KEYBOARDS FOR WIND INSTRUMENTS INVENTED BY LEONARDO DA VINCI

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It is odd that the many sketches for musical instruments and musical machines contained in the pages of Leonardo da Vinci's notebooks have never found a thorough and systematic interpretation. It is true that some look rather fantastic, at least to us today, and others are clearly only quick embodiments of passing ideas put down on paper by Leonardo to aid his own memory. However, nearly all the sketches reveal themselves as most interesting, and many as ingenious new inventions, if they are scrutinized and analyzed in the right context, that is, against the background of the instruments existing at Leonardo's time, as well as with a knowledge of the mechanical devices used by Leonardo outside the field of musical instruments, and examined in the light of Leonardo's leading ideals for instruments, which can be distilled from a comparison of all his drawings and from his many remarks on music, musical aesthetics, and acoustics.

The eight sketches on the bottom of page 263 of the Arundel Codex concern one of the crucial problems in the construction of wind instruments with sideholes: the control of fingerholes spaced wider than the reach of human fingers. The laws of acoustics determine the distance between fingerholes bored in the side walls of the tube of a wind instrument in order to obtain different pitches from it; ¹ and the lower the range desired, the longer the tube must be and the larger the distance between the holes. Thus in the building of larger instruments with sideholes, a critical point is reached when a device is needed for transferring the action of the fingers to the distant holes, in order to close them. One device for this purpose is the key or lever, pressed on one end with the finger and closing the fingerhole by means of a pad on the other end.

¹ There are, of course, as any player knows, other means for obtaining a variety of tones, such as overblowing (the special combination of breath and lip pressure to produce harmonics), mechanical devices such as slides and, since the 19th century, valves.
Keys are used today in all so-called woodwind instruments (such as transverse flutes, clarinets, oboes, bassoons, saxophones, etc.).

Keys on woodwind instruments came into use only gradually, however. The first evidence I know of is in Sebastian Virdung’s *Musica getutscht* (Basel 1511).² There, two of the many wind instruments illustrated in the woodcuts show one key:

Fig. 1 Sebastian Virdung. Illustrations showing a keyed shawm and a keyed recorder. From his *Musica getutscht und ausgezogen durch Seb­ bastiamun Virdung Priesters von Amberg . . . Basel, 1511*. Facsimile ed., Robert Eitner, ed., Berlin 1882.

These instruments are: a bass shawm (*Schalmey*), also called a *Bombardt*, and the largest of the recorders, there called *Flöten*. In Virdung’s illustration, only the upper end of the key or finger plate is visible (swallow-tailed in shape for use by either the right or left hand), its lower part covered by a perforated cylinder. The purpose of this key was to control a hole placed out of reach of the little finger. The collection of ancient musical instruments in the Vienna Kunsthistorisches Museum contains several 16th-century Italian shawms with single keys (Nos. A.

² Facs. ed. R. Eitner (Berlin 1882); however, none of the three recorders appearing in the title woodcut of Silvestro Ganassi’s *Regola Rubertina* (Venice 1542) shows a key.
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191, C. 192, and C. 193 in the catalogue by Julius Schlosser, Vienna 1920). They seem, however, to come from the latter part of the 16th century.

But in earlier times it was not only woodwind instruments that had sideholes. There existed wind instruments that had mouthcups comparable to those of trumpets (and other "brass" instruments) and at the same time had sideholes: these instruments were the cornetti of the Renaissance, straight or curved tubes made of wood covered with leather or made of ivory (Pl. 3oa, b). Many kinds existed, of different sizes and shapes—curvi, diritti, muti—and later their larger relatives, the serpents. Still later, in the second half of the 18th century and the beginning of the 19th century, a number of brass instruments with sideholes were constructed: the basshorn, ophicleide, keyed trumpet, keyed bugle, and keyed horn. They all soon became obsolete through the invention of the valve mechanism, a device employing pieces of metal tubing added to the main tube of the instrument to change its pitch.

The family of the cornetto is the only known case of a mouthcup instrument with sideholes at Leonardo's time. And while, of course, we cannot exclude with mathematical certainty the possibility that the principle of sideholes may occasionally have been transferred to the metal trumpet, it is highly unlikely. No picture, sculpture, musical treatise, or any other contemporary record represents or mentions such an instrument.

The eight sketches concerning wind instruments on our page fall into two groups: four on the left dealing with the trumpet, and three on the right dealing with the pipe (zufolo). Evidently connected with these latter is the schematic drawing lowest on the left side; the reasons for this separation will become clear from the following analysis.

We begin with the upper left sketch (Pl. 31, No. 1), which shows a straight tube of cylindrical shape terminating in a narrowly flaring bell; six holes are clearly indicated, and they seem connected with little circles on a stick or tube that runs parallel to the main tube. The whole sketch represents a trumpet with sideholes, equipped with an auxiliary rod beneath it that carries a key mechanism for closing the sideholes. Trumpets of this shape but with no side holes abound in Italian paintings, especially of angel concerts—for instance, in Giotto's Coronation of the Virgin in S. Croce, Florence (Pl. 32a) and in one of the panels of Luca della Robbia's Cantoria (Pl. 32b). Thus, if our interpretation of Leonardo's sketch is correct, we have in it the first conception of a brass in-
strument with sideholes and keys; at least, no trace exists of an instrument of this kind from so early a time.\(^3\)

The second sketch (Pl. 31, No. 2), more elaborate, shows a larger trumpet with wider bell and with seven sideholes. On the right, the tube curves upwards under the auxiliary rod and terminates in a clearly drawn mouthcup. On the right of the auxiliary rod, above rather than below the trumpet in this drawing, we see a keyboard of seven keys, marked “a b.” From the auxiliary rod, seven double lines lead to the seven sideholes. The text (between drawings Nos. 3 and 4) explains, “Tasti stretti, a serrano buchi di gran distanza infra loro, e sono al proposito della tronba prossima di sopra in a b.” (Translation: “Straight keys, they close holes separated by wide distances, and belong to the trumpet drawn above and are indicated by a b.”)

The auxiliary rod appears to be hollow, as we may conclude from its right end: from this opening a faint double line in loop shape appears. I should tentatively venture to guess that these lines indicate wires or threads that run inside the auxiliary rod to connect the touch piece with the closing key. Leonardo has recorded this idea quickly and very sketchily. However, perhaps the same function can be attributed to the two other sets of double lines emanating from the keyboard.

If this conjecture of mine is correct, then one may possibly go one step further and surmise that Leonardo was stimulated in the invention of this keyboard and stopping machinery by his profound knowledge of the anatomy and physiology of the human hand. The threads, then, running inside the sheath that I have called the auxiliary tube, would function like tendons conveying an impulse to the furthest point where movement is wanted, that is, the fingertips or, in terms of our wind instrument, the closing pads. Reading Leonardo’s descriptions and looking at the drawings of the play of moving bones, muscles, and tendons (for example, see his Fogli d’anatomia, Windsor 19009, fol. A, 10\(^v\)) one cannot help being reminded of his technical inventions. An even closer analogy between the stopping machinery and the tendons of the human finger can be found in Folio A, 10\(^v\) of the Fogli d’anatomia, which is accompanied by a text that I quote only in part: “The first demonstration of the hand will be made of the bones alone . . . The fourth demonstration will be of the first set of tendons which rest upon these muscles and go to supply movement to the tips of the fingers . . .” (transl. Edward MacCurdy, The Notebooks of Leonardo da Vinci, London 1938, I, 107). Mechanisms observed by the dissector of the

\(^3\)A keyed trumpet was first introduced publicly in Vienna by Anton Weidinger in 1801 and a keyed horn by Kölbl appeared in St. Petersburg as early as 1760.
human body would lend themselves to use by the maker of mechanical tools and machines. And, on the other hand, the experience gathered by Leonardo as a builder of machines would help him to understand more readily and profoundly the mechanisms made by nature. How conscious Leonardo was of the connection is evident from his plan to introduce his demonstration of the movement and force of man and other animals by a treatise on the elements of mechanics: “Fa che’ll libro delli elementi macchinali colla sua patica vada inanti a la dimostrazione del moto e forza dell’omo e altri animali; e mediante quelli tu potrai provare ogni tua proposizione” (Fogli d’anatomia, fol. A, 10r).

The little schematic sketch beneath the trumpet and immediately above the text (Pl. 31, No. 3) apparently gives a side view of something like a tracker mechanism, connecting the pad that closes a sidehole on the left with a key on the right. The drawing beneath the text (Pl. 31, No. 4) is a more elaborate version of No. 3: on the left, two of the closing levers are shown; on the right, the keyboard is again drawn with seven keys. Leonardo’s verbal explanation, quoted under No. 2, connects this drawing with the two trumpets drawn above (Nos. 1 and 2).

We now turn from the drawings concerned with trumpet keys to the key mechanism for the zufolo (Pl. 31, No. 6). On top we find an elaborate keyboard of no less than ten keys whose thin stems are connected with the horizontal rods or wires that presumably lead to the sideholes. Only the lowest of these horizontal rods shows, connected with it, a bent lever which cannot be anything else than the lever with the closing pad. It is marked with a little a, referring to the text on the bottom of the page, which says: “a entri i’ loco dell-ordinarie poste che hanno i pratici ne’lor busi de’zufoli.” (Translation: “a marks the place where normally the players have the holes in their pipes”; or, more literally: “the sketch a indicates what comes into the place of the ordinary locations where the players have the holes in their pipes.”)

The drawing beneath this (Pl. 31, No. 7) shows the complete mechanism connecting key with closing pad: a long rod turns in loops that hold it at its left and right ends; the right end bends forward and then upward, terminating in a broad key with a square touch surface; the left end bends forward and then down, terminating in what appears to be the closing pad. If the key is depressed, the long rod rotates and

4 At first glance, one may perhaps connect the a with the drawing beneath it and especially with the upright rod immediately below it; but such an interpretation would make little sense, since that rod is evidently a key shaft and far away from the closing pad which alone can be identified with the “loco dell’ordinarie poste dei busi.”
turns the left end down so that the pad closes the hole.

While the rod in No. 7 is straight, the drawing beneath it (Pl. 31, No. 8) shows a rod in the form of a crankshaft. It is held by four loops near its two projecting sections; the projection on the left carries the stopping lever with the pad, and the projection on the right carries a key; still further to the right five more keys appear, inserted into what must be an auxiliary rod like that which we saw attached to the trumpet sketches, Nos. 1 and 2. A schematic sketch of this latter rod, with two projections, appears on the lower left of the page (Pl. 31, No. 5). There can hardly be any doubt that it belongs to the zufolo sketches, particularly to No. 8.

Many details of the mechanisms in these sketches are not as clear as one would wish. However, the drawings are not, after all, blueprints for the workshops of instrument makers but rather are rapid records, embodiments of new ideas confided quickly to paper, to be taken up again and perhaps elaborated at some later time. Yet the gist of these drawings is quite clear—it is nothing less than the invention of a complete keyboard mechanism for wind instruments for the purpose of overcoming fundamentally, and at once, the incapacity of the player's fingers to control distant fingerholes on the tube of his instrument.

Only if we consider the fact pointed out above, that at Leonardo's time wind instruments had no keys, or perhaps at the most one single key, can we estimate the significance and novelty of his idea. A complete keyboard for wind instruments, radically replacing, on principle, all finger stopping, was not introduced into instrument building before 1840. It was then based largely on the inventions of a flutist in Munich, Theobald Boehm, although Boehm incorporated ideas of some contemporaneous flute makers such as Nolan, Nicholson, and Gordon (Pl. 30c). It may not be without interest to mention here that Boehm arrived at his radical invention through an unusual combination of interests, studies, and skills: as the son of a goldsmith, he became skilled in this craft; he also learned to play the flute and built his first instrument at the age of sixteen. He became a professional flute player of wide reputation, composed many pieces for this instrument; and, combining this practical experience with a thorough knowledge of theoretical acoustics, he embarked on his reform of the flute. His invention spread immediately and, by the middle of the 19th century, revolutionized the making of all other woodwind instruments as well. Leonardo da Vinci, in the sketches discussed above, anticipated Boehm's epochal invention by three centuries and one-half.
Plate 30a  *Cornetto curvo* of wood covered with leather. France, early 17th century (New York, Metropolitan Museum of Art, Crosby Brown Collection)

Plate 30b  *Cornetto curvo* of ivory, c. 1600, with gilded mounting and original mouthpiece (New York, Metropolitan Museum of Art, Crosby Brown Collection)

Plate 30c  Silver flute made by Theobald Boehm, Munich, 19th century (New York, Metropolitan Museum of Art, gift of Mrs. J. L. Corning, 1923)
Plate 31 Leonardo da Vinci, detail of wind instrument sketches, British Museum, MS Arundel 263, fol. 175°