unusual musical role. Indeed, instead of falling into an aeolian chamber and thus generating pressurised air to feed organ pipes, they fell into a set of special containers which – excited by the noise produced – started resonating on the note to which they were tuned.

Such a proposal had already been made in 1503-04, in a rapid note by Leonardo da Vinci, but its interpretation is not completely devoid of questions. This specific and unusual employment of water is however fully confirmed by the documentation on two other Italian fountains, only a few decades later than the one sketched by Leonardo. In the following century, as a result of the progress of the Scientific Revolution, a Jesuit *fisico-matematico*, Mario Bettini, proposed yet another application of the same principle for a fountain to be included in what Filippo Camerota defined as a *giardino matematico*, a garden based on *mirabilia* differing from those of Mannerism. For this purpose, another *fisico-matematico,* Father Emanuel Maignan, also proposed statues with surprising acoustical performances.

Several new devices based on sounds 'extracted' from the noise of a moving fluid, such as water and air, have also been designed and created – together with a prototype of Leonardo's fountain – in recent times.

The subject matter will be divided into the following four sections:

K.1. A proposal for an 'Echo' statue and other acoustical *ingenia* for Villa Pamphilj, Rome (1644-45)

In addition to what we have seen in Chapter I, a curious device proposed by Emanuel Maignan about a century earlier, again for Villa Pamphilj, is worth mentioning. Although dying at his hometown of Toulouse, between 1636 and 1650 Father Maignan taught philosophy and theology at the Convent of the Minims on the Pincian Hill in Rome. During this period, he came into contact with Athanasius Kircher and his interests were

Chapter L

Harpsichords and organs activated by sunlight: an attempt at a 4th class of musical automata

This chapter will first and foremost examine the classification of automata, based mainly on the writings of Hero of Alexandria, translated from the Greek by the Italian humanists (1570-90). One of the four categories of such devices – i.e. the one related to those activated by thermal energy, already duly considered by Hero – was only sporadically applied. As far as musical instruments are concerned, early experiments were made at the end of the 10th century, by Gerbert of Aurillac. Six centuries later, a new attempt in this regard was made in 1605-10 by the Dutch engineer Cornelis Drebbel, with his "virginal" activated by solar energy, built for James I of England, then followed by Salomon de Caus' theoretical proposals, again concerning such machines (1615-24). In 1653 Athanasius Kircher reported that he had successfully realized a device with a reed organ pipe (or a set of harp strings) activated, like the previous ones, by sunlight; a device improved, in 1686, by Francesco Lana Terzi.

The subject matter will be divided into the following four sections:

L.1. Humanist investigations during the age of Villa d'Este and Pratolino (1570-1590)

L.2. Machines operated "by fire": the *sufflator* and Gerbert's hydraulis

L.3. Organs and harpsichords activated by sunlight: Drebbel, de Caus, Kircher, and Lana Terzi

L.4. Conclusions

L.1. Humanist investigations during the age of Villa d'Este and Pratolino (1570-1590)

L.1.1. Hero's Machine Spiritali and Machine Semoventi combined: a late-Renaissance development

In the previous chapters we have seen that, in the sector of machinery, Hero of Alexandria left two important manuscripts: the *Pneumatica* and the *Automata*; both were translated from Greek and printed in the last quarter of the 16th century. The Latin version of the *Pneumatica* appeared in 1575, the work of the mathematician and humanist Federico Commandino (1509-1575), followed in 1589 by an Italian version by the architect and designer of automata Giambattista Aleotti (1546-1636), with several original additions of his own.[1] A pupil of Commandino's was the mathematician and humanist Bernardino Baldi

[1] Hero 1575; Hero 1589. To which we must add a further translation into Italian – also illustrated: that by Alessandro Giorgi: Hero 1592.

Chapter M

Magia artificialis in Kircher's museum

The famous *Musaeum* was originally set up at the Collegio Romano by Athanasius Kircher (1602-1680). Still presenting the *mirabilia* of the traditional model of *Wunderkammer*, it included items of various kinds, representing the principal categories according to which they were then classified: *artificialia*, *antiquaria*, *naturalia*, and *curiosa*.[1] Apart from these, visitors could also see a performance of several sounding automata, which will be analysed in this chapter and, partly, in the next.[2] They largely consisted of purely musical automatisms, such as organs, harpsichords (some also provided with fairly elementary small androids) and the famous Vulcan's forge (this will be examined in Section N.3). To these were added devices producing non-musical sound effects, such as various kinds of "monster" (then a still-popular theme) and the so-called "Oracle of Delphi", simulating the performance of the speaking statue of the same name in Ancient Greece.

As we shall see, such devices were destined above all to exploit the ingenuousness of the public, thus constituting what – from as early as the end of the previous century, as seen in Section L.1.2 – was labelled as "Magia humana", or later – by Kaspar Schott (1608-1666) – as "Magia artificialis". It was in this connexion that Caspar Schott, a co-religionist and pupil of Kircher's, in a work that appeared posthumously (1677) took care to state that such magic – together with what was known as "natural magic", i.e. produced by natural phenomena – was accepted by the Church as "good and allowed", in contrast to the "work of the devil", which was clearly "bad and prohibited" (see the myths concerning the transformation of men into beasts, statues that come to life, the creation of new individuals from nothing, etc.).[3]

These automata will also be examined from a chronological point of view, since the museum suffered ups and downs. Indeed, we shall see that – starting in about 1638, in Kircher's private apartment – already in 1652, as a result of a major donation, it had become so large that it was transferred to other premises in the Collegio Romano. This was followed by a period of decline that lasted until 1699, when it was officially reopened and, under the direction of the Jesuit Filippo Bonanni (1638-1723), extended with new acquisitions. In this permanent form it remained efficient for almost the whole century, only to fall into rapid and definitive decline.

The subject matter will be divided into the following three sections:

M.1. The musical automata

M.2. The spread of "horrible monsters"

M.3. The two versions of the *Oraculum Delphicum*

[1] On private collections in Rome and the development of museographic criteria, see: Sparti 1992, 67-82; Previdi 2017, 41-52.

[2] This analysis will mainly focus on the structural aspect and actual consistency of these sounding automata, during the various periods the museum went through. More generally speaking, on the derivation and conceptual basis of Kircher's various machines and *experimenta*, see: Camerota 2001; Gorman and Wilding 2001. On the "enigma of the musical instruments of the Kircheriano", now wholly lost, see too Previdi 2017, 75-86.

[3] Schott 1677, *Pars prima*, 18-53 ("De magiae universim sumptae divisionibus, ac praecipuè Naturalem, Artificialem, et Prohibitam"), and in particular 18-23.

Chapter N

Vulcan's forge

The present chapter will illustrate a special kind of automaton, inspired by a project first proposed by Giovanni Battista Aleotti in 1589: that of the forge where Vulcan works together with his three Cyclopes, forging the gods' weapons with hammers and anvil. At least six automata of this kind were constructed in Italy.

In Section J.2 we saw the elaborate version of it – inserted in a complex mythological drama – created by Jean Baillou in 1718-24, in the *Commedia muta* of the Farnese palace at Colorno, Parma. In the Grand Duchy of Florence, on the other hand, this myth became an auspice for the military glory of the famous House of Medici, and as many as two of these automata were created, in the gardens of Pratolino and of Palazzo Pitti respectively. Another two followed, both of a decidedly recreational character, at two villas in the Marche belonging to minor noble families: the Mosca (Caprile, Pesaro) and the Buonaccorsi (Porto Potenza Picena, Macerata) respectively. The sixth of these automata, doubtless the most famous in any absolute sense, is the one designed by Athanasius Kircher in 1650 and made in the early years of the following century to be placed in the "Gabinetto armonico" of his Museum, alongside other automata: in his original design, it was accompanied by 'Pythagorean Music' which he himself composed, since, in this case, the purpose of the automaton was to illustrate the legend of the 'hammers of Pythagoras', according to which the famous philosopher deduced the ratios of musical intervals from the sound emitted by smiths' hammers in forging their products on the anvil.

The subject matter is divided into the following three sections:

N.1. At the Medicean gardens
N.2. In other Italian mansions
N.3. In the Musaeum Kircherianum, Rome

N.1. At the Medicean gardens

The revival of the myth of Vulcan – symbol of fire and industry – in modern times was first manifest in the Grand Duchy of Florence, where Medicean engineers achieved the first automated versions of his legendary forge, located beneath Mount Aetna. In traditional iconology, Vulcan is portrayed as, with his three Cyclopes, he forges the thunderbolts of 'fulminating Jupiter' and the invincible arms of many gods and heroes, including Mars, Achilles and Aeneas.[1] In this connexion, in about 1564, the well-known painting by Giorgio Vasari, reproduced in Fig. N.1.1, appeared at the Medici Court, destined for the *Studiolo* in Palazzo Vecchio, commissioned by Cosimo I (1519-1574) and his son Francesco (1541-1587). The

[1] On the symbology associated with him, see Hall 1974, 338.

Chapter O

Some non-hydraulic musical automata: from Italy to China and Japan *c*1580-1780

This chapter will illustrate some automatic musical instruments – mostly non-water-powered – either sent to the missions in the Far East, or actually made there by European missionaries. Particular emphasis will be given to Italy, for which we shall also seek to document the effective diffusion of this particular class of automata.

In the work of evangelisation carried out by these missionaries – from the Portuguese base at Goa, on the west coast of India, it spread throughout the Far East – music played a considerable role. Indeed, from as early as 1553 it is reported that, at the masses celebrated in this diocese, the "canto de orgão" (meaning *musica concertata*, in opposition to the *canto llano*, i.e. plain chant) "greatly stimulated the people's devotion", natives included;[1] for this reason, all religious services saw wide use not only of the organ, but of all kinds of instrument, such as trumpets, bombardas, *charamellas* (i.e. schawms) and flutes.[2] This may initially seem surprising, in view of the Jesuits' reluctance to allow such music in their religious services ('Gesuita non cantat'). Not only was the organ greatly appreciated by the natives, however, but it was also of great use to them in learning to pitch the notes of the western musical scale; in 1576, this necessity induced Alessandro Valignano – a Jesuit recently appointed as "Visitatore generale" of the missions in the East Indies, as those of the Far East were then called – to grant officially, at the Goa college, that the organ could be taught, albeit only to young natives.[3] In 1584, as a result of this permit, Goa became a "cappella not inferior to Rome", provided with all kinds of musical instrument. In 1591 it was reported that, to the great indignation of several Jesuit fathers, the "Padre Provincial" had even allowed the mass to be celebrated using popular songs accompanied by "profane" instruments, such as guitars and citterns ("gitaras, céteras y otros semejantes").[4]

In such a context, including the liturgy, musical automata also played a major role. We will see that, as early as 1584 a small automatic keyboard instrument was sent to Japan by the above-mentioned Fr. Alessandro Valignano. In 1585, furthermore, a lively interest in this kind of instrument was shown by four young Japanese, officially invited to the Papal Court in Rome. In the Land of the Rising Sun, however, evangelisation activities were brought brusquely and

[1] See the letter by Alexius Dias, dated Armuzia, 24.9.1553, published in *Documenta Indica* 1948-, III (ed. Ioseph Wicki, 1954), 24: mass with "canto d'orgão, que faz muita devação à gente".

[2] See, e.g., letters by the Jesuit fathers: Gomes Vas, Goa, 12.12.1567, publ. in *Documenta Indica* 1948-, VII (ed. Ioseph Wicki, 1962), 398; Eduardus Leitão, Goa, 16.11.1570, in Id., VIII (1964), 334: mass and vespers with "canto d'organo, com charamelas, frautas e trombetas, e outros instrumentos musicos"; Gaspar Alvares, Cochin, 10.1.1580, in Id., XI (1970), 810-11, which mentions "frautas", "trombetas", "cameras de bombardas" and "espingardaria".

[3] *Documenta Indica* 1948-, X (ed. Ioseph Wicki, 1968), 622, on 3.11.1576. Albeit not officially, this permit had already been communicated to Rome by Valignano himself, in a letter dated 25.12.1574, sent from Goa, in which he states that he had decided to tolerate *canto figurato*, because the people liked it: *Documenta Indica* 1948-, IX (ed. Ioseph Wicki, 1966), 495.

[4] See the letter in which Fr. Nuno Rodrigues advises Fr. Claudio Acquaviva, General of the Company of Jesus, written at Goa on 3.12.1591: *Documenta Indica* 1948-, XV (eds Joseph Wicki and John Gomes, 1981), 721-2.

Chapter P

Michele Todini's *Galleria armonica*, Rome 1650-1868

In the previous chapters we have examined mechanisms controlled by programmable keyboards, i.e. real automata. In this chapter, however, we shall view mechanisms bringing together various kinds of commonly used musical instruments, controlled by a single manual keyboard. Such instruments consequently do not belong to the category of automata, but to the more general one of *ingenia* announced in the title of this volume.

Two such "harmonic machines" were designed and built in Rome by Michele Todini in the second half of the 17th century: the "greater machine", consisting of a large harpsichord that also activated a band of six other different instruments (spinet, *spinettone*, *tiorbino*, organ, violin and lyre) and the "machine of Polyphemus and Galatea", activating – by means of a keyboard and other controls of what is known today by the name of the "Golden Harpsichord" – an improved model of sordellina, i.e. a particular type of bagpipes. Todini also made two ingenious clocks, provided with a new kind of mechanism. All these *ingenia*, splendidly decorated, could be seen, on payment, at the "Galleria armonica" set up in his private apartment.

All that remains today of Michele Todini's work is the celebrated Golden Harpsichord in the Metropolitan Museum of New York and his *Dichiaratione della galleria armonica*, which he published in 1676. It was only after 1988 that the first documented details of his life began to emerge.[1]

The subject matter will be divided into the following eight sections, the first of which – to facilitate the reader by providing a general overview – contains a summary of what is then analytically documented in those following:

Further abbreviation:

T = Michele Todini, *Dichiaratione della galleria armonica eretta in Roma da Michele Todini Piemontese di Saluzzo, nella sua habitatione, posta all'Arco della Ciambella*, Roma, Francesco Tizzoni, 1676 (also reprint, with an "Introduzione" by P. Barbieri, Lucca, LIM, 1988).

[1] See: Todini 1676, "Introduzione" of the reprint 1988; Barbieri 1989, 202; Id. 2002.

Chapter Q

Giambattista Della Porta's 'singing' hydraulis according to Fabio Colonna's *Herone riformato*. With other expressive devices for the organ, *c*1560-1860

In the previous chapters we have described organs, whether hydraulic or not, activated automatically or manually, but belonging to complex mechanisms that also include other musical instruments. We shall now deal with several ingenious devices aimed at lessening the static nature of the organ's sound by endowing it with some of the expressive resources typically used by singers: these included dynamics, vibrato, *messa di voce*, and *portamento*. The earliest such efforts to be considered here date from the second half of the 16th century in Italy, and were based at least in part on increasing awareness of water-operated organs of the ancient world; as we have seen above, this was the period in which interest began to rekindle in the water organs of classical antiquity, following the first printed editions of the writings of Vitruvius and Hero of Alexandria on Greek and Roman organs.

We shall see that, as early as 1589, the Neapolitan scientist Giambattista Della Porta included in his most famous *Magia naturalis* a chapter bearing the title *De hydraulicis organis*, in which he proposes the construction of a device capable of making the Vitruvian hydraulis also produce "voices tremulous and pleasing", in certain aspects similar to the vibrato of modern singers. Twenty years later, the idea was taken up, without however citing the source, by the scientist Fabio Colonna, who was also Neapolitan. Now, not only does he provide accurate construction drawings, but also reports that he had built a small organ equipped with this device, which furthermore had the honour of being played by Giovanni de Macque, the organist of the Royal Chapel in Naples.

Other inventions and experiments dealt with in this connexion range from the late 17th to the mid-19th centuries, from a device invented by Claude Perrault in 1684 to the *Melodica* keyboard announced in 1772 by Johann Andreas Stein and, in the following century, to the invention of the *organo fonocromico* by Giambattista De Lorenzi. None of these new devices managed however to become a stable part of the structure of ordinary organs or to modify the static quality of their sound emissions. Attempts to make emissions 'expressive' and vocalic were later abandoned, since it was then accepted as a concept that the organ's sonority is static by nature.

The subject matter will be divided into the following four sections:

Q.1. The different employment of water between the Graeco-Roman hydraulis and the Renaissance water organ

Q.2. Della Porta's 'singing' hydraulis, as realised by Colonna

Q.3. Fabio Colonna's *Herone riformato*

Q.4. Later proposals for a 'singing' type of organ

In the past few years, a considerable re-awakening of interest has been noted in the hydraulic musical automata which, from the Late Renaissance onwards, were installed in the gardens of several noble families, first in Italy and subsequently in other European countries. The present volume aims at documenting the development of such automata, together with other kinds of *ingenia*, in Italy, setting them in their European context and investigating both mechanisms and their symbolism.
The volume may be deemed ideally divided into two parts. The first, comprising ten chapters, deals with water organs (including the musical compositions with which they were provided) and several automata of Heronian design, such as the Fountain of the Owl, the androids of the Farnese court, the hydraulic imitation of the explosion of the Catherine Wheel, and the one illustrating the myth of Faun and the nymph Echo. The various systems for producing the pressurised air needed for their operation are also analysed from a technical and scientific point of view, and we shall see that shortly afterwards they were also adopted in industry, for forges and melting furnaces. The seven last chapters of the volume, on the other hand, deal with *ingenia* of various kinds which, unlike the water organs, were not always hydraulically activated or had programmable functions. This is the case of fountains and statues provided with curious acoustic effects, as well as sounding automatisms activated by thermal energy (such as, for example, sunlight), or by counter-weights. To these are added those that once figured in the Roman museum of Athanasius Kircher, those constructed for the Imperial Court of Peking (including an ingenious harpsichord-organ-viol invented by Kircher), several reconstructions of Vulcan's forge and the creation of various sounding monsters, once very fashionable. The volume closes with Michele Todini's famous "Galleria armonica" and with a special type of hydraulis made in Naples in the Late Renaissance.

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