To Build a Better Violin

Can science determine why some instruments sound great?

By RICHARD LIPKIN

Before morning breaks in Montclair, N.J., Carleen M. Hutchins enters the cellar of her rambling Victorian home. There, in her laboratory, she switches on electronic acoustical equipment, then saunters to a chipped workbench on which newly varnished violin fronts are strewn. Beside them are piles of fresh wood shavings. Behind her, cellos line up along a wall.

A tone sounds as she taps the thin, arched top of an instrument. Her hands gauge its delicacy, its thickness, its edges. She takes a tool and shaves away a sliver of wood. Again, she feels and taps the violin's top. Again, a tone sounds. Trained ears listen. Another scrape. Another tap. Now the overtones harmonize mellifluously.

Soon, she will begin tuning the curly maple back of another violin — tapping, scraping, listening, coaxing it to vibrate at a precise 370 times a second, radiating the perfect blend of sound.

The crafting of fine violins has proceeded for centuries as a secret art, handed down through apprenticeships from generation to generation. It takes 8 years, at least, to train a competent craftsman, decades to hone a master. The great luthiers of 16th to 18th century Italy — Andrea Amati, Antonio Stradivari, Giuseppe Guarnieri — understood subtleties that today's makers have yet to decode. Those old masters still reign in music, their secrets embedded within their violins' wooden walls.

The question that has driven Hutchins for the last 45 years sounds simple enough: How did the old masters make so many fine instruments that have set the violin standard of all time?

"I want to know why," says Hutchins, "what mechanisms underlie the great tonal qualities that players hear and feel in an instrument? For many years I've been looking at the relationship between a violin's wood and the air moving within its body as it's played. How do the vibrations of the wood and air affect each other? Is this something we can understand and control? I think so."

In search of answers, Hutchins has studied exhaustively some of civilization's greatest stringed instruments, as well as roughly 400 violins, violas, and cellos she herself has fashioned.

"I think we can find out why great violins sound so good, learn their mechanisms, and use that knowledge to make consistently better instruments," she says. "There's no reason that music students should have to mortgage their futures to own a truly fine-sounding violin."

"Already, some first-rate violin makers have instruments that [after being played for 80 years] may sound better than Stradivari's," she adds.

Which ones? Only time will tell.

To say the least, Hutchins' ideas defy conventional wisdom of conservative, guild-style craftsmen, who contend that science has little to offer violin makers. As such, her strong will, tireless study, and what some call revolutionary approach to fiddle fashioning have made her a bit controversial.

Yet, after 40 years of meticulous research, the ideas of this 83-year-old independent experimenter have become so central to the craft that they may alter the future course of how stringed instruments are made.

"Her contribution in the long run will be very significant," predicts Joseph Curtin, a violin maker in Ann Arbor, Mich. "Her research is very interesting. She works in the gap between violin making and physics, caught between the two worlds. Sometimes, scientists treat her as a violin maker, and violin makers treat her as a scientist. Many of her instruments are done as controlled experiments to try out an idea."

Hutchins bought her first viola at age 37, making her achievements even more unusual. She built her first violin after bearing her first child, then learned acoustical physics from Frederick A. Saunders of Harvard University.

Hutchins' foremost idea bears the name "plate mode tuning." In essence, the theory holds that what makes for the smooth, sonorous sounds of a great instrument is the subtle, synergistic interaction of air vibrating inside a violin's body and the vibrations of its top and bottom wooden plates. The modes refer to specific vibrational patterns and frequencies. Together, these three vibrating bodies — two plates (top and bottom) and the air in between — interact to create a complex stream of sound.

In a primitive sense, one can think of a violin as an unsealed wooden box, strung with 60 pounds of force, that resonates when stroked with a bow. The motion of a bow dragged across those strings sets them vibrating. This causes the violin body to undulate rapidly, expanding and contracting some 400 times a second. Those vibrations move air, setting in motion sound waves that eventually tingle a listener's ears.

But understanding and controlling how those front and back plates vibrate is no simple matter. It's tough enough to know if they're moving in synchrony. Even trickier is controlling the frequencies and shifting the center of these vibrations to just the right spot, so the violin's front plate, back plate, and the air in between vibrate in harmony.

Hutchins focuses on the dynamics of those vibrations — learning how to "tune" the top and bottom plates. When stroked by a bow, a violin in fact undergoes many different kinds of vibrations through its top and bottom, its neck, its fingerboard, and around the "f-shaped holes" cut into its top. One of Hutchins' more controversial theories holds that by adjusting a small difference in frequency between a particular pair of air and wood vibrations — a difference she calls "the A1-B1 delta" — one can critically alter the violin's tonal qualities.

"The smaller the delta, the less powerful the instrument and the easier it is to play a sweet, smooth sound," Hutchins says. "I used to think the smaller the delta, the better the instrument. But then I found that isn't so. There's a whole range of deltas with different sound qualities. The delta itself doesn't tell you if an instrument's good. But it does tell you who will want to play it."

Soloists — who want a strong, bright sound — like violins with a delta of 60 to 80 hertz (Hz), she says. Orchestral players prefer deltas between 60 and 40 Hz, chamber musicians a delta of 40 to 20 Hz. Deltas below 20 Hz work best for amateurs.

Hutchins says she has worked out a method for adjusting the delta. "There's a way to move the delta to control the type of instrument you want to make. This is a breakthrough. Violin makers are already doing it, but the key is to learn how to control it with simple rules."

Tuning the delicate wooden plates still comes down to tapping and listening, she says. But knowing where the vibrations occur on the plates — where their "nodes," or intersection points, are located — makes the tuning process more precise. By shaving and tapping the wood, one can shift the rate at which the plates palpitate and the position of their vibrations. Sometimes a piece of chewing gum pressed onto the wood dampens it just enough to reveal where it needs a little tuning.

Another of her key ideas bears the name "bi-tri octave tuning." In essence, Hutchins argues that the best-sounding instruments share a specific relationship in the way their front and back plates vibrate. In the ideal combination, she maintains, three modes of the violin's front plate and two modes of its back plate vibrate in "octave frequencies" — or as multiples of one root note. Hence, the phrase bi-tri octave tuning.

In addition, the four quadrants of each top and bottom plate should be equally stiff. This allows the plates to resonate together, producing good overtones. This type of plate tuning, Hutchins says, "makes for the finest instruments, although...some violins are still better than others."

"We still don't know why. And I want to know why," she says. "I suspect the key is in the relation between the way the four quadrants of each plate vibrate and how they interact with the air inside the violin."

Hutchins' tests and experiments are meticulous. To prove an idea can take her 8 to 10 years. Some 400 experimental instruments over 40 years have yielded 2,200 files of detailed technical data — most of which will soon go into the musical archives at Stanford University.

"Carleen's measurements are very dependable, very careful," says Gabriel Weinreich, a physicist at the University of Michigan in Ann Arbor. "When she reports something, it's true. Her data have proved enormously useful to scientists and instrument makers."

Hutchins collects and tests old wood for its vibrational qualities. When a friend heard of the razing of a Swiss chalet built in 1756, he snagged a chunk of spruce beam for her. She carved it into a violin top. A violin apprentice — one of the 50 she's trained — scooped up some planks from a New Hampshire hospital built in 1830. That wood, too, gained a second lease on life as part of an instrument.

"A wood's age is very important," she says. "Violin makers' lore says that it takes 50 years for optimum seasoning. I respect that lore. Most of the time it turns out to be right."

Why does aged wood play better? No one is quite sure. Scientists know that once a tree is cut, crystals begin to form in its cell walls. The older the wood, the greater its crystallinity and the less susceptible it is to airborne moisture. Hutchins believes that those crystals alter the wood's resonant frequencies by augmenting its vibrations.

Violin lore holds that how an instrument is played affects the way it eventually sounds. Craftsmen also believe that a top violin needs 80 years of good playing to get broken in properly. Players often report that an unused instrument "goes to sleep" and requires regular playing to bring back its luscious sound.

Hutchins thinks the explanation lies in how the harmonic vibrations of bowing affect the polymer chains of violin wood. Over time, the polymers tend to suffer microscopic breaks, which then reform into subtly different patterns. To test her theory, she ties some instruments to speaker cones and subjects them to 1,500 hours of classical music. "They do sound better afterwards," she says.

Though Hutchins has spent most of her career tinkering with materials, another project may prove her most enduring legacy. In 1957, the composer Henry Brant pressed Hutchins to design and make a set of violin-family instruments, each with a violin's power, clarity, and tone — yet together able to cover a four-octave range. Unlike the violin, viola, cello, and bass — all originally designed to fit fiddlers' bodies rather than their musical needs — Hutchins' instruments are crafted to be acoustically superior and to have an orderly span of sizes.

The result: the Octet family of instruments, whose eight members range in size from a tiny treble violin to a hefty large bass. Rooted in calculations done by Saunders in the 1930s, then modified with an updated scaling theory, the Octet family projects violin tones into seven other ranges. Together, the eight instruments form a graduated series, each violin a half octave above, or below, its neighbor.

Though musicians fashioned similar instruments during the 16th century, those violins never caught on, for assorted technical reasons. However, the modern Octet could. Though Hutchins finished the first Octet in 1965, it has taken nearly 30 years of painstaking labor to get all the kinks out. Today, six sets of Octet instruments travel around the world for musicians to muse upon and play. A set was flown recently to Russia's St. Petersburg Conservatory of Music for players to try out. Concert artists such as cellist Yo Yo Ma have experimented with the new instruments.

No one can say for certain if the Octet instruments will become the fiddles of choice for musicians, as some claim, or historical relics, as others think. One impediment to their use is that very little music has been written specifically for them. While some classical and jazz musicians have shown interest, Hutchins thinks it could take 50 years for the new instruments to catch on.

In an unusual concert aimed at comparing the sounds of 17th and 18th century Italian instruments with the tones of the best modern instruments, the Tokyo String Quartet in June performed music by Debussy at the Massachusetts Institute of Technology. Among the leading modern luthiers represented were Hutchins, Robert and Deena Spear, and the team of Joseph Curtin and Gregg T. Alf.

Edith Munro

Carleen M. Hutchins completes a violin.

"People don't realize how difficult it is to come up with technical descriptions that truly distinguish between a good and a really good violin," says Oliver E. Rodgers, a mechanical engineer at the University of Delaware in Newark.

"What Carleen has done over the years is to work out basic rules for violin makers to follow. She's done this partly by experiment and partly by intuition, coming up with a bunch of rules that, if followed, will produce a good instrument every time. Yet no one can tell today if any of those instruments will turn out to be great. That may take 50 years."

Hutchins admits that science never will — in fact, can't — supplant the art of a skilled craftsman. At best, science can augment it.

"To make a good violin, you still have to do the same things the old masters have done for centuries," she says. "It's just that now we can understand more clearly what's going on physically and why a plate sounds good." □