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Strange Musical Instruments in the Madrid Notebooks of Leonardo da Vinci

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THE SENSATIONAL reappearance at the National Library in Madrid in February 1967 of two of Leonardo da Vinci's notebooks, comprising some 700 pages in all, has substantially enlarged our knowledge of his research and thought in many fields and his activities in the realms of art, science, and applied technology.¹

It is not generally known that Leonardo da Vinci was deeply involved in music, not only as an admired performer, improviser, and teacher, but in many areas of research, such as acoustics, musical aesthetics, and the invention of numerous ingenious musical instruments.² And even if the notebooks in which he jotted down all these thoughts and inventions had been lost, his intensive concern with the phenomenon of music would be revealed by his profound definition of music as "figuratione delle cose invisibili." The Madrid notebooks contain only two pages devoted to musical instruments, and although two pages are not very much, they add considerably to our comprehension of Leonardo's restless, indefatigable mind, so overwhelmed by new ideas, associations, and technological

imagination that he could cope with this onslaught only by jotting down passing thoughts, often so sketchily that important details, which he evidently took for granted, are neither delineated nor explained in his comments.

Folio 75 verso shows in the upper right corner (Figure 1) a bell with a wide rim and no clapper inside. Two hammers strike the rim from opposite sides. To the left of the bell there is a mechanism including what seems to be a set of four keys operating on a tracker action that in its turn controls four levers that end in oval heads. In my opinion these heads must be dampers. The accompanying text says: "Una medesima campana parranno essere quattro campane. Tasti d'organo, con la campana ferma e battuta da due martelli. Ed avrà mutazione di voci, a similitudine dell' organo."³

Acoustically important in this explanation are the statements that the bell is firm, neither swinging nor equipped with a clapper in the manner of a church bell, and that it produces "a change of tones," which

1. A complete transcription of the text of the Madrid notebooks and an English translation have been announced by McGraw-Hill.

2. See Emanuel Winternitz, "Keyboards for Wind Instruments Invented by Leonardo da Vinci," *Raccolta Vinciana* 20 (1964) pp. 69–82, "Leonardo's Invention of the Viola Organista," *Raccolta Vinciana* 20 (1964) pp. 1–46, "Melodic, Chordal and Other Drums Invented by Leonardo da Vinci," *Raccolta Vinciana* 20 (1964) pp. 47–67, "Leonardo da Vinci," *Die Musik in Geschichte und Gegenwart*, XIII (Kassel, 1966) cols. 1664–1667, "Anatomy the Teacher—

On the Impact of Leonardo's Anatomical Research on His Musical and Other Machines," *Proceedings of the American Philosophical Society* 3, no. 4 (August 1967) pp. 234–247, "The Role of Music in Leonardo da Vinci's Paragone," *Collected Papers in Memory of Alfred Schütz* (University of California, Santa Cruz, in press).

3. "One and the same bell will appear to be four bells. Organ keys, with the bell stationary and beaten by two hammers. It will have a change of tones comparable to that of an organ."

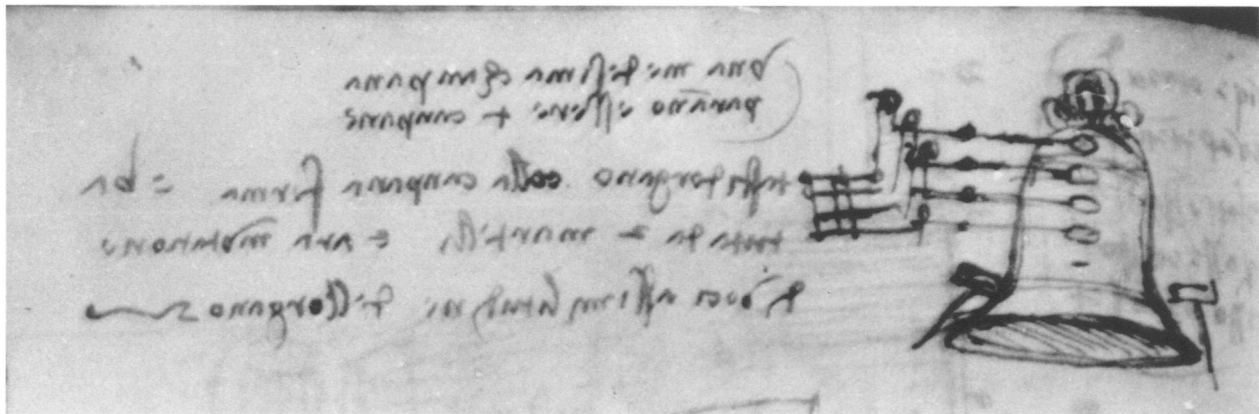


FIGURE 1
Bell with damper mechanism. MS. 8936, fol. 75 verso, National Library, Madrid

is in all probability one of pitch, not of timbre.⁴ Thus, Leonardo must have believed that the upper section of the bell has ring-shaped areas that produce tones of different pitch if they are slightly muted when the rim is set into vibration by the hammers. I must, however, sadly add that my own experiments with smaller and medium-sized bells in the Metropolitan Museum's collection brought no conclusive results.

Hermann von Helmholtz, in his famous book *Die Lehre von den Tonempfindungen . . .*, did not rule out at least the possibility of areas of a bell producing tones of different pitch.⁵ Anyhow, it is interesting that Leonardo, here, as in many other of his musical inventions,

4. Theoretically the change of tones could also mean change of timbre; but this is not likely, since a difference between these four kinds of timbre would be small, and also because Leonardo insists that his invention enables the bell to do the job of four bells, implying probably the effect of a carillon.

5. *Die Lehre von den Tonempfindungen als Physiologische Grundlage für die Theorie der Musik*, 4th ed. (Braunschweig, 1877) p. 125. "Der stärkste Ton ist nicht der tiefste; der Kessel der Glocken, angeschlagen, giebt tiefere Töne als der Schallring, letzterer dagegen die lautesten. Uebrigens sind auch wohl noch andere Schwingungsformen der Glocke möglich, wobei sich Knotenkreise bilden, die dem Rande parallel sind, diese scheinen aber schwer zu entdecken, und sind noch nicht untersucht."

6. Winternitz, "Drums."

7. The page is headed "De strumenti armonici." Then follows the text: "Per piva, sia fatto il tramezzo del mantice .a., fermo alla cintura. Ed il .b. sia fermo con il braccio, il quale braccio poi, muovendosi in dentro ed in fuori, aprirà e serrerà il mantice, al bisogno, cioè quando il mantice .n. aprirà, il mantice .m. serrerà. E quando .m. aprirà, .n. serrerà. E così il vento sarà continuo."

tried to obtain from one instrument what could normally only be produced by several or a whole set of instruments. Among the other examples are his drums, drawn in the Codice Arundel, folio 175 recto, which permit a change of pitch while being beaten and can therefore produce a whole series of tones without an interruption in the playing.⁶

On folio 76 recto (Figure 2), the first of the sketches (Figure 3) represents a wind instrument; two pipes point into the air, a third one points down. They all emerge from a contraption that is, beyond doubt, a bellows. The three pipes give the instrument a superficial similarity to a bagpipe in that they resemble its chanter (the melody pipe) and its drones. And indeed, Leonardo begins his verbal description⁷ with the explanation that the new bellows used here are made "per piva." The word *piva* means, or at least can mean, "bagpipe."

Leonardo was, of course, very familiar with an instrument as popular as the bagpipe (Figure 4). In Manuscript M, folio 4 verso, he shows a bagpipe squeezed by a vise (Figure 5). Among the drawings at Windsor Castle there is a sketch (no. 12585) showing a bagpipe man on horseback (Figure 6). This drawing has often been misinterpreted.

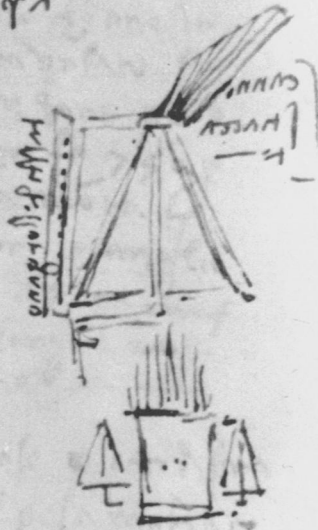
Bernard Berenson describes the figure as a "boar-

FIGURE 2
Page from MS. 8936, fol. 76 recto, National Library, Madrid

Handwritten text at the top of the page, possibly a title or header.

Handwritten text in the upper left quadrant, arranged in several lines.

Handwritten text in the middle left quadrant, positioned above the figure of a man.



Handwritten text in the lower left quadrant, arranged in a vertical column.

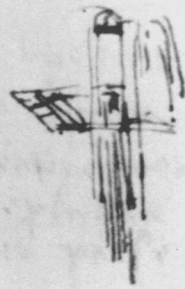


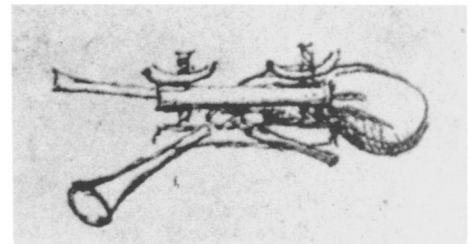


FIGURE 3
Musical instrument with bellows and three tubes (triple trumpet?).
Detail of Figure 2

FIGURE 4
Bagpipe, showing blowpipe, chanter, and drone, played by the angel in the center of the left group. Detail from a fresco of the
Glorification of St. Francis, school of Giotto. Church of San
Francesco al Prato, Pistoia



FIGURE 5
Allegory, bagpipe in a vise. MS. M, fol. 4 verso, Bibliothèque de
l'Institut, Paris



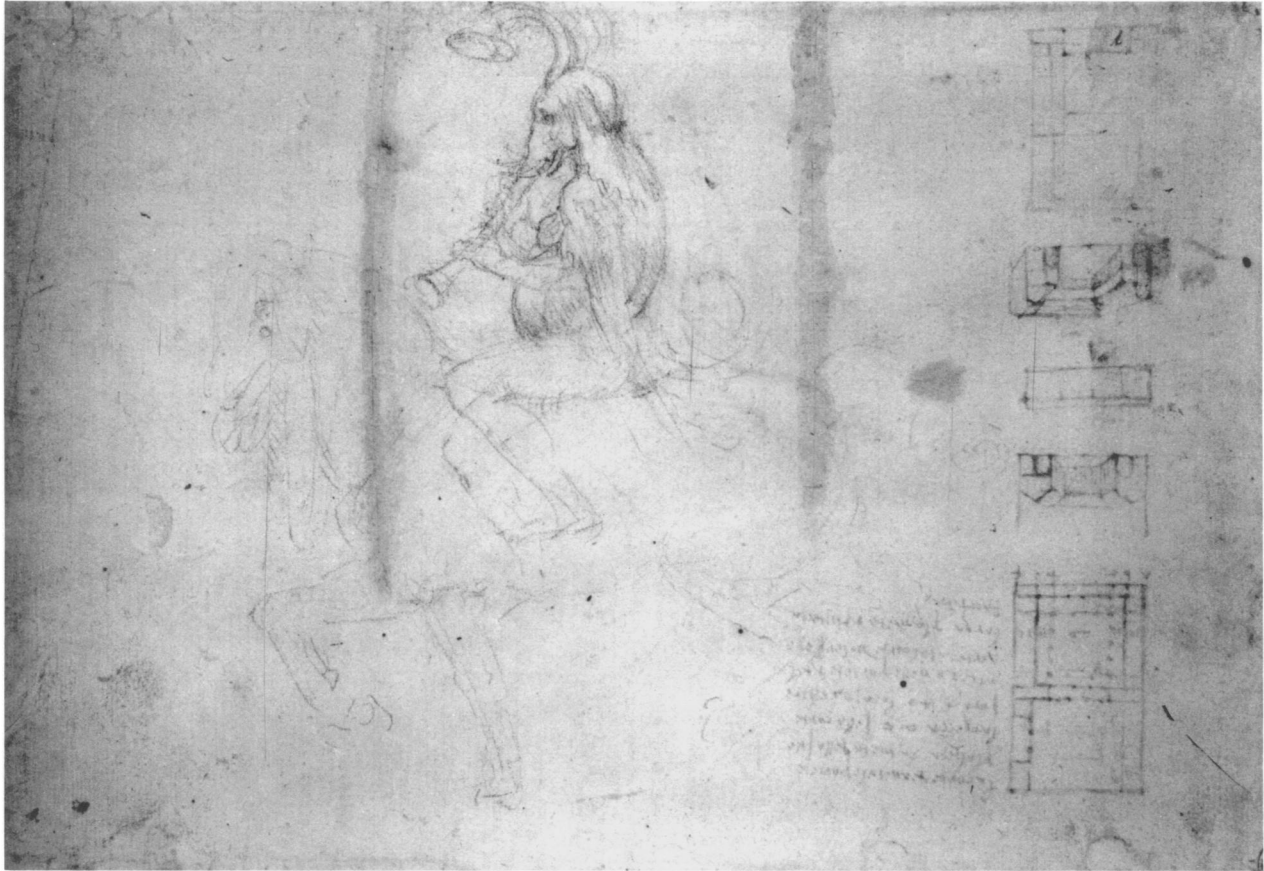


FIGURE 6

Costume for a man masquerading as a bagpipe, from the drawings of Leonardo da Vinci at Windsor Castle, 12585 recto. Reproduced by the gracious permission of Her Majesty Queen Elizabeth II

headed man on horseback, playing on a horn (probably for a masquerade and possibly the one of Galeazzo da San Severino in January, 1491).⁸ Gerolamo Calvi calls the sketch an allegory;⁹ Woldemar von Seidlitz describes the figure as a monster on horseback playing a clarinet;¹⁰ and Edmondo Solmi calls the creature a figure on horseback who sounds a reed pipe with his own nose.¹¹ Heinrich Bodmer identifies the monster as *omo salvatico* without further explanation.¹² Sir Kenneth Clark interprets the drawing as follows: “A masquer-

ader seated on a horse, which is walking in profile to left. He wears a head like an elephant, with long ears like bat’s wings, a curly horn like a gramophone, and a trunk, on which he is playing as if it were a flute. He also appears to have a pot belly, and a curly tail.”¹³ No mention is made of a bagpipe. Giuseppina Fumagalli, in a very interesting article, reviews the earlier interpretations and declares, with cogent and elaborate reasons, that our bagpipe man is one of the *omini salvaticchi*.¹⁴

8. *Drawings of the Florentine Painters* (New York, 1903) p. 62.

9. *Un'allegoria di Leonardo* (Milan, 1904) p. 482.

10. “I disegni di Leonardo da Vinci a Windsor,” *L'Arte* 14 (1911) p. 286.

11. “La politica di Lodovico il Moro nei simboli di Leonardo,” *Scritti varii di erudizione e di critica in onore di R. Renier* (Turin, 1912) pp. 71–72.

12. *Leonardo* (Stuttgart, 1931) p. 203.

13. *Catalogue of Drawings of Leonardo da Vinci in the Collection of His Majesty the King at Windsor Castle* (New York and Cambridge, 1935) p. 99.

14. “Gli Omini Salvaticchi di Leonardo,” *Raccolta Vinciana* 18 (1960) pp. 129–157.



FIGURE 7

Fama with quadruple trumpet in a tapestry depicting the Triumph of Fame, North French or Flemish, XVI century. The Metropolitan Museum of Art, bequest of George D. Pratt, 41.167.2

Actually the rider masquerades as a bagpipe, his belly, or rather his whole upper body, forming the bag, and the continuance of his nose, the chanter. A large drone pipe appears over his head. There can be no doubt that this amusing disguise was drawn for a procession or similar entertainment.

To return to the sketch in the Madrid notebook, the

bellows shown there is indeed ingenious—it consists of two sections arranged to the left and right of an immovable dividing wall. If the right section is pushed against the wall, the air enclosed is compressed and pushed toward the pipes; at the same time, the left section is automatically expanded, inhaling air. This kind of automatically synchronized, alternating breath-

ing is an improvement—or at least a simplification—of the conventional two alternating bellows, which were ordinarily used in Leonardo's time and long thereafter for organs and, of course, for many extramusical purposes, such as the blacksmith's forge and metal-smelting furnaces, and which had to be pumped by two people or two motor impulses.

Leonardo's accompanying explanation reads as if this contraption had occurred to him as a new invention. In fact, I do not know of earlier examples of this type of bellows in texts or illustrations. Perhaps it worked best in small sizes, while for smelting and other industrial purposes the arrangement of two alternating large, separate bellows proved more practical.

At the end of his explanatory text, Leonardo claims that his new bellows produces "continuous wind." This claim, of course, has to be taken with a certain reserve. There is, first, the inevitable dead point when, one of the bellows sections having reached its maximum volume and the other its minimum expansion, the pumping action goes into reverse. This imparts to the pipes a moment of silence, which, however short, is just as noticeable as the pauses between the upstroke and the downstroke of a fiddle bow, or when the player of a concertina turns from the expanding phase to the compressing phase, or vice versa.¹⁵

Quite apart from this dead moment of silence, we have to bear in mind the fact that the wind stops immediately when the bellows action stops. This is not the case with the bagpipe. The sounding pipes of a bagpipe are supplied with wind by a bag, made of the skin of an animal. This flexible wind reservoir is filled with air either from the player's mouth by means of a blowpipe or, in later specimens, such as the musette of the eighteenth century, from a pair of bellows.¹⁶ A bag of this type supplies wind for some time, even after the player has ceased to breathe into the blowpipe or to pump the bellows with his arm. In this way, a real

continuity of sound is achieved.¹⁷ Such a bag is missing in Leonardo's contraption.

Furthermore, another essential feature of the bagpipe is missing: the chanter or melody pipe, which is a reed pipe equipped with finger holes. These are stopped by the fingers of the player to produce the melody, while the larger drone pipes supply the continuous humming bass. Normally, the chanter has a shape different from that of the drones. In Leonardo's sketch, only the pipe on the left pointing down is approximately in the position of a bagpipe chanter, but it has the same shape as the other two pipes and, more important, does not show the faintest trace of finger holes. Therefore, Leonardo's contraption is certainly not a bagpipe, and if he calls it *piva*, he uses this word not as an equivalent for *cornemusa* or *zampogna*, both common names for bagpipes, but in its original meaning, that is, *pipa*, "pipe" or "pipe instrument."

What then is our instrument? Since there are only three tubes—not enough for a scale or melody—and since there is not even machinery for selecting or alternating single tones, we can only assume that three simultaneous tones of different pitch formed a chord, in all probability a triad. The tubes would then be trumpets rather than reed pipes, and the whole machine would be not an instrument designed to play actual music, but possibly a gadget created to sound a three-voice signal as a kind of fanfare. One recalls the manifold activities of Leonardo as an organizer of fêtes, processions, and stage entertainments. Perhaps our musical gadget served as a hidden machine that produced fanfares easily to accompany the appearance of allegorical figures, such as Fama or Gloria, who, by long iconological tradition, had trumpets or even multiple trumpets. Just as one example, I might mention the beautiful quadruple trumpet in the hands of Fama (Figure 7) in one of the early sixteenth-century tapestries at the Metropolitan Museum, representing

15. How much Leonardo was aware of the mechanical limitations of bellows is clear from an observation he made in quite a different realm: "If flies produced with their mouths the sound that can be heard when they fly, they would need a great pair of bellows for lungs in order to produce a wind so strong and long, and then there would be a long silence in order to draw into themselves an equal volume of air; therefore, where there was a long duration there would be a long intermission." Codice Arundel 263, fol. 257 recto, British Museum.

16. The blowpipe, unbecoming to a lady's cheeks, was replaced by a dainty little bellows attached to her wrists. This was the case in the elegant and lavishly decorated musette, the fashionable bagpipe of the perfumed pseudo-shepherdesses in the *fêtes champêtres* of Versailles and Fontainebleau.

17. For the evolution and mechanism of bagpipes, including those of Leonardo's time, see E. Winternitz, "Bagpipes and Hurdy-Gurdies in their Social Setting," *The Metropolitan Museum of Art Bulletin* 2 (1943) pp. 56–83.

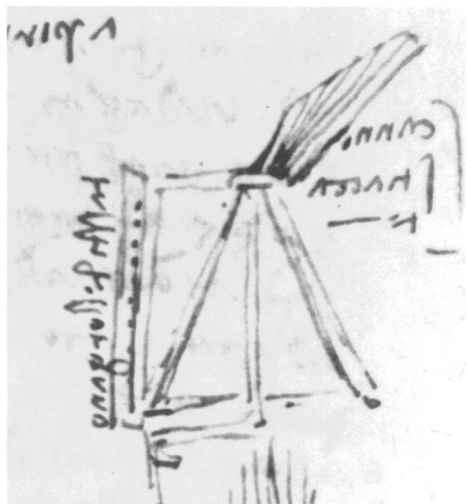


FIGURE 8
Set of pipes worked by a bellows. Detail of Figure 2

the Triumph of Fame over Death, one of the numerous illustrations of Petrarch's *trionfi* in Leonardo's time.¹⁸

Leonardo must have been more impressed with his new bellows than with the whole triple trumpet machine, for in the next two drawings he applied it to a small set of organ pipes and even to a large chamber organ.

The sketch of the portable organ (Figure 8) bears two inscriptions: on the left, *tasti dell'organo* ("keys of the organ"); and on the upper right, *canne stiacciate* ("flat pipes"). As the text on the left reveals,¹⁹ they are made of wood (*righe*) or cardboard (*carta*). Six pipes can be distinguished—a strange number, too many for a chord and too few for a scale, though the sketch may, of course, be only a hasty suggestion.

An indispensable element of an organ, the one by which the single keys open up and shut off the access of the wind to the single pipes, is not indicated at all. Here again Leonardo may not have taken the trouble, as so often happened in his quick embodiments of passing ideas, to include technical details that he took for granted.

The combination of organ pipes and bellows recalls immediately the construction of an *organetto*, an im-

18. See James J. Rorimer, "The Triumphs of Fame and Time," *The Metropolitan Museum of Art Bulletin* 35 (1940) pp. 242–244.

19. "Organi di canne schiacciate fatti di righe o di carta."



FIGURE 9
Positive organ with alternating bellows, from the Unicorn Tapestries, about 1500. Cluny Museum, Paris

mensely popular and practical instrument used in Leonardo's time and for centuries before. We may, therefore, cast a quick glance at various types of *organetti*, concentrating on the question of bellows. If we disregard the larger instruments, which were played on a table and which required the use of both hands on the keyboard and therefore an extra person to operate the alternating bellows at the back (Figure 9), we find the following arrangements used in *organetti*: one small bellows beneath the wind-chest, operated by the player's left hand (Figure 10); a single large bellows at the back of the wind-chest operated by the player's left hand while his right hand pressed the keys with the fingers in a position that would strike a later



FIGURE 10

Angel musician playing an *organetto*, detail, Florence, xiv century. Museo dell'Opera del Duomo, Florence (photo: Alinari)

musician as very awkward (Figure 11); two small alternating bellows at the back of the wind-chest, operated by the player's left hand (Figure 12).

In all these small instruments, where the single or alternating bellows had to be worked by one hand, there was an inevitable pause in the wind supply, and therefore in the music, between the movements of the bellows. However, as the fingers on the keys could play only melodic lines without substantial chords, the pause caused by the bellows mechanism was not more noticeable than that of an experienced singer breathing

FIGURE 11

Angel playing an *organetto* with a large single bellows on the back of the instrument. Detail of the organ panels from Nájera by Hans Memling, c. 1465. Art Museum, Antwerp



FIGURE 12

Angels, one of whom plays an *organetto* with two alternating bellows. Relief by Agostino di Duccio, c. 1460. Rimini Cathedral



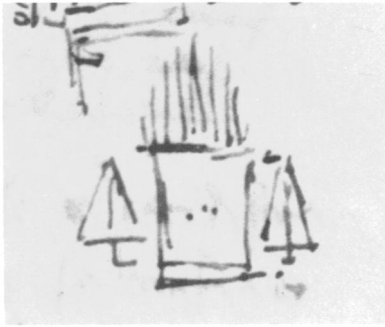
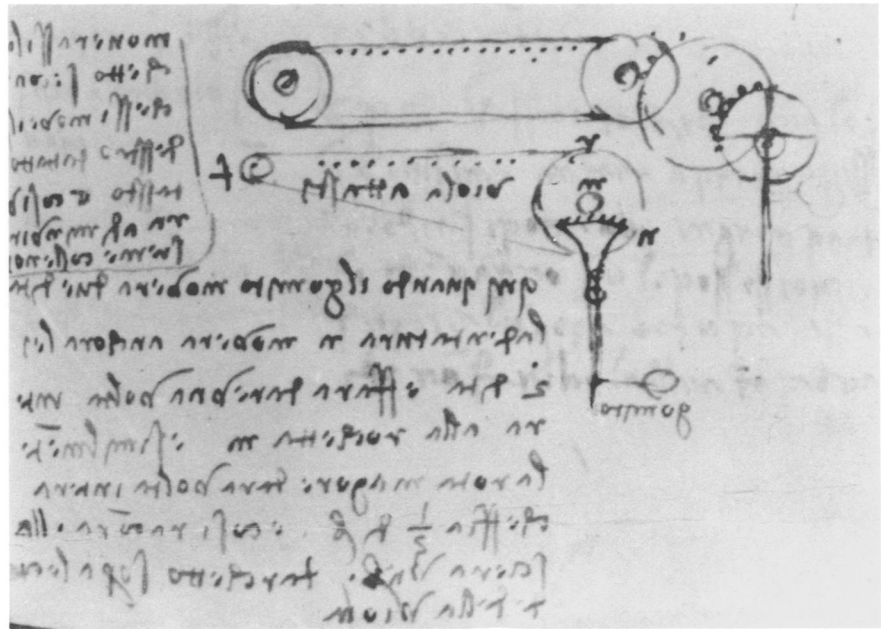


FIGURE 13
Chamber organ with flanking bellows. Detail of Figure 2

FIGURE 14
Two different devices for moving an unending bow of a *viola-organista*.
Detail of Figure 2



in the middle of a phrase. Still, the wind-chest, essential to every *organetto*, must have helped somewhat to bridge these pauses, although it did not have the flexibility of the bag in the bagpipe as a wind reservoir.

At any rate, our sketch does not include any visible wind-chest. Thus the wind supply depended exclusively on the action of Leonardo's special bellows, which, however, as we have already pointed out, immediately stops providing air when pumping ceases. One possibility that would justify the new bellows remains. The sketch shows a little curve at the lower left corner of the bellows. If this indicates a handle, it was perhaps worked with the elbow (*con gomito*), thus leaving both hands free for the keyboard, an achievement that would indeed have meant notable progress if we as-

sume that this instrument was supposed to have many more pipes than the six delineated.

Even more problematic is the small sketch of a chamber organ (Figure 13) flanked by two bellows evidently of the same construction as those in the two upper sketches. The big box from which the pipes arise contains, of course, the inevitable wind-chest that, in every pipe organ, guarantees an even wind pressure and continuous sound just as the bag does in the bagpipe. Therefore, the application of Leonardo's special bellows to this organ makes little sense. Any simple conventional bellows would do just as well.

The operation by *gomito* mentioned earlier may have captured Leonardo's mind to such a degree that he proceeded to extend this playing technique to string

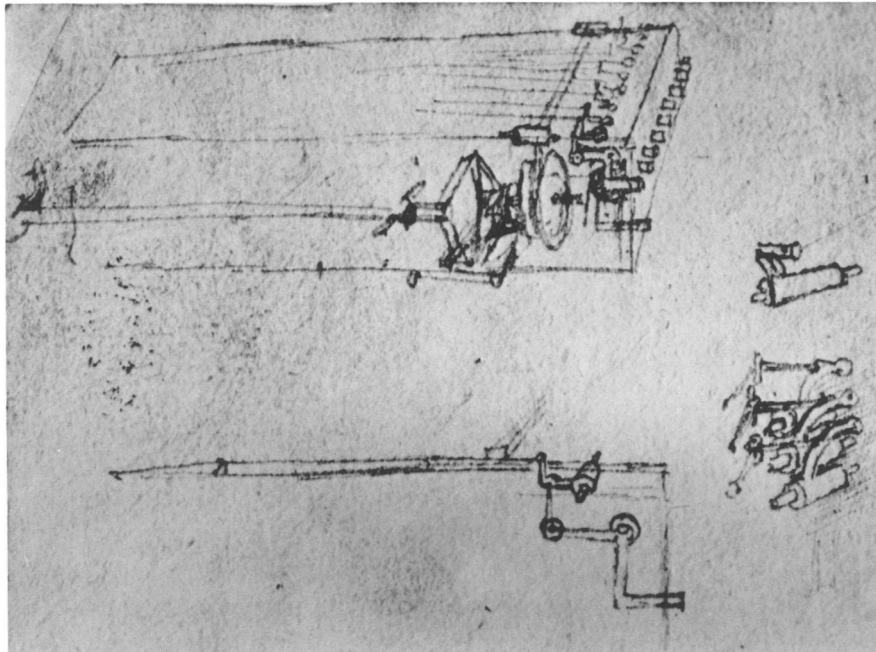


FIGURE 15

Sketch for a *viola-organista* with a cross section of the playing mechanism and two details of the devices for pressing strings against the unending bow. MS. H, fol. 45 verso. Bibliothèque de l'Institut, Paris

instruments. In two sketches at the bottom of the page (Figure 14) he delineated schematically string instruments, of which at least one is operated by an elbow action, again possibly in order to free both hands for the keyboard. Enigmatic as these instruments appear at first glance, their interpretation is easy if one recalls Leonardo's profound interest in the *viola-organista*, a complex instrument that permitted the bowing of many strings through the control of a keyboard, and therefore allowed ten fingers to produce the tone of a whole little orchestra of viols. Leonardo designed many different and elaborate models of this instrument; four of them appear in the Codice Atlantico, folio 218 recto-c, four others in Manuscript H at the Institut de France, folios 28 verso, 28 recto, 45 verso, and 46 recto.²⁰ In early models the friction of the strings was achieved by a mechanical bow traveling sideways, back and forth over the strings or a revolving wheel, as in a hurdy-gurdy (*ghironda*). In later models he turned to the device of a friction belt made of horsehair as an endless bow (*archetto*). The most practical and detailed model appears in the sketch in Manuscript H, folio 45 verso (Figure 15).

Anyone looking at this sketch will easily realize the link with the sketches in the Madrid manuscript, if he

recognizes that the sixteen dots marked in a horizontal line in our upper sketch are nothing other than cross sections of the strings shown in Figure 15. Over these strings moves the endless bow supported on the left and right by two rotating wheels. In other words, the upper sketch in the Madrid notebooks (Figure 14), is a schematic front view of the instrument shown from the side in the illustration in Manuscript H, folio 45 verso. The latter sketch also shows clearly a keyboard, or rather a set of frontal push buttons, which by means of a tracker action, move little circular loops that grasp the strings in order to draw them against the moving *archetto*, which then sets them vibrating.

In the upper sketch in Figure 14 we see two interacting cogwheels moving the right wheel of the two that support the *archetto*. The cogwheels in turn must receive their impulse from some motor, the player or his assistant. The aforementioned sketches in Manuscript H and one in Manuscript B, folio 50 verso, show motors for driving the *archetto*.

The lower sketch differs from the upper one in several respects: It indicates only eleven dots for strings; beneath the dots is written *viola a tasti* ("keyed viol"). The left wheel is much smaller, and above all, the device for driving the right wheel is different: instead of two cogwheels, here only a segment of one is visible; it is operated by a lever with a handle inscribed

20. See Winternitz, "Viola-Organista."



FIGURE 16
Youthful musician in fancy garb. Detail of Figure 2

gomito. The use of this wheel segment does not permit a continuous movement of the *archetto* in one direction but facilitates only a forward and backward movement comparable to that of the actual bow of a viol or any other bowed instrument. All these features point to a smaller and simpler version of the *viola-organista*, and possibly to a portable version. If *gomito*²¹ here means not a movable part of the mechanism but the human elbow, then both hands would be free to operate the keys or push buttons, and this would constitute a substantial advantage over the hurdy-gurdy, in which the keys—a very small number for that matter—are operated by one hand, while the other works the crank to turn the friction wheel.

21. The text to the left and beneath the upper and lower sketch reads: “Moverassi l’archetto secondo che si muove il braccio destro da tasto a tasto e così vorrà a diminuire insieme colle note.” “Qui, quando il gomito muoverà due dita, la dentatura .n. muoverà ancora lei due dita. E farà dare una vòlta intera, alla rochetta .m. E, similmente, la ruota maggiore darà vòlta intera, che sarà un terzo di braccio. E così raccoglierà e lascerà un braccio di archetto, sopra le corde della viola.” This text is largely cryptic because of the repeated use of some ambiguous terms. When *gomito* is used, it can mean the human elbow or certain parts of machines. In the same way, the term *braccio* can stand for the human arm as well as for a unit of measurement.

We have not yet commented on the charming little figure jotted down with a few rapid strokes in the center of the page (Figure 16). Unfortunately the instrument played by this youth is not recognizable; it might be the little organ shown in the sketch to the right of his head, or the viola mentioned twice in the text. In any case, he is a musician in fancy garb; his three-tiered hat,²² short pleated tunic with square neck, and shepherd buskins characterize him as a participant in a masquerade or stage entertainment.

His exotic appearance may provide the clue for the interpretation of all the instruments shown on this page, except for the small chamber organ with the flanking bellows. Evidently these instruments are conceived not for the performance of serious music but as contraptions for fêtes,²³ stage entertainments, or one of the colorful masquerades whose organization and artistic preparation were among the duties of the courtier Leonardo. There are many more sketches of instruments in Leonardo’s other notebooks that must have served similar purposes.

The results of our interpretation, then, are comparatively meager as far as the musical importance of these machines is concerned. However, they are interesting in another way; they show Leonardo’s restless, quick imagination at work, leaping by rapid association from one idea to the next. The triplet trumpet begets the idea of a new kind of simplified bellows with automatic synchronization; these bellows are applied to a small set of organ pipes, and even to a massive, positive organ. Then fantasy takes another turn: just as the bellows can be operated by the elbow in wind instruments, an equivalent simple playing method *con gomito* may be applied to string instruments, and so a smaller portable version of the *viola-organista* is born.

22. My colleague at the Metropolitan Museum, Dr. Olga Ragio, Curator of Western European Arts, has kindly led my attention to the fact that similar hats occur in the embroideries after designs by Pollaiuolo in the Museo dell’ Opera del Duomo in Florence. See Sascha Schwabacher, *Die Stickereien nach Entwürfen des Antonio Pollaiuolo in der Opera di S. Maria del Fiore zu Florenz* (Strassburg, 1911) especially pls. xix, xxxi. The designs for the biblical scenes depicted there may also have been used for or inspired by the performances of sacred plays.

23. See E. Winternitz, “Instruments de Musique étranges chez Filippino Lippi, Piero di Cosimo et Lorenzo Costa,” *Les Fêtes de la Renaissance*, I (Paris, 1956) pp. 379–395.