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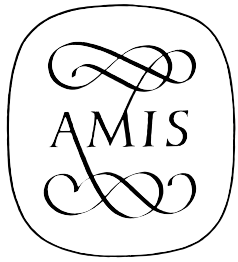

Giambattista Della Porta's "Singing" Hydraulis and Other Expressive Devices for the Organ, c. 1560–1860

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The present study describes a number of attempts to lessen 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, in addition to some specialized stops aiming to imitate the human voice, such as the regal called *Vox humana*. The earliest such efforts to be considered here date from the second half of the sixteenth century in Italy, and were based at least in part on increasing awareness of water-operated organs of the ancient world. Later inventions and experiments extended from the late seventeenth to the mid-nineteenth centuries, although none of these technical devices achieved general acceptance as part of the instrument's normal design and functioning.

The Organo hydraulico *of Porta and Colonna: A Historical Outline*

Among the consequences of the earliest printed critical editions of the work of the first-century writers Vitruvius and Hero of Alexandria, which appeared during the sixteenth century, should be included the rediscovery of the ancient hydraulis, the Greco-Roman organ whose air supply was pressurized by standing water. One version of this instrument, about which little is known, was proposed prior to 1589 by the Neapolitan scientist Giambattista Della Porta (1540–1615). A few years later his fellow countryman Fabio Colonna (1567–1640), without acknowledging Della Porta's proposal, provided an accurate description of a prototype of the very same instrument, which he had had built.[1] This device attempted not only to revive the ancient hydraulis, but also to imitate one

1. Both of these inventors became governing members of the Accademia dei Lincei, the first of the research societies founded as part of the movement we now know as the Scientific Revolution.

of the ornaments prescribed by the *canto di gorgia*, a style of singing codified in Naples itself by the physician and singer Giovanni Camillo Maffei in 1562 and still much in fashion at the turn of the century. The type of organ described by Porta and Colonna is important also because it indirectly confirms the advice of Ludovico Zacconi, in his *Prattica di musica* of 1592, that singers should adopt a kind of constant *tremolo* that in fact turns out to be a "trembling of voice" very close to a vibrato.

Greco-Roman and Renaissance organs using water. Medieval references to the hydraulis are rather vague, when not downright fanciful. Nothing precise is known, for example, about the "hydraulic organs" invented by the Venetian priest Georgius (Aachen, 826) or by the Benedictine abbot Gerbert (Rheims, 991–95).[2] In order to better understand the position of the Porta-Colonna innovation, it may be helpful to outline briefly the application of water to organs up through the sixteenth century.

The hydraulis was the true organ invented by Ctesibius, an Alexandrian engineer of the third century BCE. There are only two extant descriptions, both dating from several centuries later, one by Hero of Alexandria and the other by the Roman architect Vitruvius; the latter describes a version equipped with several stops rather than just one, as in Hero's instrument. Unlike the so-called water organ (see below), this instrument was played manually, and its winding was not directly provided by bellows at operating pressure, being introduced instead by one or two pumps into a chamber in which the rising water level provided the necessary pressure for sounding the pipes. The operation of this device can be clearly deduced from figure 1, which illustrates the example described by Vitruvius.[3] From this we can infer that the air pressure was not constant, the difference of water level depending on the balance between the input and output of air; but this fault was not too serious, since at that time the organ was probably played only melodically. The difference between the hydraulis and the bellows-driven organ of the Renaissance

2. Peter Williams, *The Organ in Western Culture 750–1250* (Cambridge: Cambridge University Press, 1993), 235–52.

3. On this subject see also George Ashdown Audsley, *The Art of Organ-Building* [. . .] (New York: Dodd *et al.*, 1905), 1:8–15; John G. Landels, *Music in Ancient Greece and Rome* (London & New York: Routledge, 1999), 267–70 (Appendix 2: "The construction of the water-organ [*hydraulis*]"); James W. McKinnon, "Hydraulis," *The New Grove Dictionary of Music and Musicians,* 2nd ed. (London: Macmillan, 2001), 12:10–14; and Barbara Owen and Peter Williams, "Organ," ibid., 18:583–85.

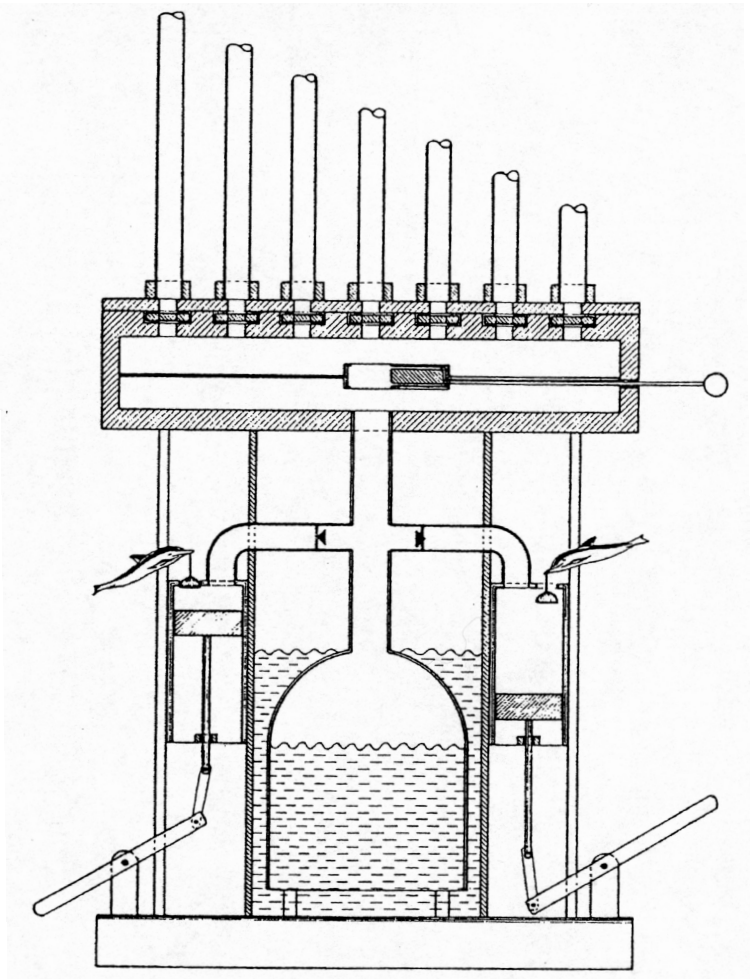

FIGURE 1. Reconstruction and operation of the hydraulis described by Vitruvius, from Friedrich Jacob, *L'organo* (Florence: Martello-Giunti, 1976), 13.
The wind feed is provided by two pumps probably driven alternately by hand. Each feeds two valves, which also open alternately and automatically: the one with the dolphin as counterweight allows air to be drawn in from outside, while the one on the windpipe lets air into the lower compartment of the wind chest. When it is pumped into the air chamber, the air displaces some of the water into the external cylindrical tank, and the water level difference thus created provides the operating pressure for the air in the air chamber. Each of the stops with which the wind chest is provided has a draw knob that opens a valve allowing the wind to pass from the lower common wind compartment to the overhead channel corresponding to the activated stop.

was not merely a matter of wind supply, however, but also involved the mechanism of the keys and the type of wind chest. Although by Della Porta's time the first serious philological investigations of early texts had already begun, there are no recorded attempts at any practical reconstruction of the hydraulis.[4]

The Renaissance version of the water organ has nothing to do with the hydraulis. It was surmounted by a pipe a few meters long, through which water was poured from a cistern at a higher elevation. In falling, thanks to an appropriate device (of which different kinds were in use), the water formed a vortex that carried air bubbles with it. On reaching the chamber below, the two components of the mixture separated naturally, the pressurized air going to feed the organ pipes while the water drove a bladed wheel. The latter in turn rotated a large barrel, whose pins opened the valves of the pipes corresponding to the notes of the composition to be performed. As far as we know, the first instrument of this kind in Italy was the one installed in about 1566–69 at the Villa d'Este at Tivoli, which was examined and described by Della Porta, and has been recently reconstructed.[5] At the end of the century another famous water organ was built and installed in the papal palace of the Quirinale, in Rome, which was mentioned by Fabio Colonna himself.[6]

The diagrams and captions in figure 2 show us how Colonna (and probably also Della Porta) intended to construct his chamber—which he

4. A modern reconstruction of Hero's model can now be seen at the *Musée Suisse de l'orgue*, in Roche (VD), Switzerland.

5. Patrizio Barbieri, "Organi e automi musicali idraulici di Villa d'Este a Tivoli," *L'organo* 24 (1986): 23–25, and idem, "The New Water Organ of the Villa d'Este, Tivoli," *The Organ Yearbook* 33 (2004): 33–41.

6. Fabio Colonna, *La Sambuca Lincea overo dell'istromento musico perfetto libri III* [. . .] *Con l'Organo Hydraulico di Herone Alessandrino dichiarato dall'Istesso Autore* (Naples: C. Vitale, 1618), 111. On this instrument see also Patrizio Barbieri, "L'organo idraulico del Quirinale," *L'organo* 19 (1981): 7–61, and Antonio Latanza, *Il ripristino dell'organo idraulico del Quirinale* (Rome: Istituto poligrafico e zecca dello stato, 1995). Already in the ninth century we have reports of some water-operated musical *automata*, but they were based on a different principle, whereby only plain water, without any air bubbles, fell into the chamber, compressing the air already present and expelling it into a flute pipe. See the works by the Banu Musa (ninth century) and Ibn al-Razzaz al-Jazari (1204–06): Jean Perrot, *L'orgue de ses origines hellénistiques à la fin du XIII^e siècle* (Paris: Picard, 1965), 253; Ibn al-Razzaz al-Jazari, *The Book of Knowledge of Ingenious Mechanical Devices*, ed. Donald R. Hill (Dordrecht: Reidel, 1974), 171–77; and Patrizio Barbieri, "Organi idraulici e statue 'che suonano' delle ville Aldobrandini (Frascati) e Pamphilj (Roma). Monte Parnaso, Ciclope, Centauro e Fauno," *L'organo* 34 (2001): 93–96.

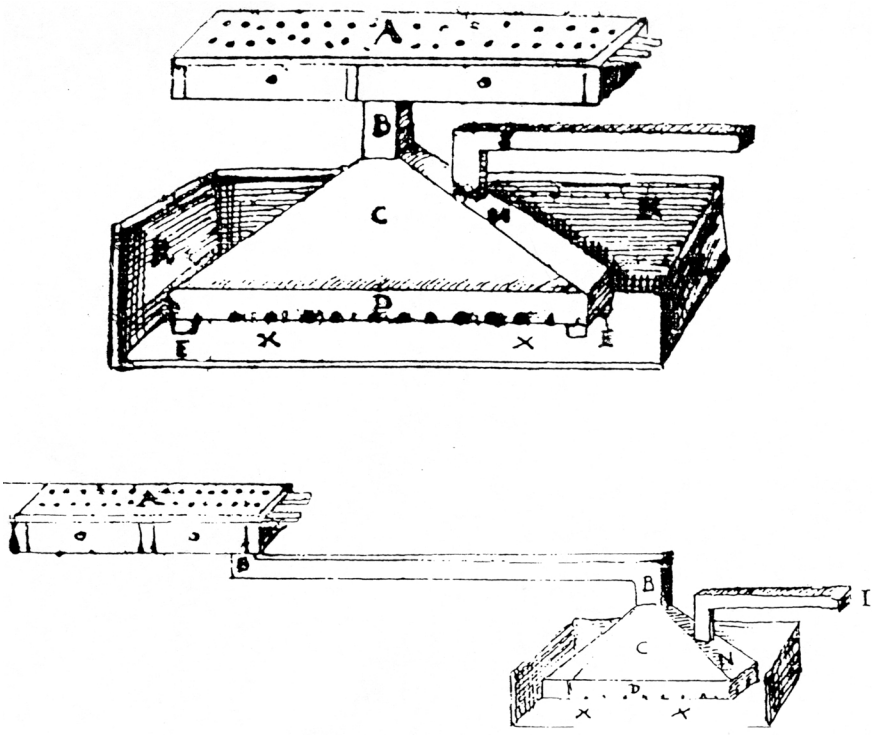

FIGURE 2. Two drawings from Fabio Colonna, *Annotazioni* [. . .] *alle macchine Spiritali di Herone Alessandrino* (Venice, Biblioteca Nazionale Marciana, Ms. Marciano Cl. IV n° 43 [= 5448]), illustrating the operation of the *Organo hydraulico* designed by Colonna himself and played by Jean De Macque. By courtesy of the Biblioteca Nazionale Marciana, Venice.

Top: The wind from the organ bellows enters tank *C* through wind pipe *I* (coming from the right). Its operation is similar to the one illustrated in figure 1, except that the extremity of wind pipe *I* is immersed in the water contained in the tank and in chest *KK*, which communicate with each other through spacers *EE* and holes *XX*: the bubbles thus produced ensure the oscillation of the air pressure coming from *B*. This modulated air feeds a common slider chest *A*. See also figure 3.

Bottom: Variant on the previous system, obtained simply by lengthening wind pipe *B*, thus becoming *BB*. In this way, the tank can be located in a room apart from the organ, together with the bellows, thus preventing the musical performance from being disturbed by the noise of the water.

called 'Heronian' in tribute to Hero of Alexandria—so as to modulate the wind supply. The air comes from the bellows of the organ itself (instead of from the two piston pumps in figure 1), while the modulated wind output feeds a slider chest (instead of a chest of the Greco-Roman type); see also figure 3 below. Porta's and Colonna's invention was consequently not a proper organ, but rather an ancillary registration device installed on the windpipe, which could be inserted by the organist when required, using two different systems Colonna describes in his manuscript. Colonna adds that he had constructed—"many years earlier"—a small organ of this kind, "which was played by the most excellent musician Giovanni de Macque, disciple of Filippo de Monte" and director of the royal chapel at Naples.[7]

A positive organ of 1559, built by Michael Strobel and still to be found at Castel Coira (near Sluderno, Bolzano), already contained an application similar to the Porta-Colonna idea, although limited to the six pipes of a device called *filomela*, a name by which Virgil metonymically designated the nightingale (fig. 3).[8] This application appears to have been extended to the entire keyboard of the organ at the cathedral of Orvieto, built in 1591 by the Parisian Vincenzo Fulgenzi Quemar, which was actually provided with an "entire stop of nightingales on which each key separately produces this effect."[9] It must be stressed, however, that the average pressure of the Porta-Colonna device still depended on the water level, as in the hydraulis. In the *filomela*, on the contrary, the water level was constant, and the fluctuation of air pressure depended on the balance between the input and output of air. For quantitative information on the index of pressure-modulation in different situations of air absorption, in both cases experimental measurements should be performed.

Finally, a device known variously as *uccelli* (birds) or *rossignolo* (nightingale) consists of a certain number of small flue pipes bent to form an upside-down U, with their open ends immersed in a small tank of water. If the pipes are only a few centimeters long and the water level is carefully chosen, a warbling sound is thus produced; however, because its

7. Colonna, *La Sambuca Lincea*, 112: ". . . con poca fatica ne facemmo uno piccolo [organo hydraulico], che fù sonato dall'Eccellentissimo Musico Gio: de Macque discepolo di Filippo di Monte."

8. Egon Krauss, "L'organo rinascimentale di Castel Coira," *L'organo* 10 (1972): 149–53.

9. Luigi Fumi, *Il duomo di Orvieto e i suoi restauri* (Rome: Società Laziale Tipografico-editrice, 1891), 457: "Un registro integro di rosignoli che ogni tasto farà l'effetto suo della sua voce appartata."

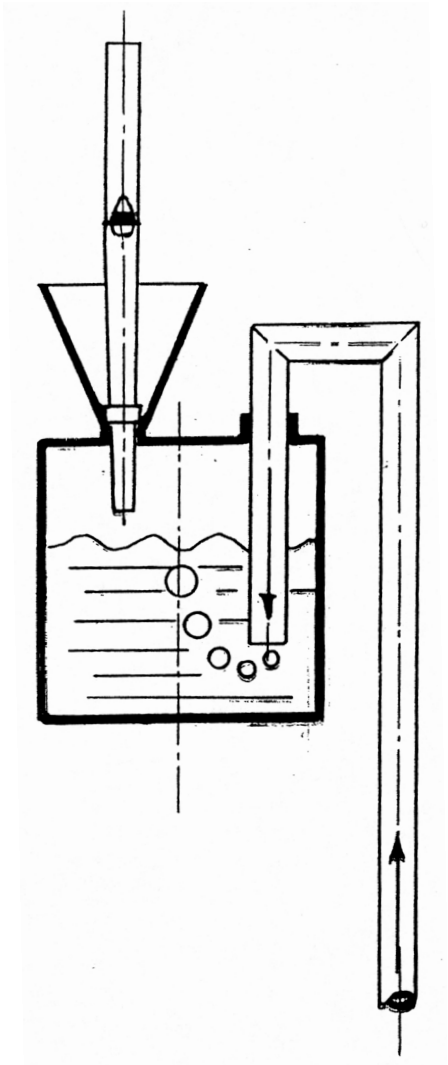

FIGURE 3. *Filomela* stop of the organ at Castel Coira (M. Strobel, 1559), plate 13 from Egon Krauss, "L'organo rinascimentale di Castel Coira," *L'organo* 10 (1972): 149–53.

pitch is unsteady, it is unsuitable for producing consonant chords and thus for use as an organ stop extended to the whole keyboard.[10]

Colonna's *Herone riformato*. Fabio Colonna's fame rests on his activities as a naturalist, especially his work on medicinal herbs, which led the eighteenth-century Swedish scientist Carolus Linnaeus to call him the "forerunner of all botanists." He is, however, also known in the field of music for his construction of the *sambuca*, an enharmonic clavichord whose octave was divided into thirty-one acoustically equal parts according to the same system already devised by Nicola Vicentino in 1555 for his *archicembalo*. Colonna published a meticulous description of this instrument in *La Sambuca Lincea overo dell'istromento musico perfetto* (1618), and it was later also examined by Galileo Galilei and Federico Cesi, respectively a fellow member and the founder of the Accademia dei Lincei, with whom he corresponded.

According to the title page, at the end of this volume Colonna added an appendix bearing the title "On the hydraulic organ described by Hero of Alexandria, explained and experimented upon by Fabio Colonna *Linceo*. Taken from his *Herone riformato*, and explained in chapter LXXV."[11] This description by Hero can be identified in chapter 75 of his *Pneumatika*, according to the edition by Federico Commandino (1575).[12] Colonna was not, however, the only one to have drafted appendices to this work. Giambattista Aleotti, for example, in his 1589 Italian translation of the volume, had attached four further chapters, all illus-

10. In Italy, devices of this kind are still found on many antique organs and work perfectly, provided the water level is correctly set. That their artificial twittering is fairly convincing is demonstrated by the following episode: in June 2003 the present author, together with Leonardo Lombardi and the organ builder Rodney Briscoe, was engaged in testing a similar device on the Heronian automatism of the *Fontana degli uccelli e della civetta* at Villa d'Este at Tivoli. It was 2 p.m. and the sun was rather strong, so that the real birds, perched on the branches of the surrounding trees, were resting in the shade. As soon as the hydraulic device began to operate, they suddenly began to respond as a chorus, with a festive twittering that greatly surprised and amused the tourists gathered to admire the fountain.

11. *Dell'organo hydraulico descritto da Herone Alessandrino, dichiarato et esperimentato da Fabio Colonna Linceo. Cavato dal suo Herone riformato, et dichiarato dal Cap. LXXV.* The sobriquet "Linceo" after the author's name refers to his membership in the Accademia dei Lincei, as does the third word of the treatise's title.

12. *Heronis Alexandrini Spiritalium liber. A Federico Commandino Urbinate ex Graeco, nuper in Latinum conversus* (Urbino: D. Frisolino, 1575), chapter 75.

trating his own innovations.[13] Of Colonna's *Herone riformato* itself, on the other hand, only the chapter 75 mentioned in the title to his 1618 appendix has come down to us, consisting of six pages in a manuscript copy kept at the Biblioteca Marciana in Venice. In the same order as Hero's *Pneumatika*, it must have been followed by chapter 76, dealing with the organ pipes fed by a windmill; but of this chapter only a few initial lines are present, introducing the topic.[14]

As mentioned above, Colonna intended to reconstruct Hero's hydraulis, believing—for reasons to be discussed below—that its sound was characterized by the so-called *canto di gorgia* ("throat singing," sometimes written as *canto di gorga*) or *gargante*. Although Colonna does not say so, this style of singing was already described in 1562 by Giovanni Camillo Maffei.[15] At Naples, in 1613, the Spanish expression *cantar de garganta* was widely used to designate the performance of a melody embellished with many different kinds of ornamentation:[16]

13. *Gli artifitiosi et curiosi moti spiritali di Herone. Tradotti da M. Gio. Battista Aleotti d'Argenta. Aggiuntovi dal medesimo Quattro Theoremi* [. . .] (Ferrara: Baldini, 1589), 96. Between 1605 and 1619 he then drafted a version of this work containing further additions, some also connected with the water organs he had designed: *Libro delli ingegnosi Spiritali d'Herrone ridotti in lingua italiana da Giovanni Battista Aleotti detto l'Argenta, architetto di N.S. PP. Paolo V, pub. in Ferrara et dal medesimo giuntovi un Libro dell'istessa materia nel quale si mostra come con l'acqua si fanno sonare musicalmente gli organi et gl'altri instromenti hidraulici* [. . .], London, British Library, Ms. C.112.f.14. On this manuscript, see Paolo Fabbri, "Aleotti teorico musicale," in *Giambattista Aleotti e gli ingegneri del Rinascimento*, ed. Alessandra Fiocca (Florence: Olschki, 1998), 189–94, and Patrizio Barbieri, "Ancora sulla 'Fontana dell'organo' di Tivoli e altri automata sonori degli Este (1576–1619)," *L'organo* 37 (2004): 187–221.

14. Fabio Colonna, *Annotazioni* [. . .] *alle macchine Spiritali di Herone Alessandrino*, Venezia, Biblioteca Nazionale Marciana, Ms. Marciano Cl. IV n° 43 (= 5448). It contains only the whole of chapter 75 ("Dell'Organo Hydraulico") and the start of chapter 76 (without title). Nothing is known about this work, neglected by modern scholars, and it is not to be found in the Vatican Library, to which Colonna left his manuscripts in his will: see Nunzio F. Faraglia, "Fabio Colonna Linceo," *Archivio storico per le Province Napoletane* 10 (1885): 747. The version of chapter 75 published by Colonna in his *Sambuca Lincea*, 111–16, is abridged and lacks the illustrations found in the manuscript.

15. *Delle lettere del Signor Giovanni Camillo Maffei da Solofra libri due. Dove tra gli altri bellissimi pensieri di filosofia, e di medicina, v'è un discorso della voce e del modo d'apparare di cantar di garganta, senza maestro, non più veduto, n'istampato. Raccolte per Don Valerio de Paoli da Limosano* (Naples: Raymundo Amate, 1562), 29, 36, 198 (on pp. 168–69 there is also a letter addressed to Giambattista Della Porta). On this subject see also Giuliana Montanari, "Scienza e voce: Giovanni Camillo Maffei," *Hortus musicus* 4, no. 2 (April–June 2003): 93–99.

16. Pedro Cerone, *El Melopeo y Maestro* (Naples: Gargano e Nucci, 1613), 541 ("Libro VIII. En el qual se ponen las reglas para cantar glosado y de garganta").

> *Este modo de cantar y estas gracias y hermosuras, del vulgo comunemente es llamado,* Cantar de garganta*, (que es lo mesmo que* Cantar de gorgia*, segun el vocablo de los Italianos).*
>
> This mode of singing and these grace-notes and embellishments are commonly called *Cantar de garganta* (which is the same thing as *Cantar di gorgia* [*gorgia* = *gola* = throat] in Italian).

In his *Prattica di musica* of 1592, Lodovico Zacconi advised singers that they could perform all these diminutions more easily by adopting a style of voice production that used *tremolo* at all times. However, by this term he did not mean that particular *gorgia* consisting of a rapid repetition of a single pitch, but rather something very close to a vibrato:[17]

> *Il tremolo, cioè la voce tremante, è la vera porta d'intrar dentro a passaggi, et di impat[r]onirse delle gorgie. [. . .] Questo tremolo [. . .] sempre usar si deve; accioche l'uso si converti in habito; perche quel continuo mover di voce, aiuta, et volontieri spinge la mossa delle gorgie, et facilita mirabilmente i principij de passaggi.*
>
> The *tremolo*, that is the trembling voice, is the true entryway into diminutions, and for mastering ornamentation. [. . .] This *tremolo* [. . .] must always be employed, so that its use becomes a habit; because that continuous movement of the voice helps, and is apt to push the beginning of the ornaments, and miraculously facilitates the beginnings of diminutions.

Zacconi's recommendation of a constant "trembling of the voice" helps us to understand why in the Porta-Colonna device this kind of vibrato was not limited to selected notes, but was treated as a general style of singing. That it was not a rapid repetition of a single pitch is indirectly confirmed by Colonna, who says that the sound was "without interruptions" and aimed at imitating the melodious vocal utterance of the nightingale.[18] Zacconi, too, had already observed that the *gorgheggiare* of the *canto di gorgia* reminded listeners of the singing of "many well trained birds."[19]

At that time, two organ stops were widely used to produce sounds of this kind, about which, however, Colonna—in the very same chapter on

17. Lodovico Zacconi, *Prattica di musica* [. . .] (Venice: G. Polo, 1592), vol. 1, fol. 60r.

18. Colonna, *La Sambuca Lincea*, 113 ("it doubles the sound without any interruptions and the intensity seems to be multiplied" [*raddoppia la voce senza interrompimento, et par che sia moltiplicato il suono*]) and 111 (*roscignuolo*).

19. Zacconi, *Prattica di musica*, vol. 1, fol. 58r ("it seems to us to hear many well-trained birds, which move our heart with their singing" [*ci pare d'udir tanti bene ammaestrati augelli, che col canto loro ci rapiscono il cuore*]) and 58v (*gorgheggiare*).

the hydraulic organ appended to his *Sambuca Lincea*—is rather critical. One, called *uccelli* (birds), he judged unsuitable for use in a stop extending across the whole keyboard, for the reasons already noted above. The other was the tremulant, a mechanical device installed on the windpipe that rhythmically modulates the airflow to the wind chest, producing a vibrato with an almost constant frequency. In this connection Colonna observed that, whereas with his *organo hydraulico* the sound production, although *gargante*, is cheerful [*allegra*] and full, with the tremulant it is sad [*malinconica*], since it "interrupts and shakes the sound." (Based on this description, he must have been referring to a mechanism known as a *tremblant fort* or *à vent perdu*, which rhythmically opens a breather hole on the windpipe.) On the other hand, Colonna does not mention the stop known as *Voce umana* or *Fiffaro*, in which each note is produced by two pipes not in perfect unison with each other, thus producing slow beats. Although reported with certainty in northern Italy starting in 1571, at Naples this is documented for the first time only about 1640,[20] which would explain why it was apparently unknown to him.

In the final lines of his *Sambuca Lincea* Colonna recommends that Pope Paul V install at St. Peter's a "perfect organ" [*organo perfetto*], by which he means one having both of the innovations put forward in his work: division of the octave into thirty-one equal parts and the *mutazione di suono gargante* presently being considered. In February 1619 he even went to Rome for this purpose, but—even with the support of Prince Federico Cesi, the founder of the Academy of Lincei—without achieving his aim.[21]

Colonna as plagiarist. Although Colonna claimed credit for both inventing and constructing the *sambuca*, at Naples this idea was not a new one. Scipione Stella, a musician working in that city, in 1594 visited the court of Ferrara together with Carlo Gesualdo, Prince of Venosa, where he was able to hear Luzzasco Luzzaschi play on the *Archicembalo*. On returning

20. Luigi Ferdinando Tagliavini, "Il Fiffaro o Registro delle Voci umane. Origine ed evoluzione dei registri 'battenti'," *L'organo* 33 (2000): 116–17, 129–30; Pier Paolo Donati, "Maestri d'organo 'fiamminghi' nell'Italia del Rinascimento. I: Testimoni, protagonisti, nuove risorse sonore," *Informazione organistica* 14 (April 2003): 45.

21. Patrizio Barbieri, "La *Sambuca Lincea* di Fabio Colonna e il *Tricembalo* di Scipione Stella. Con notizie sugli strumenti enarmonici del Domenichino," in *La musica a Napoli durante il Seicento*, ed. Domenico Antonio D'Alessandro and Agostino Ziino (Rome: Torre d'Orfeo, 1987), 200–01.

home, Stella constructed two similar instruments, the *Tricembalo* and the *Pentorgano*, both based on a division of the octave into thirty-one equal parts. Colonna was clearly inspired by these very instruments, as is shown by a copy of the *Sambuca Lincea* held by the Library of Congress in Washington, D.C., that contains autograph annotations by Stella, making strong accusations of plagiarism against Colonna.[22]

The 1589 edition of Della Porta's very famous *Magia naturalis* contains a chapter entitled *De hydraulicis organis*, from which it can be deduced that not even the *gargante* device that Colonna boasts of inventing was original.[23] In this chapter, Della Porta discussed several experiments he carried out after reading the passage in which Vitruvius described the hydraulis. As Colonna also pointed out later on, he began by saying that no complete organ stop could be obtained with small pipes that had their upper ends immersed in a water tank ('birds'): since the pitch of the notes emitted was very unstable, the sound of any one of them played singly was pleasant, but when others were added the chords produced were always dissonant. He then went on to interpret, in his personal way, the wind chamber of Hero-Vitruvius:[24]

> *Hoc verò modo, et tremulum, blandique mormorij sonum efficit, et tonum conservat. Arca, in quo ventus defertur, fiat aenea, et aqua semiplena, ventus ex modiolis, vel follibus excitetur, qui per cervicem sub aquis excurtat, erumpens verò spiritus ex medio aquae in arca excluditur, quùm igitur ad pinnarum motus referantur epistomia fistularum, ventus tremulus fistulas subintrans, tremulas et satis iucundas voces facit, quod nos experti sumus, et verum invenimus.*
>
> In this [other] mode, [the pipe] not only emits a tremulant and sweetly murmuring sound, but also maintains a constant pitch. The chamber into which the air is introduced should be of copper and half full of water, the air is supplied by piston pumps or bellows, and through a pipe it escapes below water level: emerging from the water the said air collects in the chamber;

22. Stella's notes are reproduced in Fabio Colonna, *La Sambuca Lincea* [. . .] *con annotazioni critiche manoscritte di Scipione Stella (1618–22) / with critical manuscript notes by Scipione Stella (1618–22)*, ed. Patrizio Barbieri (Lucca: Libreria Musicale Italiana, 1991), XXVI–XXIX, LII–LVI, and in Barbieri, "La *Sambuca Lincea*," 204–07. For example, on p. 6 Colonna writes that the construction of his enharmonic clavichord was commissioned by Stella himself, but a note in the latter's hand reports that the above statement was a "lie" (*bugia*).

23. Giovanni Battista Della Porta, *Magiae naturalis libri XX* (Naples: apud Horatium Salvianum, 1589), 288. Probably Della Porta developed this device between 1564 and 1589, because it is not present in the first edition of the *Magia*, published in 1564.

24. Ibid.

> when the keys are played, the holes in the pipes open, the tremulant air enters the pipes and produces tremulant and rather pleasing sounds, which we have experimented with and in truth discovered.

The wind from the bellows was thus made to bubble in the water contained in the chest, a statement one would seek in vain in Hero or Vitruvius. From the context, Della Porta probably drew his information from a comment that Daniele Barbaro attached to his 1556 translation of Vitruvius's *De Architectura*, which reads that, according to some people, the pipes of the hydraulis "made a trembling sound."[25] We do not know Barbaro's source, nor if this effect was due to unsteady pressure as mentioned above. Certainly there were many varieties of the hydraulis in antiquity: according to Svetonius, for example, the Roman emperor Nero (37–68 CE) played "hydraulic organs of a new and unknown kind."[26]

As we can see, Colonna then constructed his device based on the very principle illustrated by Della Porta, but without citing that author. It cannot even be said, by way of justification, that Colonna reached his conclusions independently, since the famous work by his fellow citizen—who, moreover, was the person responsible for Colonna's being admitted to the Academy of Lincei in 1612—was by now being widely circulated in Europe. The accusation of plagiarism this time did not strike home, perhaps because Della Porta died before Colonna's *Sambuca Lincea* was published. To the latter remains, however, the merit of a practical realization of the device, of having advertised it through an eminent organist, and of underlining its affinity with the *canto di gorgia*. In any case, not even Della Porta's idea was fully original, as shown by the organs of Castel Coira and Orvieto, mentioned above.

25. *I dieci libri dell'architettura di M. Vitruvio. Tradutti e commentati da Monsignor Barbaro* [. . .] (Venice: Francesco Marcolini, 1556), 266. The original text reads "*Nerone tanto si dilettava di queste machine Hidraulice, che contenevano l'acqua, et per più canne mandando fuori l'aere con l'acqua insieme facevano un tremante suono,*" which translates literally as "Nero greatly enjoyed these hydraulic devices containing water, which, by expelling air together with water through many pipes, produced a trembling sound"; however, I believe Barbaro's meaning was "Nero greatly enjoyed these hydraulic devices containing water, which, expelling air through many pipes, by means of water produced a trembling sound." (In the Latin version of the book this sentence is omitted.)

26. C. Svetonius Tranquillus, *De vita Caesarum Libri VIII*, ed. Maximilianus Ihm (Leipzig: Teubner, 1933), 251 (chapter 41.2): "*organa <h>ydraulica novi et ignoti generis [Nero] circumduxit.*" See also Günther Wille, *Musica Romana. Die Bedeutung der Musik im Leben der Römer* (Amsterdam: P. Schippers, 1967), 348.

Later Proposals for a "Singing" Type of Organ

Efforts by European organ builders to achieve a more vocal quality focused on two main areas, the imitation of expressive potentials and the imitation of tone color, which we shall now examine separately.

Expression. The device described by Della Porta and Colonna aimed to obtain a particular kind of vibrato differing from that produced by the tremulant stops then in use. That it did not manage to gain popularity was due not only to its practical complexity, but probably also to the almost contemporary success of undulating stops such as the beating *Voce umana*, with its more intense and suggestive effect. Toward the end of the seventeenth century, however, thought was given to providing dynamic action on the intensity of single organ pipes. The devices invented for this purpose differed both from the swell box (introduced in the eighteenth century and still in use today) and from the modern crescendo pedal. Instead, they aimed to provide greater intensity for only those notes chosen by the performer by means of increasing the pressure of his finger on the key. Claude Perrault, in his 1684 edition of Vitruvius's *L'architecture*, not only illustrates a reconstruction of the hydraulis (fig. 4), but is also the first to propose this kind of innovation:[27]

> *[P]ar ce moyen lorsqu'on touche les marches legerement, il n'y a que les tuyaux de la laye de devant qui sonnent, et lorsqu'on enfonce davantage les tuyaux de la laye de derriere sonnent aussi; et estant ainsi jointes avec ceux de la laye de devant qui leur sont accordez à l'unisson, ils doublent la force du son: ce qui fait un fort bel effet, quand une main legere est habituée à bien menager ce fort et ce foible.*
>
> [I]n this way, touching the keys lightly only the pipes of the front pallet box sound, while pressing more firmly makes the pipes of the back pallet box sound as well; and being thus united with those of the front pallet box, which are tuned in unison with them, they double the force of the sound: which has a rather nice effect when a light hand is practiced in handling this loud and soft properly.

In this connection it should be noted that when using this device, the difference between the two sound levels would have been minimal,

27. Claude Perrault, *Les dix livres d'architecture de Vitruve corrigez et traduits nouvellement en François, avec des notes et des figures. Seconde edition revue, corrigée, et augmentée* (Paris: Coignard, 1684), 322–27: "Chapitre XIII. Des machines hydrauliques qui font joüer des orgues."

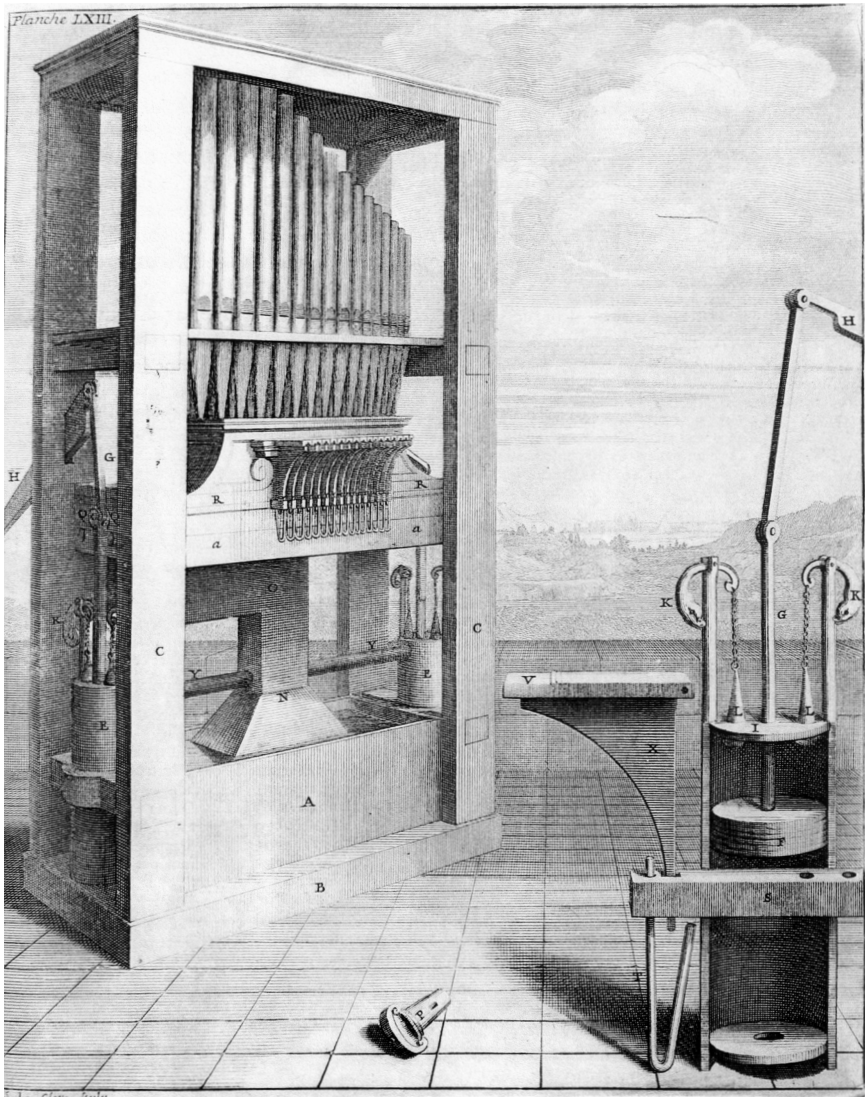

FIGURE 4. Reconstruction of Vitruvius's hydraulis, from Claude Perrault, *Les dix livres d'architecture de Vitruve* . . . (Paris: Coignard, 1684), plate LXIII on p. 325. *VX* shows the detail of a key, with its return.

equal to just three decibels (the value corresponding to the doubling of the acoustic power emitted, as Perrault says). This idea of Perrault's was applied by Jean Moreau, in 1736, to the organ of St. Jean at Gand (Ghent), on which three different finger pressures on the key caused the three keyboards to be coupled together, one after the other.[28]

About the middle of the nineteenth century, Perrault's solution was also independently taken up and implemented by Giambattista De Lorenzi (1806–1883), who provided his *organo fonocromico* with two pallet boxes, which could be coupled by increasing finger pressure on the key. The stops in the two compartments were the same, with the sole difference that the pipes of the second (destined to reinforce the sound volume) had a slightly larger diameter. Here is how he describes it, writing in 1857:[29]

> *L'organo Fonocromico ha la facoltà di dare la voce collorita alla pressione di ogni singolo tasto. I tasti agiscono su due punti; col primo punto si ottiene una voce piana e delicata, abbassando il tasto al secondo punto si rinforza la voce, e questa va sempre più aumentando quanto più si preme sul tasto per un breve movimento che fa tutta la tastiera. Si aggiunge a questa voce a volontà anche il tremolo mediante la pressione di un apposito pedale che ha pure l'attività di aggiungere maggior forza ancora alla nota mediante un mantice espansivo il quale per l'apertura d'una valvola viene quasi a raddoppiare la gravità dell'aria.*
>
> The *fonocromico* organ is capable of adding color to the sound of each individual key. The keys act at two points: at the first, a soft and delicate sound is obtained; by pressing the key down to the second point, the sound is stronger and continues to increase the more the key is pressed; [this requires only] a small movement, until the key is fully depressed. As desired, to this sound the tremulant can also be added by pressing an appropriate pedal, which provides still greater force to the note by means of an expansion bellows which, by opening a valve, almost doubles the air pressure.

A working specimen of the *fonocromico* (De Lorenzi's opus 172) is still extant in the cathedral of Malo (near Vicenza), installed in that church in 1878 and recently restored (1997). The organ has two manuals, Great and Swell (= *Fonocromico*). Of the latter, the pipes referring to the "first point" are enclosed in a swell box, whose shutters are operated by means of a pedal; the pipes inserted at the "second point" are enclosed in an-

28. Corrado Moretti, *L'organo italiano*, 2nd ed. (Milan: Eco, 1973), 358.

29. Giuseppe Radole, "L'arte organaria a Trieste (continuazione)," *L'organo* 8 (1970): 46.

other box, whose shutters are this time progressively opened by further pressure on the keys.[30]

Of this type of organ, first demonstrated in Milan in 1851 and in Paris in 1855, a few other specimens still survive in the Veneto, for example on a few stops of the single-manual organ in the church of S. Corona at Vicenza,[31] at the church of S. Pietro in Belluno (dated 1860), and at the church of S. Cassiano in Quinto (Treviso), for whose *fonocromico* restoration funds were allocated in 2001. The organ presented at the Paris Exhibition (1855) was rediscovered in 1923 in a warehouse in the same city and carefully restored. The one at S. Corona, built in 1847, was inspected and described by G. Helbig in 1931, who stated that the double pressure bellows did not alter the tuning of the instrument, due to the low pressure at which it was tuned (ranging from 40 to 65 millimeters of water column).[32]

We have seen that the expressiveness of De Lorenzi's system not only provided two dynamic levels, but also both regulated the frequency of the tremulant (i.e. of the *vibrato*) and, by including a supplementary bellows and progressively opening the swell box, made it possible to increase sound intensity still further. Thus it was also possible to regulate the *messa di voce*. This effect, also called *filatura delle voci*, had already been obtained by Giovanni Banci (1803–1874) on the flue and reed pipes of an organ built by him at Castiglion Fiorentino, Arezzo (1849). However, because no technical details are known about this instrument, we can only infer that its operation was not limited to single notes, as the performer had to activate it with a pedal.[33]

30. Diego Bonato, "L'organo del duomo di Malo: note sul restauro," *Arte organaria e organistica* 4, no. 20 (Oct.–Dec. 1997): 32–37. The swell has five stops, all of singing character, and all divided in two parts (*bassi* and *soprani*, i.e. bass and treble): Flicorno 8′, Flautone 8′, Flauto traversiere 4′, Viola 4′, Ottavino 2′.

31. Giuseppe Piazza, "Uno scledense geniale: Giambattista De Lorenzi," in *Schio – note di storia costume attualità* (Schio: A.S.G.E.S., 1983), 94; Mario Saccardo, *Arte organaria, organisti e attività musicale a S. Corona* [. . .] (Vicenza: La Grafica & Stampa, 1976), 38–56 (full description of the Santa Corona organ).

32. G. Helbig, "Étude sur les tuyaux d'orgue à pression variable," *Revue musicale* 12 (November 1931): 366–68. See also Sandro Dalla Libera, *L'arte degli organi nel Veneto. La diocesi di Cèneda* (Venice and Rome: Istituto per la Collaborazione Culturale, 1966), 239–41, 247–48. The bellows in question had two compartments, one being the double of the other: by pressing a pedal, the organist emptied the smaller compartment, so that all the weight of the bellows came to bear on the other.

33. Franco Baggiani, *Regesto di notizie organarie tratte dalla gazzetta toscana (1766–1865)* (Ospedaletto, Pisa: Pacini, 1987), 60, 63, 78.

To complete its imitation of vocal expressiveness, the organ now lacked only the *portamento di voce*. This was provided for by Francesco Natale Seriacopi, in the organ that this amateur built in 1857 for the parish church of a small town again near Arezzo (Foiano). Among the many new devices with which it was provided, two stand out for their "vocality." The first of these was a tremulant acting only on the note chosen by the performer, by regulating his finger pressure on the key, rather like the violinist's vibrato. (In Italy the earlier tremulant stop had fallen into disuse, because it acted simultaneously on the whole keyboard.) The second was a *portamento di voce* effect on the *flauto traverso* stop, which could provide an upwards slide of a much as a major third, depending on how the key was pressed.[34]

A final application of the "double touch," facilitated by electrical action, is found in so-called cinema organs that were used during the period 1911–40 for the accompaniment of silent films. This system made it possible for the organist to use different stop combinations for individual notes or melodies simply by applying additional pressure to the keys, thereby facilitating the playing of solo and accompaniment on the same manual.[35]

This host of innovations was certainly encouraged by the fact that, in nineteenth-century Italy, organists were wont to paraphrase the most popular operatic arias during the liturgy. In Great Britain, on the other hand, there is no mention of similar attempts to add dynamic capabilities to the organ; only the *sforzando* pedal is reported, which enjoyed a brief vogue during the 1850s and 1860s.[36] Instead, British organ builders

34. *Relazioni sull'organo dell'insigne collegiata di Fojano ricostruito da Francesco Natale Seriacopi dilettante meccanico* (Cortona: Colonnesi, 1857); Luigi Ferdinando Casamorata, "Lettera seconda," *Gazzetta musicale di Milano* 16 (1858): 246–47 (the other devices of this instrument are described in the same author's "Lettera prima," ibid., 235–39). Casamorata's two letters were also published in the *Monitore toscano*, and are reproduced in Baggiani, *Regesto*, 70–78.

35. David H. Fox, "Cinema organ," *The New Grove Dictionary of Music and Musicians,* 2nd ed. (London: Macmillan, 2001), 5:861–62.

36. The organist played on the Swell, and by depressing the *sforzando* pedal brought the Great into action; as soon as the pedal was released, the connection was broken. Nicholas Thistlethwaite, *The Making of the Victorian Organ* (Cambridge: Cambridge University Press, 1990), 367.

focused mainly on different ways to control the shutters by means of the swell pedal.[37]

Tone color. During the Renaissance, the tone of Italian organs was oriented towards sweetness and timbres of vocal character, thus abandoning the rigid *Blockwerk* characteristic of earlier centuries and still used in many European churches.[38] The materials believed to possess such qualities were wood and, more especially, lead.[39] Girolamo Cardano, in assessing the tone-color potential of organ stops, in 1550 observed that, using them, it was possible to imitate "trumpets, horns, syrinxes, *tibiae* [i.e., reed instruments with finger-holes], drums," concluding, however, "All that is lacking is the human voice, which is harder to imitate, because it is sweeter than the others."[40] But just a few years later, in 1567, we find the first mention in Italy of a reed stop called *Voce umana*, equipped with short resonators of (as far as possible) constant length.[41] Let us examine the acoustical reasons why this stop earned its name.

The human vocal apparatus comprises a double reed, the so-called vocal cords, whose emission is selectively filtered by the vocal tract. According to the conformation we give to the latter (by means of

37. An extreme solution was patented by Henry Willis in 1861: "[T]he player had within his reach a mouthpiece ('something like that of a cigar holder') attached to a flexible tube. This led to a small bellows which, when the player breathed into the mouthpiece, expanded, ultimately setting the shutters in motion" (ibid., 364).

38. This system was still in use as late as 1684, at the cathedrals of Paris and Rheims, as vouched for by Perrault, *Les dix livres d'architecture de Vitruve*, 324: "we still have organs, made scarcely more than 200 years ago, like those of Notre Dame in Paris and Notre Dame in Reims, which have only one stop composed of twenty pipes on each manual, without any registers" (*nous avons encore les orgues qui sont faites il n'y a gueres plus de 200 ans, comme celle de Nostre-Dame de Paris, et de Nostre-Dame de Reims, qui n'ont qu'un jeu composé de vingt tuyaux sur chaque marche sans aucuns registres*). On the sweetness of intonation of Italian organs in the sixteenth century see Mario Manzin, *Arte organaria nella cattedrale di Cremona* (Gavirate: Nicolini, 1985), 13, and Furio Luccichenti, *Documenti per la storia degli organi in S. Giovanni in Laterano a Roma (1427–1984)* (Rome: Leberit, 1994), 94.

39. Patrizio Barbieri, "Alchemy, Symbolism and Aristotelian Acoustics in Medieval Organ-Pipe Technology," *The Organ Yearbook* 30 (2001): 16.

40. Girolamo Cardano, *De subtilitate libri XXI* (Nuremberg: apud I. Petreium, 1550), 158: *[. . .] atque in eodem organo audies tubas, cornua, fistulas, tibias, tympana. [. . .] Solo deerat humana [vox], quae eo difficilius imitatur, quo suavior est caeteris.*

41. On the introduction of this stop in Italy see Pier Paolo Donati, "Maestri d'organo 'fiamminghi' nell'Italia del Rinascimento. III: I registri ad ancia," *Informazione organistica* 15, no. 3 (December 2003): 201–04.

movements of the tongue, the lips, and the soft palate), the selected harmonics are grouped into particular frequency bands (called 'formants') that are characteristic for each vowel, and these bands are independent of the note on which the vowel in question is intoned. This feature is exploited nowadays, for example, in MIDI synthesisers, whose tone-color menu provides a choice of *choir Aahs* or *Oohs*.

At least as early as the sixteenth century, this schematization of the vocal organs was unknowingly imitated by the above-mentioned kind of regal, called *Vox humana* (or *Vox pueri*, *Vox tauri*, etc., according to the timbre to be imitated). In fact, in this case the vocal cords were simulated by the beating reed, and the vocal tract by the volume of the overlying resonator, which contracted only slightly as it rose towards the high notes. Based on dimensions observed in seventeenth- and eighteenth-century instruments,[42] the low pipes sound on the U vowel, the middle range on O and A, and the high ones on E (using English pronunciation). Even with modern organ makers, this stop is provided with appropriate "vowel cavities," sometimes perforated or with shades that can be regulated, whose volume is adjusted so as to reproduce the formants of a given vowel.[43]

Such an effect cannot be obtained with flue pipes, but only with the kind of pipe described above, in which the resonator has a weak feedback on the reed, so that the reed can be tuned (after taking appropriate precautions) to the note required, whatever the volume of the resonator itself; the resonator can thus be sized so as to obtain the formants of the desired vowel.[44] Towards the end of the eighteenth century, the newly-

42. Some measurements of the *Vox humana* pipes used at the time of Mersenne and Kircher can be found in Patrizio Barbieri, "More on the Italian Activities of the Jesuit Organ-builder Willem Hermans, 1650–1674," *The Organ Yearbook* 34 (2005): 64–66. For the eighteenth-century French *voix humaine* see Dom François Bédos de Celles, *L'art du facteur d'orgues* (Paris: Académie des sciences, 1766), 1:84.

43. Thomas D. Rossing, *The Science of Sound*, 2nd ed. (Reading: Addison-Wesley, 1990), 322–25. On the acoustics of the *Vox humana* see also Henri Bouasse, *Instruments à vent* (Paris: Delagrave, 1930), 2:217–19. The physical mechanism of vowel sounds (formants) was only identified in the second half of the nineteenth century by Hermann von Helmholtz: see Robert T. Beyer, *Sounds of Our Times. Two Hundred Years of Acoustics* (New York: Springer, 1999), 63.

44. On the feedback of the resonator on the reed, see Thomas D. Rossing, Judit Angster, and Andràs Miklòs, "Reed Vibration and Sound Generation in Lingual Organ Pipes," in *Musical Sounds from Past Millennia: Proceedings of the International Symposium of Musical Acoustics 2001*, ed. Davide Bonsi, Diego Gonzalez, and Domenico Stanzial (Venice: FSSG-CNR c/o Fondazione Cini, 2001), 1:313–16.

invented speaking automatons also comprised a reed whose harmonics were filtered by a resonator, shaped on a time-by-time basis to obtain the desired vowel sound.

Although in this way an imitation of the human voice could be artificially obtained, the stop used to do so belonged to a category (regals) whose sound Italians have as a rule always judged rather harsh, since it is rich in high harmonics; it is for precisely this reason that it gradually disappeared in Italy during the seventeenth century. Before this happened, attempts were made to soften its tone by making the reed of the regals operate by aspiration, rather than by insufflation, of air. However, experiments of this kind carried out in Rome by Nicolò Borbone during the first decades of the seventeenth century were not followed up.[45]

An effect that cannot be obtained with the beating reed is variation of the intensity level, since the frequency of the note emitted varies with any change in the wind pressure. Dynamic variation had to wait until 1810, when Gabriel-Joseph Grenié officially introduced the free reed, which keeps vibration frequency fairly stable when the pressure (and thus also the sound intensity) varies.[46] It is possible, however, that Borbone may have already used that type of reed, since its use is reported—still in Rome, a few decades later—by Filippo Testa, in his "organino."[47] This solution was also used by Erard in 1830, in an organ for the chapel of the Tuileries, where one of the stops consisted of free reeds and the

45. This is drawn from the testimony of Giambattista Doni, *Compendio del Trattato de' generi e de' modi della musica* (Rome: Fei, 1635), 57, who states that Nicolò Borbone had also constructed a regal whose reeds—described as very gentle (*soavissime*) compared to those commonly employed—sounded with the wind entering the resonator, and not coming out, as customary (*per attrattione, et non per infusione del vento*). Contrary to what has been maintained up to now, this kind of reed had been invented at least as early as 1635, although Doni does not bother to specify whether they were of the "free reed" type (like the ones employed in the nineteenth century for harmoniums) or "beating reed" type (about which we have no information as to whether they were employed in the "wind suction" version). As demonstrated by a rapid test I carried out together with Francesco Saverio Colamarino, even the latter may have been sounded by "wind suction," in which case their acoustic emission appears—although confirmation will have to be provided by a more rigorous survey—to be sweeter than when sounded by blowing. It is worth recalling that during these very years Borbone was a pupil of Girolamo Frescobaldi and the engraver of his two books of toccatas (1615, 1627). The above innovation had already been mentioned by Benvenuto Disertori, *La musica nei quadri antichi* (Calliano, Trento: Manfrini, 1978), 58.

46. Barbara Owen, "Reed organ," *The New Grove Dictionary of Music and Musicians*, 2nd ed. (London: Macmillan, 2001), 21:64–71.

47. At least according to Owen, "Reed organ," 64. No example of this instrument survives, however.

expression was obtained by pressing the finger all the way down on the key.[48] In Tuscany, a stop of this kind, called *Fisarmonica*, was for the first time added to an organ in 1840.[49] Lastly, in 1840–42 the Parisian François Debain patented the harmonium, in which dynamics were simultaneously extended to all notes by increasing wind pressure, obtained by pumping faster; but here we are dealing with an entirely new kind of instrument.[50]

One of the factors that hindered the organ from imitating vocal tone was its structural inaptitude, owing to the prominence of flue pipes, to emit preestablished fixed formants. Recent experimental investigations have, in fact, confirmed that only rarely does the organ maker construct the pipes of some of the stops—particularly those of the *ripieno*—so as to make the sound particularly pleasing and gentle, with a timbre that maintains certain characteristics when note frequency varies (this sometimes involves the creation of one or more fixed formants, known as pseudo-formants).[51] The presence of these particular band frequencies, on the other hand, is peculiar to some string instruments provided with a resonator, a feature that has made the fortune of some bowed instruments; the response curves of some old Italian violins, for example, are in fact characterized by a maximum at around 2500 Hz, quite similar to the formant found in the spectra of most opera singers.[52]

In conclusion, attempts to make the organ sound expressive and vocal having been abandoned, it is currently accepted that this instrument's proper sonority is of a static type.

48. Helbig, "Étude sur les tuyaux d'orgue à pression variable," 368.

49. Baggiani, *Regesto*, 52 (by Antonio Ducci, on an organ in Florence).

50. The times were already ripe for this innovation: at the very same time (1841), in Great Britain, Wardle E. Evans built an harmonium called "Organo Harmonica" (Thistlethwaite, *The Making of the Victorian Organ*, 307).

51. Patrizio Barbieri, Laura Bazzanella, and Giovanni Battista Debiasi, "Rilevamenti acustici su alcuni organi di Roma in margine al restauro dell'organo F. Testa di Santa Maria in Trastevere," in *Esperienze e ricerche nel restauro dell'organo Altemps in Santa Maria in Trastevere a Roma*, ed. Giuseppe Basile (Rome: Fratelli Palombi, 1998), 43–44. Research into the particular sector mentioned has been carried out by G. B. Debiasi.

52. Neville H. Fletcher and Thomas D. Rossing, *The Physics of Musical Instruments*, 2nd ed. (New York: Springer, 1998), 315.