The Violin

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Part 2. Continuing the discussion of one of the most important instruments in music. This installment covers the basic construction of the body of the instrument.

IN LAST MONTH'S installment, the history of the violin was discussed briefly, and some of the basic characteristics of the tone-producing operation were described. While the violin is apparently an instrument which is reasonably familiar to most laymen, many will be surprised as the intricacies of its construction. It will be seen that this instrument is not just "a cigar box with a handle on it."

The Bridge

Figure 5 shows the shape of the bridge as finally determined by Stradivarius. The name bridge is very apropos, for it acts as a bridge over which the vibrations of the string may pass to the body of the violin, thence to the confined air, and finally out through the *f*-holes to the air in the room.

The bridge is at a node of the string; indeed, it establishes a node in the string where the latter passes over it. But this does not mean that there is no vibration whatsoever at the bridge; rather it means that the impedance to the propagation of the vibrational energy is much higher in the bridge than in the string. As a result of such an impedance discontinuity, reflections and standing waves are set up in the string, but some of the energy does pass on through the bridge and into the body of the violin.

Figure 6 indicates the action of the string on the bridge. The lowest or G string is shown. The bow causes it to vibrate laterally as is indicated by the double-headed arrow F. It causes the bridge to rock on foot A as a fulcrum, and foot B presses down on the top of the violin body setting it into vibration. The moment of the string is the force F it exerts on the bridge multiplied by the lever arm *a* (assuming for the moment that the bridge acts as a rigid body).

The top or belly of the violin reacts with a counter force at B. which has for its lever arm distance *b*. The two moments, of course, are equal and opposite; the force at B is equal to Fa/b. The question may arise as to why the bridge does not rock on foot B, and set the belly of the violin into vibration at point A. The reason is that the belly under foot A is stiffer and resonant to a higher frequency than the part under B, so that for the low-frequency G string the vibration is as indicated.

The E string is located over foot A. When it vibrates, it causes the bridge to rock, presumably on foot B as a fulcrum, and the foot at A causes the belly of the violin to vibrate, because the belly here is more nearly resonant to this range of frequencies. With regard to the A and D strings located in between the G and E strings, the probability is that the fulcrums are somewhat less clearly defined, and both feet rock and cause the belly to vibrate to some extent beneath them. In short, the bridge is not a well-defined bell-crank lever, and is probably caused to rock more or less on both feet, depending upon the frequency involved.

The incisions in the bridge, shown in *Fig.* 5, undoubtedly introduce a certain amount of compliance or "give" in the bridge. Such shunt compliance tends to break up the vibratory mass of the bridge into separate sections, thus forming a number of low-pass filter sections in cascade. This is the same principle as that employed in the original orthophonic Victrola and in the double-voice-coil speaker of Olson: namely, to extend the frequency response by dividing one large mass into two or more smaller masses with shunt compliances interposed between them. The result is a more extended frequency response than would perhaps be obtained from a solid bridge. It is remarkable that Stradivarius and even those before him hit upon this expedient without actually knowing the scientific reasons behind it.

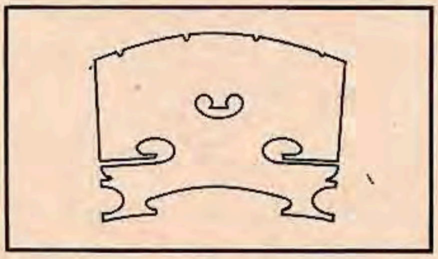

Fig. 5. The bridge.

The bridge is not glued to the belly of the violin, but its feet must fit the belly precisely, otherwise the compliance at the point of contact will be too great and the higher frequencies particularly will not be transmitted to the body of the violin. The tone is then "hollow and dull."

The height of the bridge is important. If it is too high, lever arm *a* of *Fig.* 6 is too great relative to lever arm *b*, and presumably the impedance match between the string and the belly of the violin is impaired, particularly for the higher frequencies. At any rate, the tone is dull and "sluggish," which means it lacks higher frequencies. On the other hand the tones are fairly loud.

If the bridge is too low, the tone is not as loud, but is harsh and piercing, which means that the higher harmonics are unduly accentuated. It is said that a high bridge accentuates the faults in a fiddle, which faults are glossed over by a low bridge.

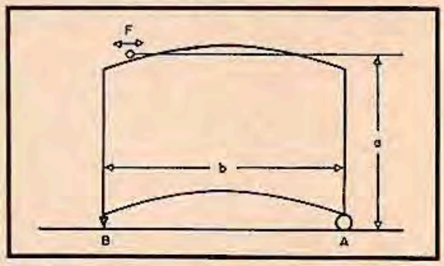

Fig. 6. Lever arms involved in bridge action.

The Body

The body is a composite structure of pine or spruce and maple, and is the heart of the instrument. The top or belly is made of pine, usually with two pieces glued together edge to edge to form a seam running down the middle of the violin. This is also the direction in which the grain of the wood runs; if the grain ran cross-wise, the tone would not be as brilliant.

The back and sides are made of maple, although pear and sycamore wood have also been used. The back is also usually made of two pieces of wood glued edge to edge, and for the same reason: it is more difficult to obtain one single piece of wood of the proper characteristics.

The ration of stiffness to mass is higher in pine than in maple, so that an identical shape would have a higher pitch when set into free vibration. However, the presence of the *f*-holes in the pine belly tends to lower its pitch in spite of the bass bar, and the maple back is made thicker so that its pitch is about one note higher when struck or bowed like a string.

This difference in tone between the top and bottom before they are glued to the sides appears to be important to the final tone of the violin. If the back is made thinner so as to have the same tone as the belly, the violin is found to give a feeble and unsatisfactory tone. Even if there is a difference in pitch, but the difference is less than one tone, the

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sound of the instrument is found to throb. However, if the difference is greater than one tone, the results are said to be even more unsatisfactory. More will be said about this presently.

The thickness of the wood is important. It must not be too thin, otherwise the tone is weak and feeble. This depends, however, on the shape. The old German violins were high-breasted (highly arched), which made their top and bottom structurally stiffer. In order to have the correct pitch, the wood had to be made thinner. In this case the main disadvantage is that the instrument tends to be too weak to withstand the pull of the strings. This, by the way, corresponds to a total pull of 68 pounds, and the vertical pressure on the bridge is about 26 pounds. Yet the entire violin weighs but 8½ ounces!

If the wood is too thick, the tone is sluggish and dull, which indicates suppression of the harmonics. Nevertheless, a violin with thicker wood will develop in time with continued playing, and will probably withstand the ravages of time more successfully than a violin made of thinner wood (within reason, of course).

The body encloses a certain volume of air, which must be correct so as to resonate at the proper fundamental frequency. This corresponds to about 300 cps, which is in the range of the G string.

The comments of musicians concerning the proper volume is of interest: If the air volume is too great, the low notes are weak and dull and the high notes are sharp and thin. If the volume is too small, the low notes are coarse and those of the E string lose their brilliancy. We note, in passing, that in the case of the cello, the depth is relatively greater than that of the violin, in order to avoid too large an instrument.

When the body is glued together, it shows a strong resonance peak around B flat on the A string. This can be distressingly strong, in which case it produces a tone that varies cyclically in intensity, and is known as a "wolf note" from its ululant nature. Cellos are particularly plagued by this phenomenon.

Experiments by Kessler indicate that it corresponds to a particularly strong mode of vibration of the pine belly of the instrument, with one node coinciding in part with the bass bar under the G string, and another node under the E string and passing through the sound post.

Elimination of the wolf note is not easy; in the case of a violin it is a fairly sharp peak, and if it can be made to fall between two adjacent notes of the instrument, it will be less objectionable. In the case of the cello it unfortunately is a broad resonance peak and embraces approximately four notes, so that its elimination is exceedingly difficult.

Directly under the G string, and running for 10½ inches of the length of the instrument, is the bass bar, *Fig. 7.* It is made of pine, cut to fit the contour of the belly, and glued to its under side. Its action appears to be that of adding stiffness to the belly along its line of contact and therefore to raise its frequency. This effect compensates for the lowering of the stiffness and hence natural frequency of the belly when the *f*-holes are cut; the bass bar restores the natural frequency back to approximately C, or 512 cps once more. It also prevents segmental vibrations of the wood in this region, in contrast to the sound post.

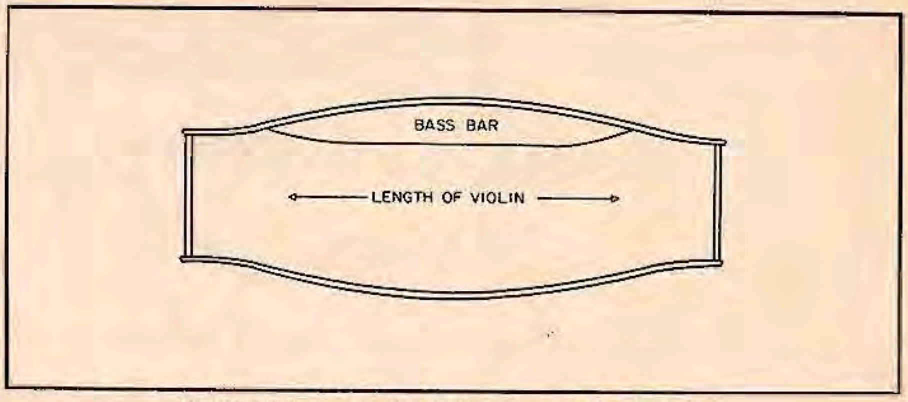

Fig. 7. Side cross-sectional view showing the bass bar.

The sound post is a ¼-in. rod or dowel of white pine, which is inserted vertically as a kind of prop inside of the body between the belly and back of the violin. As is indicated in *Fig.* 8, it rests in a line with the right foot of the bridge (directly below the E string). Actually it is set about ¼-in. behind or below the foot of the bridge, with its grain at right angles to that of the belly.

This is perhaps the most important element in the instrument; upon its setting and thickness depends the tone of the instrument. In the first place, we note that it is not glued to either the belly or back, but merely wedged between the two. As such its action appears to be similar to that of the finger on the string when playing a harmonic; the finger is pressed lightly so as to establish a mode for the desired harmonic and to kill any fundamental vibration of the string.

In the same way the sound post appears to force the wood to vibrate in segments such that where it presses against the wood a node is established. Thus the right foot of the bridge rests on a part of the belly that is constrained to vibrate at the higher frequencies by the sound post, whereas the left foot rests over the bass bar where a lower natural frequency of the wood occurs, and segmental higher-frequency vibrations are prevented by the stiffening action of the bass bar.

It is for that reason that the bridge was stated to rock about the right foot for low-frequency vibrations, and about the left foot for high-frequency vibrations, for in either case the other foot finds the wood it is resting on can "give" and vibrate at the frequencies to which it is approximately resonant.

We note that a poor violin is often improved by placing the post nearer the bridge, although it requires very careful playing to render the tone even. On the other hand, if the tone is even but rough and harsh, the post must be moved back a little (thereby presumably de-emphasizing the higher frequencies).

If the high strings are weak and the low ones are harsh, the post should be moved a little outwards toward the *f*-hole. If the low notes are weak and the high ones shrill, the post should be moved slightly toward the center.

It is possible to simulate the action of the sound post by pressing with a weight on top of the belly, as was discovered by Professor Savart, a famous French investigator of the violin. This indicates its nodal action in the violin.

Perhaps one of the most striking features of the action of the sound post is that it deadens the sounds of plucked strings (pizzicato). For that reason it is absent in the mandolin and guitar; this is perhaps as important a difference between these instruments and the violin as their method of being energized, that is by plucking rather than by being bowed.

The final important feature of the body of the violin is the *f*-holes. These

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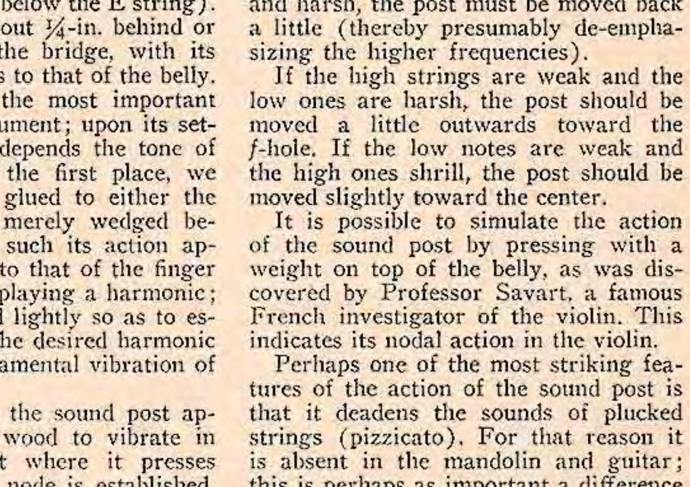
Fig. 8. Cross-sectional view through the middle of the violin, showing sound post and position of the bass bar.



THE VIOLIN

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are the *f*-shaped openings in the belly that are presumably there to let the sound out. They appear to act like the ports in a reflex baffle, or as the inertia component which together with the air in the body of the violin form a Helmholtz resonator.

The following comments are made regarding them by reference (2): If they are cut in the back of the violin, the tone is muted. If they are too small, the sound (resonant frequency) of the contained air is lowered; if too large, the sound is raised. If they are too large or too near one another, the violin becomes harsh and shrill; if too small or too far apart, the tone becomes more wooly.

Although one is tempted to dismiss these observations as being inconsequential, we must not forget that in a musical instrument second-, third-, and even fourth-order effects may be important, and perhaps the changes in the position and size of the *f*-holes may be of importance.

On the other hand, much nonsense has been written by well-meaning and naive violin makers about all these factors, and we must be on our guard as to what is merely their opinions and what is experimentally true. Experiments indicate, for example, that above the air-body resonance, the belly is the principal radiating surface. In vibrating, its nodes are not necessarily at its edges; instead, they may be within its surface, and the edges and sides of the body may vibrate with amplitude.

The body has to be fitted with a neck and scroll of maple, and tail piece, fingerboard, nut, pegs, and even chin rest of ebony or rosewood. It also must be varnished, and here we come to more controversy and pseudo-scientific arguments than were presented by the alchemists of old.

It appears that the varnish of the old Cremona masters has never been duplicated, and arguments have waxed hot and furious as to whether they used a spirit or oil varnish. This is considered more than a mere academic argument, for the varnish is considered to add considerably to the tone of the violin.

There has recently appeared an article (4) that indicates that in the manufacture of the varnish, metal rosinates were introduced that fortunately added to the quality of the varnish. Rosin was dissolved in potash lye, and then alum and coppers (ferrous sulphate) added to precipitate out the corresponding rosinate. These were then dissolved in turpentine and linseed oil added to form the varnish. To what extent, if any, the varnish affects the tone is hard to say; one has the feeling that emotion rather than reason sways the luthier in this respect. The old Cremona varnish, however, is a beautiful, lustrous coating that has withstood in remarkable fashion the ravages of time.

(*To be concluded*)