PREFACE

Le hardi Vaucanson, rival de Prométhée,
Semblait, de la nature imitant les ressorts,
Prendre le feu des cieux pour animer les corps.

Voltaire

Jacques de Vaucanson was born into an aristocratic family in Grenoble on February 24th, 1709. Of his first years all we know is that he displayed an early interest in mechanical devices. In 1735, at the age of 26, he arrived in Paris to further his studies. A contemporary source informs us that "having applied himself to the sciences since his youth, he spent what little money he inherited in order to perfect himself (in them). He was aware that in his impoverished state it would be impossible for him to finish the moving figures he had started to build, and he dreamed of receiving help by producing some machine capable of arousing the curiosity of the public. He conceived the idea of making a statue playing the flute by means of an embouchure and the action of its fingers".[1] By 1737 he had borrowed enough money to build such a mechanical flute player.
It was exhibited in Paris in 1738 to enormous success. The *Mercure de France* reported the event in extravagant terms:

> At the Hôtel de Longueville, rue St. Thomas du Louvre, for about two months the whole of Paris has been going to see with admiration a phenomenon of mechanics, the most singular and at the same time the most pleasing that has perhaps ever been seen.
>
> It is the representation in wood of a lifesized faun, raised on a pedestal that is harmonious but also strong enough to contain the whole of a complicated action... The outside is painted the colour of white marble. This figure is seated in a simple, appropriate pose, and arranged as it would be in order to play the flute. In a word, it is an exact and very well rendered copy of the faun executed in marble by the famous sculptor Coyzevaux (which is displayed at the end of the great terrace of the Tuillerie Gardens), with the sole difference that the copy we are discussing actually and very realistically plays the flute.
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> One's ears hear the sounds, all their inflections and even the tongue-strokes in a way impossible to imagine. One's eyes see with surprise the articulated movement of the fingers and the means by which the air that leaves by an interior duct and finishes at the mouth of the auto-

1. Reported in Alfred Chapuis & Edouard Gélis, *Le Monde des automates: Etude historique et technique* (Paris: Chapuis; Neuchâtel: Gélis, 1928), Vol. 2. p. 185.

> maton becomes harmonious and susceptible of all kinds of inflections in the greatest faithfulness.
>
> In fact one has the pleasure for more than a quarter of an hour of hearing this mechanised figure play like the masters fourteen[2] *airs*, all different in character, in variety of notes and in tempo.
>
> The *doubles* (ornamental variations), so alluring when played on this instrument, are not forgotten, and the whole playing has swells, diminutions and even suitable holdings of notes, in the most perfect taste. This work, great in its combination of means – a multiplicity of movements, six bellows of various sizes, an infinity of little parts which all have their particular uses – is mounted on a pedestal closely resembling a clock. By means of a crank one can wind the cylinder continuously, or stop it and voluntarily suspend its effect at the end of each *air*.
>
> No one can deny that this is the fruit of many years of toil and the result of a great deal of industry and research. Inventive and mechanical genius are displayed in it, without a shadow of doubt. The maker... is only 30 years old, although his blessed talent is already very well known to all those who look at this singular piece of mathematics...[3]

Another contemporary, Juvigny, recounted how the audience at first refused to believe that the figure was actually playing, thinking that there must be a mechanical musical instrument hidden in the body of the player.[4] But it was in fact an example, the first of which we have any detailed knowledge, of what is now called an androide, a puppet that really plays an instrument and imitates the movements of a real player.[5] Stimulated by his great success with the flute player, Vaucanson also exhibited that year his mechanical duck, which pecked grain, drank water and evacuated the digested food afterwards, and his figure of a Provençal shepherd, which played twenty tunes on the *galoubet* (a shepherd's pipe) with its left hand while beating a drum with its right. These figures were received with no less admiration and astonishment than the flute player. Vaucanson presented a memoir on the working of his three mechanical figures to the members of the *Académie Royale des Sciences* in 1738, which was published as *Le Mécanisme du flûteur automate*, the subject of the present facsimile. In 1746 the *Académie* admitted him to membership. His three figures were soon being exhibited all over Europe. As its title

2. The abstract from the register of the *Académie Royale des Sciences* reproduced in Vaucanson's memoir (p. 18; translation, p. 20) says that there were twelve *airs*.

3. *Mercure de France*, April 1738, pp. 738-39.

4. Reported in Alexander Buchner, *Mechanical Musical Instruments*, transl. Iris Urwin (London: Batchworth Press, n.d.), pp. 85-86.

5. For more information on androides see Buchner, *loc. cit.*

page notes, the English translation of his memoir which forms the second part of the present facsimile, *An Account of the Mechanism of an Automaton or Image playing on the German-Flute,* was published on the occasion of the exhibition of the figures at the King's Theatre in the Haymarket in London in 1742.[6] A contemporary manuscript note attached to the copy of the French version of the memoir in the Gemeentemuseum, The Hague, tells us that the three figures were shown in Middelburg on February 1st, 1744, and "all the spectators were amazed" at their "smooth, natural operation". The flute player, "which plays extremely accurately, as if it were a human being" was "much admired by music lovers". Two separate German translations of the memoir were published in Hamburg in 1747 and Augsburg in 1748, presumably also following the exhibition of the figures in those cities.[7]

Vaucanson's reputation soon became so great that Frederick II of Prussia tried to attract him there. But the perspicacious Cardinal du Fleury conferred on him the elevated position of inspector of silk manufactures, in which he gained further distinction by a series of useful inventions, including a machine for twisting the silk threads.

Vaucanson spent the last years of his life collecting together and exhibiting his various inventions and designs. On his death on November 21st, 1782, he bequeathed his collection to the nation, and in 1798 it became the basis of the collection of the *Conservatoire National des Arts et Métiers*. Unfortunately, the three figures were not among it. No one seems to know what happened to them, although the indications are that they went abroad, and Vaucanson may well have sold them to finance further research.[8]

In the second part of his memoir, Vaucanson describes the workings of his flute player: bellows, which supply air; levers, which move the tongue, lips and fingers, and change the air pressure; and a cylinder with bars fixed at different places that provide the instructions for the performance of the various tunes. This is of course of considerable importance to historians of mechanical musical instruments. But the principal interest of Vaucanson's

6. Dayton C. Miller, *Catalogue of Books and Literary Materials Relating to the Flute and Other Musical Instruments* (Cleveland: privately printed, 1935), cites another edition, London: The Universal Magazine, 1752.

7. "Beschreibung des mechanischen Flötenspielers", *Hamburgisches Magazin* (Hamburg: G. C. Grund) II (1747), pp. 1-24; *Beschreibung eines mechanischen Kunst-Stucks, und automatischen Flöten-Spielers* (Augsburg: J. A. E. Maschenbaur, 1748).

8. Unless otherwise cited, the information on Vaucanson given here is taken from Chapuis & Gélis, *op. cit.*, pp. 149-52, 182-87, 263-68.

memoir for us today is in the first part, in which he uses what the contemporary *Journal des Sçavans* called "the most profound researches into physics and anatomy" [9] to explain the acoustics and playing technique of the flute.

As far as I know, Vaucanson was the first person to write about the flute's acoustics, and indeed the only person in the 18th century. Although he claims in his introduction to owe to the work of members of the *Académie* "the reflections I have made on the sound (that is, presumably, acoustics) of instruments" (p. 3; translation, p. 3), he was presumably unaware of Joseph Sauveur's theory of harmonics or partial tones based on observations of vibrating strings (1701) or did not consider the theory applicable to the flute. Vaucanson's own theory is ingenious and, on the surface, mostly plausible. It has, of course, long been superseded by theories more able to explain all the facts of the situation.[10] But at least it had the virtue that its author was able to put it to immediate and convincing practical use.

Vaucanson's theory of how the flute produces sounds – set out with "great exactitude" according to the *Journal des Sçavans* – is, as the reader may find out, not entirely clear. The substance of it seems to be as follows. Vibrations of air from the player's mouth collide with the edge of the mouth-hole of the flute, then with the "particles" of the body of the flute, then with the air outside the instrument, finally reaching the ear and creating sound. When the "force" of the air is shared among the particles of the flute, its speed is reduced in proportion to the number of particles involved. This in turn affects the pitch of the note produced (the number of vibrations in a given time). The shorter the sounding length of the flute, the fewer the particles to share the force, the greater the number of vibrations remaining, and the higher the pitch of the note. This is true throughout the first octave of the flute, up to the fingering ○○○ ○○○ ○, when the sounding length of the flute is half that for d′. This ought therefore to produce the octave, d″, but does not because of what was later to be called the damping effect of the part of the flute below the controlling tone hole; d″ can, however, be produced by forcing the air to increase the number of vibrations. To produce d″ with the same sounding length as for d′ (●●● ●●● ●), which needs double the number of vibrations in the same time, the force of the air must be doubled.

So far it seems quite logical. Then without further explanation Vaucanson

9. Review of Vaucanson's memoir, *Le Journal des Sçavans*, January 1739, pp. 16-23.
10. See Philip Bate, *The Flute* (London: Ernest Benn; New York: Norton, 1969), chapter 2; John W. Coltman, "Acoustics of the Flute", *The Instrumentalist* XXVII/6 (Jan. 1972), 36-40 & XXVII/7 (Feb. 1972), 37-43; Neville Fletcher, "Some Acoustical Principles of Flute Technique", *The Instrumentalist* XXVIII/7 (Feb. 1974), 57-61; and Arthur H. Benade, *Fundamentals of Musical Acoustics* (London: Oxford University Press, 1976), chapters 21 & 22.

says that the whole of the first octave of the flute requires one particular constant blowing pressure and the second octave a constant blowing pressure of twice as much. The third octave should require a constant blowing pressure of three times as much; but because the vibrations are now so fast, the damping effect of the part of the flute below the controlling tone hole is less than for the first two octaves. Therefore more tone holes must be opened, and the blowing pressure needed is a little less than three times as much as for the first octave. (This provides an explanation for why the third octave necessitates different fingerings than the first two.) Vaucanson's flute player did incorporate such abrupt changes of pressure for the three octaves.

As Vaucanson rightly points out, the flute has the advantage over fixed embouchure instruments of the flute family, such as the recorder, flageolet and organ pipe, that the player can not only vary the blowing pressure (controlled by "the muscles of the chest"), but also vary the size of the opening of the lips and the position of the lips on the mouth-hole, and turn the flute inwards and outwards. He mentions only varying the size of the lip aperture vertically – also a feature of his mechanical flute player – although Jacques Hotteterre le Romain's *Principes de la flûte traversière* (1707), the only flute tutor published before Vaucanson's memoir, had already advocated varying the aperture horizontally as well.[11] The increased air pressure needed to produce higher notes is furnished by both blowing harder and decreasing the lip aperture. Later he adds that the lips of his flute player are also moved forwards on the mouth-hole, which he says is equivalent to a live player turning the flute inwards; both these are methods for changing the angle at which the air stream hits the edge of the mouth-hole. He does not mention the other advantage of the flute, namely that one can also vary this angle by moving one lip more forward than the other – although this is recommended by Johann Joachim Quantz's *Versuch einer Anweisung die Flöte traversiere zu spielen* (1752), published only fourteen years after Vaucanson's memoir[12] – and his flute player does not incorporate the means to do so.

11. Jacques Hotteterre le Romain, *Principes de la flûte traversière, ou flûte d'Allemagne, de la flûte à bec, ou flûte douce, et du haut-bois* (Paris, 1707). Facsimile of Amsterdam edition of c. 1710 with German translation by H. J. Hellwig (Kassel: Bärenreiter, 1942), p. 8. English translation ed. David Lasocki, *Principles of the Flute, Recorder and Oboe* (London: Barrie & Rockliff; New York: Praeger, 1968), p. 45.

12. Johann Joachim Quantz, *Versuch einer Anweisung die Flöte traversiere zu spielen* (Berlin, 1752), chapter IV, para. 9. Facsimile of 3rd (1789) edition, ed. Hans-Peter Schmitz (Kassel: Bärenreiter, 1953). English translation ed. Edward R. Reilly (London: Faber & Faber; New York: Free Press, 1966), p. 52.

Vaucanson's advocation of increased blowing pressure to produce the higher notes is strongly criticised by Quantz.

> In producing the notes (from d″ to g‴), on no account must the wind be increased or doubled, as Mr Vaucanson erroneously teaches in his (memoir), asserting that the octaves can be produced in no other way on the transverse flute. Actually they must be effected by the compression of the air in the mouth hole, which results from advancing the chin and lips: hence the former opinion is a completely false and harmful one. Its falseness is also evident from the fact that you can sustain your breath longer in the upper register than in the lower; hence it is impossible that more wind is used in it. I admit that Mr Vaucanson's method is necessary for a flute played by a machine, since the movements of its lips are limited.[13)]

On the contrary, Quantz gives the rule that "the notes in the low octave must always be played more strongly than those in the high octave",[14)] no doubt on musical grounds, since the low notes are less penetrating than the high. He continues:

> From experience I also know, however, that the rule that the low notes must be played strongly and the upper ones weakly is disregarded on such mechanical flute players. If the octaves were to be produced by strengthening and doubling the wind, it would follow that the high notes would have to be blown more strongly than the low ones, which is contrary to the nature of the flute, and makes the high notes exceedingly coarse and unpleasant. Thus you must not allow yourself to be misled by the reasoning of Mr Vaucanson...
>
> It is true that there are many flute players who transgress against these rules. Bad embouchure is the cause. Instead of covering half of the mouth hole with their lips, these players leave it open too far, so that they are prevented from withdrawing the lips sufficiently in the low notes, and from advancing them sufficiently in the high notes. Thus, because the mouth hole is open too far, they must necessarily force out the high notes with stronger blowing. They know nothing of the necessary movement of the chin and lips, and allow them to remain constantly fixed, although playing in tune on the flute mainly depends upon movement of this kind.[15)]

Yet, as we have seen, Vaucanson was well aware of the importance of the backwards and forwards movement of the lips and incorporated it into the mechanism of his flute player, so this criticism cannot be levelled against

13. *Ibid.*, chapter IV, para. 14 (translation, p. 54).
14. *Ibid.*, chapter IV, para. 21 (translation, p. 57).
15. *Ibid.*, chapter IV, paras. 14-15 (translation, p. 54).

him. Presumably his insistence on increasing the blowing pressure was based on contemporary French flute practice, since it is also taught by Hotteterre[16] and Michel Corrette's *Méthode pour apprendre aisément à jouer de la flûte traversière* (c. 1740),[17] albeit without the abrupt changes for each octave. A modern scientific study of a number of professional and advanced amateur flute players has shown that with remarkable consistency they used a combination of all three methods of producing the higher notes: increased blowing pressure, forward movement of the lips, and reduction of the lip aperture.[18] Quantz simply used the last two of the three methods, and Vaucanson the first two.

Vaucanson's explanation of a tongue-stroke, though brief, is at least more accurate than those of Hotteterre and Corrette,[19] in that it recognises the fact that the function of the tongue is to release the pressure of the air for a moment, rather than to strike the air in some way ("tongue-stroke" is a misnomer).

Hotteterre had said nothing in his flute tutor about dynamics, even though in the following year he published his famous piece called "Echos" for solo flute, in which each phrase is played consecutively loud and soft.[20] Vaucanson's theory of flute dynamics, again less than ideally clear, is as follows. At a given blowing pressure, if the mouth-hole of the flute is completely open, a large quantity of air will be admitted to the flute, thus colliding with a large number of particles of the flute, then with a large quantity of air outside the instrument, producing loud sounds. On the other hand, if the flute is turned inwards so that the lips cover more of the mouth-hole, less air will be admitted to the flute, thus colliding with a smaller number of particles of the flute, then with a smaller quantity of air outside the instrument, producing softer sounds. Then comes an ambiguous passage (8/9):

> Therefore when there is Occasion to swell a Note (that is, make a *decrescendo* then a *crescendo*), first you turn the Flute inwards, that

16. Hotteterre, *op. cit.*, p. 7 (translation, p. 44) says that "you must augment your breath, little by little, in proportion as you ascend". He also makes the size of the lip aperture smaller (7-8/45).
17. Facsimile ed. Mirjam Nastasi (Buren, The Netherlands: Frits Knuf, 1978). Corrette (p. 10) says that "in proportion as the notes rise, you must augment your breath, but by imperceptible gradation, for the first octave, d' to d''; but to make... the notes above, you give a little more breath, always cautiously so that it is neither too strong nor given jerkily".
18. See Fletcher, *op. cit.*, p. 58.
19. Hotteterre, *op. cit.*, p. 6 (translation, p. 44) says that "you must give a tongue-stroke to each note – that is, articulate your breath as if you were pronouncing the syllable *tu* sharply". Corrette (p. 20) says that "the tongue-stroke is nothing but the little blows which the tongue gives against the opening of the lips".
20. Published in *Pièces pour la flûte traversière et autres instruments avec la basse continue. Livre premier, oeuvre second* (Paris, 1708).

the Lips coming over the Edge of the Hole may suffer but a small Quantity of Wind to go in or out, which is then driven (or, which one drives) weakly to produce a weak Sound; then insensibly (gradually) turning the Flute outwards, the Lips allow of a greater Passage and Return to the Wind, which at that Time is driven (or, which one takes care of driving) with greater Force, that it may be communicated to a greater Quantity of Air, and thereby increase the Sound. ...

This may be supposed to mean that, say, moving the lips forwards automatically makes the sound weaker, or else that one moves the lips forwards and at the same time blows more softly. This is never clarified in the theoretical part of the memoir. But in his discussion of the workings of his mechanical flute player, Vaucanson's admission that

in swellings of the sound I had, during the time of the same note, to substitute a strong wind for a weak, and a weak for a strong, and at the same time to vary the movements of the lips – that is to say, to put them in their correct place for each wind (16/19)

shows that in practice he varied both the forward and backward movement of the lips and the blowing pressure. (He ignores the possible effect of the variation in blowing pressure on the validity of his theory.)

Yet even what Vaucanson claims to be his practice is puzzling, because altering the blowing pressure and moving the lips backwards and forwards change not only the dynamic but also the pitch of the note (and mostly also the tone quality), unless one also changes the size of the lip aperture. For example, both increasing the blowing pressure and moving the lips backwards increase the dynamic and raise the pitch, although the former adds overtones and the latter subtracts them. Now changing the *width* of the lip aperture was impossible on his flute player. But since he repeats in the section on dynamics his comment that one of the advantages of the flute is that "the Wind may be modulated by the greater or less Opening of the Lips..." (7/8), perhaps in varying the dynamics on his flute player he varied the *height* of the lip aperture. Live flute players do not use this procedure, but it is possible that moving the lips backwards and increasing the height of the lip aperture, probably while increasing the blowing pressure, could be made to increase the dynamic without changing the pitch. However, there is a limit to the effectiveness of this procedure[21], and the

21. Fletcher, *op. cit.*, p. 60 reports that the modern flautists he studied did not make the height of the lip aperture exceed about 1.3 mm. He notes that "we might have expected... that a jet more than 1.3 mm in thickness would have had more power and produced a louder sound than a 1.3 mm jet. However, the larger lip opening and thicker jet simply produces a dull *mf* sound with little intensity. The reason for this is that the thicker jet is less responsive to the tube vibrations and so produces a tone with less harmonic development".

tone quality would be changed considerably. Quantz's practice was quite different (and perhaps more effective in that the tone quality would probably be changed less): he says that to play more softly you blow less, withdraw the lips and turn the flute outwards; to play more loudly, you blow harder, advance the lips and turn the flute inwards.

Finally, Vaucanson suggests that the faulty tuning of certain notes on the old flute (for example, in the first two octaves the F-sharps were too flat and the F-naturals too sharp) should be corrected by moving the lips backwards or forwards, which he says is equivalent to a live player turning the flute outwards or inwards, and by blowing harder or softer. Hotteterre and Quantz also adjust the intonation by these means.[22]

A few words should be said about one of Vaucanson's other figures, the pipe and tabor player. Of this instrumental combination Anthony Baines has written:

> This unique one-man band... comprises: 1. pipe (tabor pipe, three-holed pipe): a flageolet played with the left hand only; 2. tabor (pronounced 'tabber' by English folk music authorities): a small snare drum slung at the left side of the body or from the left arm; and 3. drum stick, held in the right hand. The pipe (of wood, generally in one piece) preserves the cylindrical bore of the primitive cane flageolet, and the technique is founded on the readiness and good intonation with which a narrow-bore flageolet can be overblown to its higher harmonics. The fundamentals of a tabor pipe can be sounded, but are not used. The scale begins an octave higher, with the 2nd harmonics, and is continued upwards, by harder blowing, through 3rd, 4th, 5th harmonics and even higher. In this, the widest interval between registers is that of a fifth between the 2nd and 3rd harmonics, so that three finger-holes suffice to provide the four notes needed to make the scale continuous. This leaves one hand free to wield the drum stick. The holes are two in front for fingers I and II, and a thumb-hole above them at the back. The third and little fingers grip the end of the pipe from above and below.... The well-known French tabor pipe, the *galoubet* of Provence... is a small-bore instrument, 7.5 millimetres bore, a foot long, and normally in D (Vaucanson's is in E).[23]

Since the embouchure is fixed, the only means of producing the higher notes is by increasing the breath pressure, and there is no argument with Vaucanson's theory. As he explains, his mechanical player incorporates means of furnishing a different pressure for each note.

22. Hotteterre, *op. cit.*, chapters 3-7, *passim*. Quantz, op. cit., chapter IV, para. 23 (translation, p. 58).
23. Anthony Baines, *Woodwind Instruments and their History*, 3rd edition (London: Faber & Faber, 1967), pp. 224-25.

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