HISTORY

OF THE

ROYAL

ACADEMY

OF
THE

SCIENCES

YEAR 1724

with the memoires of Mathematics and of Physics

for the same year

drawn from the Records of this Academy

IN PARIS

AT THE ROYAL PRESS

1726

ACOUSTICS

ON THE STRINGED INSTRUMENTS of music

All springs from philosophy, even pleasures, for they have their causes, and all causes belong to it. M. de Maupertuis has sought out why the stringed musical instruments, such as the violin, the theorbo, the lute, etc. have the shapes they have, why these are not strings of different lengths stretched on plates shaped like a parallelogram, or strung in space on a kind of chassis, like those of the lyre of the ancients, or even of the modern harp.

It is known that all the bodies which surround up to a certain distance a sonorous body are for it so many echoes, whose reflected sound unites with the direct sound it has sent out, and strengthens it more or less, according as the reflection has been more or less lively. Everyone has experienced what is the difference in this respect between a room lined with wood, and one that has but its walls.

The reflection is never so strong as when the reflecting body is at the unison with the sounding body, that is to say when the disposition of the parts of the reflecting body is such that, struck with the same blow as the sounding body, it would give off the same pitch. Then the reflected sound strengthens the direct as much as is possible, it doubles it. If the reflecting body is too far away from the pitch of the sounding body, it does not reflect at all, at least perceptibly, it remains motionless. Everywhere between these two extremities, it alters more or less the pitch

of the sounding body.

An instruments string has a certain pitch determined by its natural length, by its thickness, and by its tension, but in addition it all the different pitches that the hand can give it in shortening it. All the strings together give an infinity of different pitches. To procure for them the aid of favorable reflections, they are stretched on a plate that they agitate as soon as they are agitated, which has very mobile parts, and sorts of strings of all lengths, and whose direction is the same as that of the strings of the instrument, so that there are always some of them which find themselves in unison with some string or other of the instrument, and easily take on its motion. It is clear enough that these strings of the plate are the fibers of the wood, and from this it comes that the shapes of the instruments are not parallelograms, in which all the fibers would be the same length.

We are not at all examining the interior cavity of the instruments destined to make echoes, nor the plates of the back, which have the same use as those of the top.

The drier and lighter the wood, the more mobile are its fibers, and detached from each other, so that the pitch of one is less changed by that of the others, which are little agitated at the same time. For this reason old instruments are usually better.

Since it depends on chance whether there be a greater or lesser number of fibers in unison with one pitch or another, an instrument will produce a stronger sound at a certain pitch. if And at the same time, among the other fibers which are not in unison with that pitch, there are few that are agitated, and trouble it by their particular pitches, this instrument

will be both stronger and clearer on this pitch than on the others. We also see from this that it may be stronger on one pitch, and clearer on another.

Sometimes through breaking and repairing and instrument becomes better. The wound has shortened the fibers, which were asking to be, for greater perfection.

p 92

An instrument will be the most perfect that it can be, when the number of different fibers, which respond to different pitches, will be the most equal that may be, and when, the fibers of a pitch being in motion, there shall be but the smallest number possible of fibers of another pitch that come into play.

A kind of spinet, which is square, seemed at first to reverse all the ideas of M. de Maupertuis. But he noticed very quickly that on the belly it has oblique bars, which give different lengths to the fibers. Thus the system was found on the contrary to be confirmed, and THERE, he said, IES A SORT OF REPARATION THAT MUTINOUS EXPERIMENTS OWE TO THE PHYSICIST FOR THE ALARM THEY HAVE CAUSED HIM.

M E M O I R S O F T H E R O Y A L A C A D E M Y O F T H E S C I E N C E S

O N T H E F O R M O F T H E I N S T R U M E N T S O F M U S I C

B y M. d e M a u p e r t u i s

Music may be considered under two different aspects; through the relationships that exist between the sounds, or by the effects that these sounds produce on us. If we consider in music the different relationships the sounds have with each other, it will be a science; if we consider but the different effects the sounds have on us, it will be reduced to pure pleasure. 15 Nov 1724

Music having these two parts, knowledge and pleasure, it is not surprising that pleasure should have had the preference. It is, I believe, to this cause that one should attribute the little progress the theory of music has made up to our century, while the practise seems to have been pushed to perfection. Music has fallen into two portions, to people of imagination and of sentiment. We know well enough how rare it is for these talents to be found joined with the spirit of research and exactness; these are almost incompatible qualities.

The rules of the theory, well established, might perhaps have led to pleasure; but this road would have been long indeed; and while awaiting

these rules, we have preferred to rely on sentiment, a much quicker means, and often indeed more certain for recognizing beauty.

However, since nothing comes into being without reason; that pleasure itself is subject to certain laws, which however unknown they are, are none the less laws; if it is true that the theory of music might have led to pleasure, it would have to be, that pleasure having been found first, the rules formed according to it should be the rules of theory, and those from which one would have started, if one had begun with the theory. These are two different methods to follow, but which should lead to finding the same results; perhaps even this latter, though less bold and less ingenious, has the advantage over the other of being more certain. We risk less to go astray, when we seek the cause of a fact we already know, than when we would find by reasoning what effects would follow some principles that have been announced.

Music offers us a wide field for applying this latter method. The musicians have found the facts for us; it is for us to try to explain them.

I have attempted in this Memoir to recognize good sense in the form that is given to the stringed instruments. I am going to relate a few reflections I have made, which may tend to perfect them, and to explain several singular facts that we observe in these instruments.

There are very good reasons for thinking that those who invented the first instruments were not great physicists. On this occasion, more than on any other, chance would have led the first inventors. For the first stringed

instruments that were made, it was proposed perhaps only to string cords that could give different pitches. It seems that the frame of the lyre was but a ~~chassis~~ kind of chassis destined to this use; but it was soon percieved that the strings gave a stronger or weaker sound, as they were attached to bodies of different kind; and without thought of discovering through reasoning which bodies were more advantageous for augmenting the sounds, they were sought through experimentation. p 217

They combined in a hundred different ways the application of strings to pieces of wood of different shapes, and it is only the result of a long stretch of time and of a great number of experiments that has established the form we see in the instruments of today.

But when an art lasts a long time, be it only in the hands of workers, it reaches the point of perfection to which the most enlightened physicists might have been able to lead it. The path of groping is often long indeed, but is almost always the surest. We shall see that time has given to instruments the form that physics advocated for them.

An instrument to be perfect, should, either through the number of its strings, or through the shortening that can be given to its strings, produce all the tones used in music; and since the shortening given to the strings, when the finger is put on the [illegible], does precisely the same thing as if they were different strings, we shall examine all these different lengths of the same string, as though they were different strings.

So let us leave out of account the entire body of the instrument. Let us suppose that an instrument has as yet but this first condition, that is to say, that it has only all the strings capable of giving all the pitches employed in music; all the art now consists in augmenting these sounds which are too weak to be agreable, when they are produced just by a string attached at its ends. About this it must be noted:

1. That every stretched string that moves, also moves by mediation of the air the surrounding bodies up to a certain distance: and that these bodies, set in motion, each give a sound that joins that of the string.

2. If the string is contiguous with the surrounding bodies, that is to say, if the string is attached at its ends to some of them, and that these touch the others, the motion of the string will communicate itself much more easily, and in consequence the sound will be much stronger.

3. The bodies whose vibrations are isochronal, or at least at the octave, 4, 5, of those of the string, are much easier to agitate by the blows of the string than the others, and moreover their pitch (?) is the same as that of the string.

Thus if one wishes to augment the sound of a string, one could make use of the three means that these remarks indicate to us.

1. It would be necessary to place in the neighborhood of the string bodies of such kind and at such distance that they might be agitated by the blows of the string.

2. It would be necessary that not only the extremities of the string should hold to one of the bodies it should agitate; but further that all these bodies be contiguous, that is to say that those to which the string is attached touch all the others. Through this the agitations will be transmitted much more easily, and consequently the sounds will be much stronger.

3. In the choice to be made of these bodies, it would be necessary to prefer those whose vibrations will be isochronal with those of the string, for they will be easier to agitate than the others, and (~~that~~) the pitch they add to that of the string is the same the string already had.

One would think that the instrument makers had proposed to themselves all these conditions to be fulfilled: they have made use, perhaps without thinking about it, of all these means of rendering an instrument resonant.

1. The different pieces of the instrument on which the strings are stretched make a prodigious assemblage of fibers. These fibers, which, like the strings of the instrument, have been during the life of the tree, vessels and intestins, contracted and dried, and are, one might say, so many stretched strings near the first, which receive from it their agitations, and which join their sound to its.

2. The bridge and the 'sillet' on which the strings bear, being common to the strings and to all parts of the instrument, establish this contiguity which facilitates extremely the communication of the blows. (vibrations) p 219

3. Finally the third and last condition for the perfection of the instrument is, as we have said, that we must prefer the bodies that make the unison with the string.

But since there should be on an instrument strings at all the pitches, if the fibers of the instrument were all at unison with one of the strings, the instrument would be in accord with but the single pitch of that string, and perhaps some one of its harmonics. Therefor there had to be distributed to each string an approximately equal number of fibers of the instrument.

The tops and the backs of the instruments, as we have remarked, but an assemblage of strings or of fibers of approximately equal thickness and elasticity in a homogeneous wood, such as is ordinarily used in making the instruments.

If the strings or fibers were all of the same length, they would all be at the unison, and their pricipal use would be for but one of the pitches of the instrument.

Thus it had to be that there would be found in all the instruments a certain quantity of fibers of each length proportioned to each pitch the instrument could make. Then each string would have its corresponding fibers; it will be these fibers that it will choose, to agitate, and whose sound will join with its own; all the fibers of the other strings receiving but very little of the agitation.

It seems that they applied themselves in the shape given to tops and backs of all the instruments, but to bring it about that there would be found there fibers of all lengths, one has only to cast the eyes on these instruments to perceive this.

Figure 1, is that of of the top of a clavecin.

Figure 2, is that of the top of the spinet a lItalienne.

Figure 3, is that of the psalterion.

Figure 4, is that of the marine trumpet.

We see at a glance that these tops are cut in such a way that there are fibers of several lengths that seem even to follow the lengths of the strings, and which make rows in the same direction, which further facilitates the mutual vibration.

I do not pretend to say however that the fibers of each string are found precisely under that string; the different elasticities and thicknesses of the fibers make it hardly possible to determine the location of each fiber, it is enough that in the great number of fibers of unequal length, some be found to in unison with each string so that this string may, so to say, proceed to select them, when it has need of them.

All that i say here about tops should be applied to backs, with the [illegible]tic exception one might make for the luth and the theorbo, of which the back, instead of being flat, is arched, or domed, but these domes being but an assemblage of different lengths, may be considered as flat backs.

Figure 5, is that of the top of the lute and of the theorbo.

Figure 6, is that of the guitar.

It is evident that they give fibers of all lengths, and in the direction of the strings.

Figure 7, is that of the top of "Dessus & Basses de Viole".

Figure 8, is that of violins and "Basses de Violon".

The inequality of lengths of fibers is still more apparent in these instruments than in the others, by reason of the crescents A B C which cut the tops and backs.

There is reason to believe that these crescents were originally made only to permit passage of the bow on these robust instruments; we draw from them them however another service, which is to vary the lengths of the fibers.

So several different causes have contributed to give to the instruments the shape they have. The convenience of those who play them; even the pleasure that comes from the sight of these different forms. These causes have without doubt been combined with those that produced the excellence of the instrument.

But these figures which seem so unlike, all agree however in this property, that they give to the instrument fibers of all lengths and in the same direction as the strings.

(Figure 9)

Only the square spinet upset my whole system. The top and the back

of this instrument are two rectangles in which, visibly, all the fibers are of the same length; it had to be, then, that the lute makers were right, in the construction of this instrument, to neglect the different lengths of fibers, which reversed what we have established, or that they would have found means to remedy this inconvenient equality of the fibers.

It is this that they do by the bars HI, KL, MN, OR, which they glue to the top of this instrument. These bars are, on might say, so many bridges, which being placed obliquely under the fibers, divide them into different lengths.

That which had thus seemed to me an invincible objection, provided me with new proofs of the necessity of fibers of different lengths.

Experiments, conforming in all to a physical system, do not confirm it perhaps as well as those which might seem at first to be contrary to it, and which, better examined, submit to the laws of the system; it is a kind of indemnification that a rebellious experiment owes to the physicist for the alarm it has caused him.

All the different openings that are made in the tops serve again in cutting the fibers into different lengths. Especially the openings FG of the viols, violins, and of their basses, transversal as they are to the fibers of fibers, seem even more destined to give different lengths.

I do not wish however to restrict the usage of all these cuttings to this alone; they also serve, both to let pass the air that has been struck by the fibers inside of the instrument, and to allow more movement and

more play to the parts of the instrument.

Although the top and the back are the principal parts of the instrument, all the rest of the framework, like the sides, the neck, the bridge, the "queue" (?) still has its use. The very room in which an instrument is played is then a sort of instrument body; the walls, the wainscot, the vaults, the very furnishings, like mirrors, all offer pulsating parts, and in consequence, some sound, to the string that is touched; indeed there is nothing left useless, when the instrument is resounding.

Here an objection presents itself. All the fibers of the wood, although distinct, are closely bound together, how then can each have its particular motion.

To this I answer, 1. That I do not at all mean that when one fiber moves, the others remain perfectly at rest, all the fibers are affected; I say only that they make different vibrations, and that they have more or less motion, according as they fall in more or less consonant agreement.

2. That experiment proves that each fiber gives off its particular pitch. One can be assured of this by tapping the tops of instruments in different places; one will hear different pitches.

3. Finally the fibers are not more closely interbound than are the different circles that make up a bell, and which nevertheless do not cease to have their distinct motions, since according as one strikes a bell higher or lower, it gives off different pitches.

Mr Perrault, in his treatise "On Noise", 'du Bruit', has indeed observed

that the tops of instruments divided into different sections, which, outside the general motion of the top, moved each one separately, when the corresponding strings of the instrument were played; but it does not seem that he has given to each fiber a particular motion, he seems on the contrary to considerthese different motions as partial motions that would occur in a top of metal, and of any other material that would not be composed of fibers.

It is this which makes him say that the thickness of the top should be proportionned to the strings of the instrument; it is indeed true that the different thicknesses of the top cause the parts to give different pitches. 223

But it seems that Mr Perrault has not considered that the fibers of tops were so many strings, and that all the shapes that were given to tops served much more efficiently than the different thicknesses to give fibers at all the pitches; and too, did he not propose only to discover the general cause of sound, and not the causes behind the different constructions of instruments.

The objection one might make that certain instruments, like the lute, the theorbo, the guitar, etc., are sometimes of ivory, of shell, or of wood full of knots, proves nothing, or proves for us.

For 1. these instruments always have a top of pine.

2. They are ordinarily just as duller as the others, unless, as may sometimes come about, unless the number and energy of the fibers of their tops indemnify them for what they lack.

In accordance with what we have noted, that when a string moves, the fibers at tha unison set themselves in motion much more easily than all the others; in the construction of instruments, it seems that one ought to try to bring it about that in the tops and backs were to be found fibers only at the unison of each pitch.

An instrument so constructed, would have without doubt the advantage over the others, in that beyond its being more sonorous, its sound would be still cleaher; for although the vibrations of all the fibers of the instrument add each their pitch to the principal pitch of the string, all those that are not precisely at the unison, or at one of its harmonic pitches, indeed augment the noise of the instrument, but insofar as they augment it, so far they diminish the cleanness of the sound.

If one wanted to construct instruments in that light, it would have to be that the fibers, instead of diminishing insensibly, diminished by leaps, and according to the lengths of the strings to which they should conform , which would give an entirely different shape to the tops, they would be terminated by straight lines which would make right angles. They would then be an assemblage of several bands of fibers which, if they were all homogeneous, would be in the relations of the numbers 24, 27, 30, etc which would give to the top the figure 10.

But this construction would be subject to great inconveniences. 1. To the difficulty of finding woods homogeneous enough for all their fibers of

the same length to be at the same pitch. 2. One could not tune an instrument so constructed, to profit by its construction, other than at the pitch of its fibers.

Thus it has been correct to hold to the ordinary shape of tops in which we find fibers of all lengths, and in which, if certain ones do harm when the instrument is at a given pitch, these same ones serve when it is tuned to another.

I do not speak at all here of several other causes which may contribute to the augmentation and to the modification of the sounds, such as the different materials of which the instruments are consttucted, and the different cavities of these instruments, this would depass the limits i have set for myself, and will be material for another memoir.

Let us come now to an explanation of several phenomena to be observed in these instruments, it will not be difficult after all we have just said.

1. From the fact that each fiber should move and lend its pitch to the string, when the string is in motion, can be seen that it is necessary that there be some interval between the fibers of the wood, that they be able to move.

In newly cut wood, the fibers are still coarse vessels full of juices which were to be the nourishment of the tree. As the wood ages, these vessels dry, contract, and consequently detach themselves from each other.

And so the intervals they leave between them allow them to make their vibrations more at ease, the sound of the instrument should be stronger from this, and we notice indeed that instruments have need of aging to be good.

2. We see also why, though an instrument be sonorous, it will be never-the-less more so, if it is tuned to a certain pitch, rather than to any other, higher or lower; the pitch that will suit it the best will be that at which the distribution of the fibers to each string will be most even.

3. Although all instruments may give all pitches through the length or the smallness of the strings that are affixed, however too sharp a pitch for the big instruments, such as the "Basses de Viole and de Violin", is shrill and weak; as a pitch too low for the small ones, such as the "Dessus de Viole & de Violon", is dull and faint. It is to the lack of fibers at the unison in the one and the other case that can be attributed the cause of these effects; it is apparent that finding few or no fibers in the instrument capable of being moved by a pitch too high or too low for them, they remain almost useless, and hardly anything is heard but the sound of the string alone.

4. We notice on most instruments that not all the tones are equally strong, nor equally clear; it is fairly rare that an instrument excellent for the high pitches be also excellent for the low pitches, or that an instrument excellent for the low pitches be also excellent for the high

pitches;

The reason for this is evident. The excellence of an instrument for the high tones denotes a great number of fibers in unison with these high tones, and the fibers of the instrument may be of such delicacy and of such elasticity , that in spite of their different lengths, there be found but very few for the low pitches, so the high pitches will be stronger and clearer than the low pitches. And on the contrary, if the fibers are so coarse and slow to move, that in spite of their different lengths, but very few are found for the high pitches, then the low pitches will be stronger and clearer than the high pitches.

It may happen even often that the fibers that are lacking in the instrument are neither the fibers the most prompt, nor the slowest to make their vibrations, and that in all of the different lengths there be found not any fibers of a certain pitch; the which may come from the fact that the fibers which by their lengths were destined for this pitch, prove to be too fine or too coarse, and are at the unison of some other pitch. Then the weak pitch will be one of the average pitches of the instrument. Indeed we find excellent instruments, which have however one or several pitches greatlyy inferior in force and in cleanness to all the others.

5. It has been noted several times that an instrument, formerly mediocre, had become much better after having been broken and reglued.

This way of making an instrument better, which seems so strange, conforms however to all that we have said; the instrument lacked fibers of certain lengths , and the breaking of the top and back gave them to them; for although the same pieces are reglued at the same places where they were before, the length of the fibers is always determined by the scars, it being almost impossible that the ends of a fiber be found to be precisely opposite each other, when the piece is reglued that had been separated from the instrument.

The explanation of all these phenomena seems so natural after the reflections that we have made, that it is still further a kind of proof of what we have established. It is always however but a physical hypothesis, and consequently subject to a certain degree of uncertainty which is essentially attached to these sorts of materials.

We must content ourselves with conjectures; but there are conjectures of different degrees, all more or less removed from certainty; and there are some that approach it so strongly, that they may be taken for it; or at least one might suspect him who proposes them, of deluding himself. of himself being mistaken.