Ingo Titze, Associate Editor

How Does a Singer Obtain and Maintain a Four-Octave Pitch Range?

Ingo R. Titze

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Recent cross-species investigations have shown that the mean fundamental frequency (the physical correlate of pitch) with which mammals vocalize is inversely related to body mass. In other words, on average, small animals vocalize on high pitches and large animals vocalize on low pitches. While this correlation is strong ($r^2 > 0.9$), there is not a strong correlation between range of fundamental frequency (f_o range) and body mass. Both small species and large species can have small ranges (on the order of one octave) or large ranges (on the order of four octaves). Based on biomechanical modeling, we now have a good understanding of the mechanism behind f_o range.[1]

There are two factors that influence f_o range. The first is the amount of vocal fold length change that can be produced with muscle contractions in the larynx. This is facilitated by freedom of movement between the thyroid and cricoid cartilages. The second factor is the amount of tensile stress that can be generated in either the vocal ligament or the thyroarytenoid muscle fibers that course in the anterior-posterior direction. In humans, the density of collagen fibers in the vocal ligament is the key variable. In the article cited, a vibrating string model was used to predict f_o range by quantifying the two factors. The ratio L_2/L_1 was used to quantify the longest length divided by the shortest length that can be achieved. A variable B was used to quantify the exponential stress-strain curve of the vocal ligament, essentially a measure of how dense the collagen fibers are packed to form a vocal "cord" in high-pitched phonation. This value B was measured in several species, including humans.

Figure 1 shows the result of the model prediction. The length ratio L_2/L_1 is plotted on the horizontal axis, the B value is plotted on the vertical axis, and the f_o range in octaves is labeled on the curves. Note that humans, with a B value of about 8.5, can have a four-octave range if they can produce an L_2/L_1 ratio of 2.2. In other words, the longest length must be a little more than double the shortest length. If L_2/L_1 is restricted to 1.65, only a two-octave range is possible. A rhesus monkey, on the other hand, can produce a four-octave range with this small variation in length (only 65% increase over the shortest length) because of the greater B value, which is close to 15.

What is the consequence for singers? It is likely that the B value, which corresponds to collagen fiber density, can be increased or maintained with

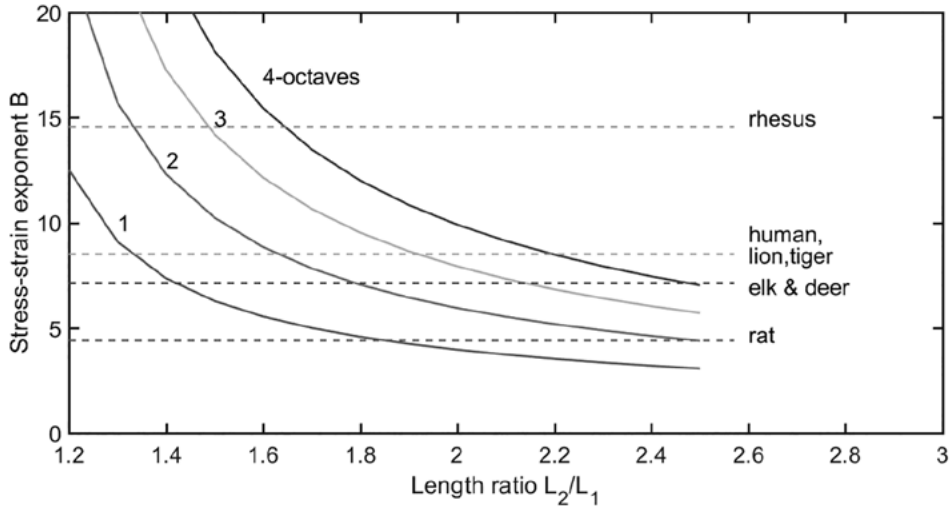

Figure 1. Prediction of fundamental frequency range based on length ratio and exponent in stress-strain relation of tissue in various species. (I. Titze, T. Riede, and T. Mau, "Predicting Achievable Fundamental Frequency Ranges in Vocalization Across Species," PLoS Comput Biol 12(6), e1004907; DOI:10.1371/journal.pcbi.1004907.)

lots of high pitch exercises, such as glides (*glissandi*), arpeggios, and scales. Stretching the tissue frequently is a necessity. It can best be done with semioccluded vocal tract techniques because they maintain small amplitude of vibration and therewith limited vocal fold collision. It is not well known how much an individual can enlarge the L_2/L_1 ratio with exercise. Some laryngeal architecture is very tight, with small spaces between cartilages. This would limit the length ratio, especially if over time the joints stiffen. Again, the solution seems to be to practice over wide pitch ranges, even if the sound at the extremes is not as loud or beautiful as the singer wishes it to be.

NOTE

1. I. Titze, T. Riede, and T. Mau, "Predicting Achievable Fundamental Frequency Ranges in Vocalization Across Species," PLoS Comput Biol 12(6), e1004907; DOI:10.1371/journal.pcbi.1004907.

Love is like the wild rose-briar,
Friendship like the holly-tree—
The holly is dark when the rose-briar blooms
But which will bloom most constantly?

The wild-rose briar is sweet in the spring,
Its summer blossoms scent the air;
Yet wait till winter comes again
And who will call the wild-briar fair?

Then scorn the silly rose-wreath now
And deck thee with the holly's sheen,
That when December blights thy brow
He may still leave thy garland green.

"Love and Friendship,"
Emily Brontë