Science for Singers

A SERIES OF VOICE RESEARCH COLUMNS BY INGO R. TITZE, PHD

# The Physiological Absurdity of Choir Arrangements

Imagine yourself as a violin maker with the charge to assemble some vocal instruments for four-part harmony. Imagine, furthermore, that singers do not exist (and had never existed) in your culture, but you are aware that the human anatomy offers a reasonable sound source and some air columns for acoustic resonance, i.e., the potential for a musical instrument. In range and quality the four instruments are to cover about four octaves, from a few notes below the bass clef to a few notes above the treble clef. Each instrument should have about a two-octave range.

As a clever acoustician, you would begin to lay out your plan according to experience gained from stringed instrument design. Since string length, body resonances, and plate resonances of a violin family are scaled according to the pitch range and desired timbre of the instrument, the string quartet would become the approximate model for the vocal quartet. The cello would become the model for the bass-baritone voice, with a pitch range of $C_2$ (65 Hz) on its lowest open string and $A_3$ (220 Hz) on its highest open string. The violin would become the model for the soprano voice, pitched about 1 1/2 octaves higher.

Understanding acoustical scaling principles, you look for basses whose vocal folds are three times longer (or, in some combination, longer and massier) than those of sopranos. All else being equal (tissue properties, geometry, etc.), this 3:1 length ratio would provide the 1 1/2 octave difference in source frequencies between the highest and lowest instruments in the ensemble. In order to resonate these source frequencies in equivalent ways, you would probably also look for airways (lungs, tracheas, and supraglottal vocal tracts) that scale in similar ratios. A trip to an anatomist would reveal that the soprano should be a 2-3 year old child and the bass should be a tall adult (or a giant, if you could find one).

Assuming that your recommendation to use small children and tall adults will meet with disapproval (for any number of good reasons), your response would be "I can use adults only, but the design won't be optimal. We can use adult males and females, but it will be like leaving out either the violin or the cello in a string quartet. The instruments might be able to reach the notes, but they won't sound right at the extremes of the range, and their acoustic power will be limited."

This scenario is repeated all over the world, every year, when choral conductors assemble their voices and begin to satisfy the composers' lust for vocal instruments that duplicate orchestral instruments. The simple truth is that male-female differences are not octave differences. We cannot line up people like stringed instruments or organ pipes, relating pitch to size, and expect to get much of an ensemble. Assuming a typical male to be 6 ft. tall and a typical female to be 5 1/2 ft. tall, we get a linear size difference of about 10%. If all anatomical lengths were scaled by this proportion, we could expect a two-semitone difference between average male and female voices. This is much less even than the violin-viola difference, which is seven semitones (a fifth) in terms of open string tuning.

Fortunately, nature has helped out a bit by scaling the larynx somewhat disproportionately with respect to the rest of the body. The overall linear dimension difference between the male larynx and the female larynx is about 20%. Furthermore, the portion of the vocal fold length that typically vibrates (the membranous length) is 60% greater in males than in females. With this scale factor of 1.6, we can expect a

**pitch difference of a little over half an octave (about 8 semitones). Thus, the violin-viola difference is appropriate for male-female pitch scaling (but not the violin-cello difference).**

**This still leaves a resonance problem. Vocal tract length, the primary determinant for uniform scaling of formant frequencies, differs only by 10-20% across gender (on the average). Thus, other adjustments have to be made to stretch out these differences. Lip rounding and larynx lowering can lower the formants, whereas lip spreading, jaw lowering, and larynx raising can raise the formants. By using these adjustments, higher and lower resonances can accompany higher and lower pitches, but the effects are not large.**

**In summary, attempts by composers to cast adult human voices into four-part harmony that stretches over several octaves seem to be incompatible with physiologic and acoustic scaling principles. As singers and singing teachers, we need to be aware of this and not get too frustrated when out vocal instruments do not perform ideally at very low or very high pitches. If instrumentalists, composers, or conductors glory in the uniformity and balance of orchestral ensembles and get upset with what they might deem a vocal impotence, ask them how well they could perform the symphonic works with a single size string instrument that has only one string.**

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