The tailpiece of the violin family is an elegant but often acoustically neglected part of the instrument. We tend to choose our tailpieces more for beauty and style than for function. But luthiers have known for centuries that this little piece of wood affects the sound of the instrument. We try to adjust for good sound, but in the end, getting the pegs, chin rest, endpin and tailpiece to match artistically are often the overriding factors.

So what is important acoustically about the tailpiece? If we consider where it is located, suspended by the strings of the instrument, we begin to get an idea of the possibilities. On one side of the bridge, we bow the strings to induce a vibration to travel into the bridge, and on the other is the tailpiece, freely suspended at its other end by the tail gut. So it is fair to say that when we bow the strings, we are not only vibrating the instrument through the bridge but also the tailpiece on the other side.

As makers and players we want our instruments to project well and we want the timbre of each note to be pleasing to the ear. This is a tall order, so naturally we tend to focus on the parts of the instrument that vibrate and produce sound. But not all vibrating parts of the instrument do produce sound. In very simple terms, sound production occurs when the corpus of the instrument bends in such a way that the overall volume of the corpus changes with each vibratory cycle. Or a given vibrating part has sufficient surface area and is long enough for it to couple well with the air at the appropriate wavelength. Parts such as the neck, fingerboard, chin rest and tailpiece vibrate, but do not usually produce much sound directly.

ON THE FACE OF IT, it is easy to conclude that the lack of sound radiation from a part such as the tailpiece is a problem. After all, we work hard at bowing, and the energy that winds up vibrating the tailpiece doesn’t seem to do anything for us – or does it?

It is important to understand that violins vibrate more strongly at some frequencies than at others. These resonances are referred to by researchers as ‘modes’. There is a whole branch
of research on the modal analysis of violins, which is quite fascinating. But it is possible to have too much of a good thing. Every player has direct experience of how a strong body mode can interfere with bowing, to the extent that a note very close to the mode may be unplayable. We call this the wolf note. Makers will move heaven and earth to ensure that this mode does not land on a playable note, as it sometimes compromises the other – and often better – qualities of an instrument.

There are many other modes on the violin. The character of the tone of an instrument is defined by its modes. An argument can be made that tonal richness may correlate well with modal richness. And certainly, instruments that avoid extremely strong individual modes are more even and playable.

In the spring of 2011 Oliver Pirquet, an engineering student at the University of Victoria (UVic), approached me about doing some research in my shop on violin acoustics. With the question of the acoustic function of the tailpiece in mind, I proposed we investigate its function as an acoustic filter.

We suspected that it might in fact be acting as a mass damper: these are commonly used to reduce the amplitude of a natural resonance in a structure. A good example of this application is in the design of very tall buildings. Such structures will sway in the wind at some natural, and alarming, frequency. Engineers place a large mass at the top of the tower suspended on springs, which is tuned to the sway and damps it out.

A tailpiece is a small mass suspended on springs, attached to a vibrating structure. But is this a reasonable analogy? We wanted to investigate whether it could also be ‘tuned’ to damp undesirable frequencies, along the same principles.

To begin with, we needed to know how the tailpiece moved and at what frequencies. Researcher Bruce Stough previously found three modes occurring below the frequency of the open G string (196Hz) and two other modes in the range of 300–800Hz, as reported in his 1996 paper The Lower Violin Tailpiece Resonances. The region of 300–800Hz on the violin is where many of the important signature body modes of...
This permitted us to string up the rig with real strings at the normal pitch and tension, with the tailpiece in its normal position. We also arranged the saddle on these rigs to be adjustable, so that we could vary the after-lengths and tail-gut lengths independently. After establishing the behaviour on a dead rig, we placed the tailpiece on a real instrument, both to measure and to play it.

Next, we measured the motions of the tailpiece using the techniques of modal analysis. We placed an accelerometer on the tailpiece in three separate locations, in order to record the movement in the three directions: X, Y and Z. We then tapped the tailpiece with a special impact hammer, which records the force in a number of known locations on the tailpiece (figure 2).

**BEFORE WE COULD BEGIN** to understand how the tailpiece interacted with the instrument, we needed to understand how it would behave without an instrument. To that end, we built two test fixtures from solid birch plywood that were acoustically dead, meaning that they had no significant resonances in the frequency range of interest. We built one of these dead rigs with the correct geometry for a violin, and the other for a cello.

Stough referred to the side-to-side modes as swing modes, the twist about the vertical axis as vertical rotation, and the horizontal twist as horizontal rotation (figure 1, page 9). He found that all of the swing modes occur below the open G, and the two rotation modes were the ones in the signature body mode region.

Using a suite of software written by George Stoppani specifically for the modal analysis of violin family instruments, we calculated frequency response functions (FRFs) for each of the hammer impact points (figure 3).

![Some of the cello tailpieces measured in the survey](image)

![FIGURE 2 An impact hammer was used to tap the violin tailpiece at each of the numbered points (the red spot indicates the accelerometer's location)](image)

![FIGURE 3 Frequency response functions (FRFs) at a mode](image)
The Stoppani software enabled us to see the exact motions and identify the frequency of each of the principal modes of the tailpiece. In addition, we were able to go beyond Stough’s work and look at the higher modes, including those where the tailpiece is flexing (Figure 4).

In order to understand how the tailpiece affects the instrument, we measured the bridge admittance of the instrument by striking one bridge corner with the hammer while the accelerometer was attached to the other. Bridge admittance gives a very clear picture of the signature body modes of the instrument, which includes the modes responsible for the wolf note.

Our first task was to examine a broad range of readily available tailpieces, to see if there were significant differences. Figure 5 shows an example of the results for nine cello tailpieces, which ranged from junkbox rescues to currently popular models.

The graph shows a visible cluster of peaks from 40–70Hz, and a second cluster from around 150–200Hz. Analysis of the modes indicates that the first cluster corresponds to the swing modes and the second to the rotational modes. There is also a wide variety of peaks above the rotational modes. There, the tailpiece behaves with increasing flexure and the motions truly become an exotic dance that is characteristic of the individual tailpiece.

We also examined the relationship between the lengths of the tail gut and after-lengths for a constant distance between bridge and saddle. Figure 6 shows the results we obtained for a single French-pattern violin tailpiece.

We wanted to see whether the after-length or the tail-gut length was more sensitive. By keeping one or the other constant, we could independently adjust the other with the results in Figure 7.

The result clearly shows that for the horizontal rotational mode, tail-gut length dominates.＞
The weight-adjustment system also provided a good opportunity to explore how such a change in the tailpiece would affect the instrument. The results from tests on a violin are shown, focusing on the region from 400–700Hz, where both the rotational modes of the tailpiece and the two important signature body modes of the instrument lie. On this violin, there was a slight wolf note associated with the higher of the two modes, at approximately 550Hz.

The scale runs from 0–110 per cent, which refers to the position of the mass along the long axis, where 0 per cent is as far as possible towards the bridge, and 110 per cent as far as possible towards the tail gut. On this violin, there was a slight wolf note associated with the higher of the two modes, at approximately 550Hz.

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