

May 24, 1883.

THE PRESIDENT in the Chair.

The Presents received were laid on the table, and thanks ordered for them.

The following Papers were read:—

- I. "On the Function of the Sound-post and on the Proportional Thickness of the Strings of the Violin." By WILLIAM HUGGINS, D.C.L., LL.D., F.R.S. Received May 21, 1883.

Sir John Herschel says: "It (the bridge) sets the wood of the upper face in a state of regular vibration, and this is communicated to the back through a peg set up in the middle of the fiddle, and through its sides, called the 'soul' of the fiddle, or its sounding-post."*

Savart says: "L'âme a pour usage de transmettre au fond les vibrations de la table . . . son diamètre est déterminé par la qualité du son qu'on veut avoir; il est maigre quand elle est trop mince, et sourd quand elle est trop grosse."†

Daguin, in his "Traité de Physique," devotes a whole page to the discussion of the functions of the sound-post. The most important sentences are the following:—" . . . l'âme n'agit pas comme conducteur du son . . . Il nous semble que l'on doit expliquer l'effet de l'âme de la manière qui suit. L'âme, ou les pressions extérieures par lesquelles on la remplace, a pour effet de donner au pied du chevalet un point d'appui autour duquel il vibre en battant sur la table de son autre pied. Si l'un des pieds n'était appuyé sur un point fixe, il se releverait pendant que l'autre s'abaîsserait, parceque les cordes n'agissent pas normalement à la table, puisque l'archet les ébranle très obliquement, ce qui entraîne le chevalet dans un mouvement transversal quand il n'a pas de point d'appui fixe. Lorsque l'archet est dirigé normalement aux tables, cet inconvénient n'existe plus, et l'âme n'est plus nécessaire."‡

Helmholtz says: "The vibrating strings of the violin, in the first place, agitate the bridge over which they are stretched. This stands on two feet over the most mobile part of the belly between the two

* "Encyclopædia Metropolitana," Article "Sound," p. 804.

† "Mémoire sur la Construction [des Instruments à Cordes et à Archet," 8vo., Paris, 1819. Also Biot's "Report," "Ann. de Chimie," tome 12, pp. 225-255.

‡ "Traité de Physique, Acoustique," tome 1, p. 575.

'f' holes. One foot of the bridge rests upon a comparatively firm support, namely, the sound-post, which is a solid rod inserted between the two plates, back and belly, of the instrument. It is only the other leg which agitates the elastic wooden plates, and through them the included mass of air."*

The experiments† which follow have been made for the purpose of ascertaining whether it be any part of the function of the sound-post to convey vibrations to the back, or whether this post acts solely as a prop supporting the belly, so that its elasticity is not injured by the pressure from the strings, and also, as Daguin states, affords the firm basis which he considers necessary for one foot of the bridge.

Mr. Hill, and other practical men, maintain that the quality of the wood of which the sound-post is made affects the tone of the violin, as undoubtedly do very minute differences of position. If the quality of the wood is important we must admit that vibrations are conveyed by the post.

Whether or not the sound-post exercises the function of transmitting vibrations, it is obvious (1) that it performs the important duty of contributing to the support of the belly; (2) that the nodal arrangement of the belly, and also that of the back, are influenced by the pressure of the ends of the post against the upper and lower plates; (3), that Helmholtz is right, at least so far that the leg of the bridge under the 4th or G string has much more power than the other, in setting the belly into vibration.

The usual way of investigating vibrations by the scattering of sand over the surface of the agitated body is difficult of application to the violin, on account of the curved form of the upper and lower plates. I found a convenient method to be by the use of what I may call a touch-rod. It consists of a small round stick of straight-grained deal a few inches long; the forefinger is placed on one end, and the other end is put lightly in contact with the vibrating surface. The finger soon becomes very sensitive to small differences of agitation transmitted by the rod.

The experiments were made on a strongly made modern violin, and in some cases repeated on a fine violin by Stradiuarius in the possession of the writer.

The sand method, and also the touch-rod, showed that the position of maximum vibration of the belly is close to the foot of the bridge under the 4th or G string. The place of least vibration is exactly over the top of the sound-post behind the other foot of the bridge. The back is strongly agitated, the vibrations being least

* "Sensations of Tone," translated by Ellis, p. 137. In the 4th German edition this passage remains unaltered.

† I wish to express my indebtedness to Mr. A. J. Ellis, F.R.S., for some suggestions in connexion with these experiments.

powerfully felt where the sound-post rests, which is at nearly the thickest part of the back. These effects were very satisfactorily observed on a violoncello, where the phenomena are on a larger scale.

When the sound-post was removed from the violin, the large difference of the amount of vibration on the two sides of the belly was no longer present, the belly was about equally strongly agitated on both sides, making allowance for the string which was bowed. The tone became very poor and thin, as is well known to be the case when the sound-post is removed. The vibration of the back was now very feeble, as compared with its vibration when the sound-post was present, a circumstance in favour of the view that the sound-post conveys vibrations to the back.

A clamp of wood was prepared which could be so placed on the violin, as to connect by an arch of wood outside the violin the place of the belly behind the bridge where the top of the sound-post presses, with the place of the back where it rests. It was expected that the wooden arch would restore to some extent the connexion of belly and back which was broken by the removal of the post, and carry, though imperfectly, vibrations from the upper plate to the back.

When this clamp was put on, the poor and thin sound was altered to the fuller character of tone which belongs to the violin when the sound-post is in its place. On testing the condition of the back its normal state of vibration was found to be in a large degree restored. If, while the strings were being bowed, the clamp was suddenly removed, the tone at the same moment fell to its poor character, and the vibration of the back as instantly diminished.

It was further observed that if the upper part of the clamp pressed upon the belly without the lower part coming into contact with the back, the tone was altered in the same direction as when the sound-post was present, but it was not until the lower part of the clamp was in contact with the back that the normal character of the tone was fully restored. A similar effect to that resulting from the pressing of one end of the clamp only was produced by firmly placing one end of a wooden rod at this part of the belly. This effect may be due to the setting-up in the belly, by pressure at this part, of the peculiar nodal arrangement which the post produces when in its place.*

* According to Daguin some similar experiments were made by Savart, but I have failed to find them in those of his papers to which I have had access.

“On peut la (l'âme) mettre en dehors, en l'appuyant à une espèce d'arcade dont on colle les pieds de chaque côté du violon. . . . On peut la remplacer par la pression d'un poids convenable appuyé sur la table supérieure.” “Savart a conclu de là que l'âme a pour effet de rendre normales les vibrations de la table. . . .” “*Traité de Physique*,” tome I, p. 575.

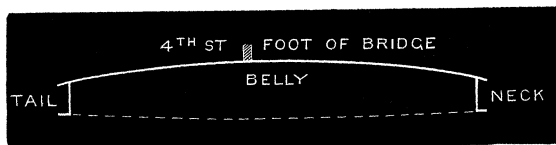
There could be no doubt that vibrations were carried by the clamp, for the lower end was powerfully agitated when the upper end rested upon the belly. If the sole function of the sound-post is to serve as a firm prop for the foot of the bridge, it should fulfil this condition most fully when placed under the foot of the bridge. In this position of the sound-post, however, as is well known, the tone is much injured.

In order to separate that part of the function of the sound-post which serves as a support from the further function it may possess as a transmitter of vibrations, it was desirable to introduce such alterations in the structure of the sound-post as would enable it to retain its supporting power, and yet greatly modify and, if possible, stop its power of transmitting vibrations. A sound-post was made in which about half an inch of the middle was cut out, and a piece of lead inserted, also a sound-post in which instead of lead sealing-wax was put in. The effect of these compound posts, which retained uninjured their prop power, was to modify greatly the quality of the tone, but not to diminish its quantity in any marked degree, a result in favour of the view that the character of the wood of which the post is made does influence the tone, and that vibration is transmitted by the post. As these compound posts could transmit vibrations freely, it was desirable to contrive a post which would not carry vibrations and yet form a firm prop. A post was made with a piece of hard India-rubber inserted in the middle, but this post was found by experiment with a tuning-fork to transmit vibrations to some extent. Other materials were tried without success. A post capped at each end with pieces of sheet vulcanized rubber stopped almost completely the sound of a tuning-fork when the foot of the fork rested on the rubber over one end of the post, while the other end equally protected with rubber rested on a body capable of reinforcing the sound of the fork. This rubber-capped post was firmly fixed in position in the violin, so that it would be able to support fairly well the belly and foot of the bridge, and yet not be able to carry vibrations; unfortunately it does not seem possible, from the nature of things, to have a *rigid* prop which does not transmit vibrations, but this post with thin sheet rubber at the ends firmly forced into position, must have been fairly efficient in its supporting power. The effect on the tone was about the same as when the sound-post was removed. When the wooden clamp was put on, then the normal tone returned, and the back vibrated strongly.

These experiments appear to show that the sound-post is more than a prop, and that besides its other functions, it does transmit vibrations to the back in addition to those which are conveyed through the sides.

Experiments with sand and the touch-rod appear to me to show that Helmholtz's statement is too absolute when he says "it is only

the other leg of the bridge which agitates the elastic wooden plates." Undoubtedly it is the 4th string foot of the bridge which is the more powerful in agitating the upper plate, but the other foot appears to me also to have an influence. When the post is placed exactly under the foot of the bridge, then the belly on this side is almost without vibration; if the post is absent, then this foot appears to agitate its own side of the belly as strongly as the other foot. As there is no post on the 4th string side of the fiddle, that foot stands in a position most favourable for setting up vibrations in the belly, being nearly halfway between the supports of the belly at the



tail and the neck end of the violin. The other side of the belly, on the 1st string side, where the other foot of the bridge rests, is divided into two parts by the damping effect of the end of the sound-post, namely, the part *a* and the part *b*. It is obvious that this foot



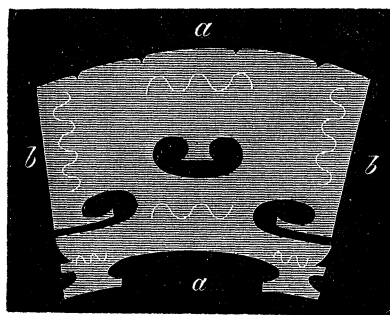
of the bridge is unfavourably placed for setting the part of the belly, *b*, into vibration, since it is so far from its central mobile part. On the other hand, its position is favourable for a portion of its energy of vibration to be transmitted through the post to the back.

Practically very small differences of position of the top of the post behind the foot of the bridge are found to alter largely the character of the tone of the fiddle, and in the case of fine instruments the setting of the post is an operation demanding much care and judgment. The explanation lies probably in the circumstance that a small difference in the position of the post will alter greatly the proportion of energy passing through the post to that which is absorbed into vibrations of this side of the belly. At the same time it must also alter slightly the nodal arrangement of the belly which must have an influence on the tone. If from the form of construction, or relative quality of the wood of the upper plate as compared with the under plate, the conditions of a violin are such that the highest quality of tone of which it is capable requires a relatively larger amplitude of vibration of the back, the position of the sound-post should be nearer

the bridge. In a contrary condition of things the sound-post should be farther from the bridge. The extreme range needed in different violins is about a quarter of an inch. At the same time any shift of the post must affect the relative mobility of the two sides of the belly.

If the sound-post transmits vibrations, these will be in addition to those received from the sides of the violin. It may be, therefore, that one condition which determines the best position of the post, is the degree in which from their form and material these fulfil this duty. All the sides must share in this duty, but the touch-rod shows that a large part of this action is borne by the parts of the sides which curve inwards under where the strings are bowed. It is in harmony with this view that Mr. Hill states, that if the inside blocks at the corners, which are put to strengthen these parts, extend in a small degree into these curved portions, the tone is injured.

The plane of the vibrations of the strings is that in which they are bowed, which is more or less oblique to the bridge. The vibrations may be considered divided into two sets at right angles to each other, *a* and *b*.



The touch-rod shows that these vibrations exist strongly in the upper part of the bridge. I venture to suggest that the use of the peculiar cutting of the bridge, which was finally fixed from trials by Stradiuarius, is to sift the vibrations communicated by the strings and to allow those only, or mainly, to pass to the feet which would be efficient in setting the body of the instrument into vibration, the other vibrations which would be injurious in tending to give a transverse rocking motion to the bridge being for the most part absorbed by the greater elasticity given to the upper part of the bridge by the cutting. Below the two large lateral cuts the touch-rod shows a very great falling off of the vibrations *b*. In the case of a violoncello these vibrations were also very greatly reduced below the side openings of the bridge.

The violin on which the experiments were made was without a bass bar, which is a piece of pine glued to the under side of the belly on

the 4th string side. This bar is regarded as strengthening the belly, and also enabling it to respond better to the lower notes. The touch-rod showed no difference in the general behaviour of this violin, from a fine one by Stradiuarius containing a bass bar.*

On the Proportional Thickness of the Strings.

As the lengths of the strings are the same, we have only the two conditions of weight and tension on which their pitch depends. It is obvious that for equal pressure on the feet of the bridge, as well as for more convenient fingering and bowing, the strings should be at the same tension. They should, therefore, differ in weight, so as to give fifths when brought to the same tension. The weights of the strings must be inversely as the squares of the number of vibrations, which, in the case of fifths, is as 3 to 2, namely, as 9 to 4. As the first three strings are of the same material, it is more convenient to take their diameters, which must be as 3 to 2, that is, each string in advancing from the 1st string must be half as thick again as the string next to it. In the case of the 4th string covered with wire, we must find the weight of the 3rd string of gut, and take a 4th string of which the weight is 9 to 4 for the 3rd string.

A good average thickness of 2nd (A) string is 0·0355 inch. Then the strings should be—

$$\begin{aligned} 1\text{st} &= 0\cdot0237 \\ 2\text{nd} &= 0\cdot0355 \\ 3\text{rd} &= 0\cdot0532 \end{aligned}$$

A gut string 0·0532 inch in diameter weighs, when of the same length as a 4th string, 0·98 grm., then the 4th = 2·20 grms.

Ruffini sells sets of strings in sealed boxes, and these were found to be in about the same relative proportion to each other as the sizes indicated on the gauges sold by several makers.

The measures of a set of Ruffini's strings were found to be—

$$\begin{aligned} 1\text{st} &= 0\cdot0265 \text{ inch.} \\ 2\text{nd} &= 0\cdot0355 \text{ ,,} \\ 3\text{rd} &= 0\cdot0460 \text{ ,,} \\ 4\text{th} &= 1\cdot4100 \text{ grm.} \end{aligned}$$

* In the "Early History of the Violin Family," Engel, speaking of the Crwth, says :—"Furthermore, the contrivance of placing one foot of the bridge through the sound-hole, in order to cause the pressure of the strings to be resisted by the back of the instrument, instead of by the belly, is not so extraordinary and peculiar to the Crwth as most writers on Welsh music maintain. It may be seen on certain Oriental instruments of the fiddle kind which are not provided with a sound-post. For instance, the bridge is thus placed on the three-stringed fiddle of the modern Greek, which is only a variety of the ordinary rabab, but which the Greeks call lyra. Inappropriate as the latter designation may appear, it is suggestive, inasmuch as it points to the ancient lyra as the progenitor of the fiddle."—P. 28.

It will be seen that the 1st string is thicker, and the 3rd thinner, and the 4th much lighter than the theoretical values. Therefore the tension of the 1st string would be greater, and that of the 3rd and 4th strings less than they should be in relation to that of the 2nd string. The greater flexural rigidity of the 4th string will have a small effect in the direction of making the vibrations quicker, and therefore of making the tension required less.

By means of a mechanical contrivance I found the weights necessary to deflect the strings to the same amount when the violin was in tune. The results agreed with the tensions which the sizes of the strings showed they would require to give fifths.

A violin strung with strings of the theoretical size was very unsatisfactory in tone.

The explanation of this departure of the sizes of the strings which long experience has shown to be practically most suitable, from the values they should have from theory, lies probably in the circumstance that the height of the bridge is different for the different strings. It is obvious, where the bridge is high, there is a greater downward pressure. By this modification of the sizes of the strings there is not the greater pressure on the 4th string side of the bridge, which would otherwise be the case. On the contrary, the pressure is less, which may assist the setting of the belly into vibration. There is also the circumstance that the strings which go over a high part of the bridge stand farther from the finger-board, and have therefore to be pressed through a greater distance, which would require more force than is required for the other strings, if the tension were not less.

II. "Note on the Atomic Weight of Glucinum or Beryllium."

By J. EMERSON REYNOLDS, M.D., F.R.S. Received May 8, 1883.

In the course of a paper by Professor Humpidge on the above subject, recently read before the Society,* the author seeks to decide between the atomic weight 9.2 for beryllium, resulting from my comparison of the atomic heat of the element with that of silver and aluminium,† and the value 13.8, arrived at by MM. Nilson and Pettersson by determination of specific heat.‡ The difference between the two possible atomic weights is so small, and the difficulties met with in

* Read April 12, 1883.

† "Chemical News," vol. xxxv, p. 124, and vol. xlii, p. 273. A slight modification of the method of comparison adopted is described in detail in the writer's "Experimental Chemistry" (Longmans), Part I, p. 59.

‡ "Proc. Roy. Soc.," vol. 31, p. 37.

4TH ST

FOOT OF BRIDGE

BELLY

TAIL

NECK





