Birdsong sounds sweeter because throats filter out messy overtones

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BLOOMINGTON, Ind. -- The purity of birdsong is owed in large part to rapid, controlled changes in the shape of the birds' upper vocal tracts, according to a new study of Northern Cardinals by scientists at Indiana University Bloomington, Purdue University and Australian National University. Their report will appear in next week's (April 4) *Proceedings of the National Academy of Sciences.*

"We show that songbirds adjust the size and shape of their vocal tract to 'fit' the changing frequency of their song," IU neurobiologist Roderick Suthers said. "This enables the bird to produce a more whistle-like, pure-tone song."

Photo by: David Bricker

Northern Cardinals actively change the volume and shapes of their throats as they sing.

Print-Quality Photo

The finding supports a growing consensus that birds and humans make sound in much the same way -- although it is presumed these processes evolved independently of each other in birds and hominids. In 2004, Suthers reported in the journal *Current Biology* that monk parakeets use their tongues to shape sound. Other studies have implicated beaks, especially beak gape, in shaping the sound that birds produce. Similarly, humans move their tongues, alter the shape of their upper vocal tracts, and change the shape of their mouths when they sing, laugh, talk and groan.

"The bird's vocal tract, like the human vocal tract in speech, acts as a resonance filter that can control the sound coming from the mouth," Suthers said. "Beak movements during song also contribute to this filter, but are not as important as changes in the size of the internal vocal tract. Human sopranos use the same technique as the cardinal to increase the loudness of very high notes so they can be heard above the orchestra."

That birds' throats vibrate when they sing will come as no surprise to birdwatchers. The effect of these oscillations on the birds' sound production, however, was unknown.

The acoustics of sound-making are complicated. Most tones produced in nature are accompanied by a complex series of higher-pitched, quieter tones called overtones. When the loudness of these overtones is high, the tone sounds more complex. Birds can control the loudness of overtones to increase the tonal purity of their song. Humans use a similar technique to produce different vowel sounds of speech by altering the shapes of their throats, the positions of their tongues and the wideness of their mouths. The *PNAS* study reveals yet another parallel between birdsong production and human speech.

"At low frequencies, the bird increases the volume of its oropharyngeal cavity and even expands the top of its esophagus," Suthers said. "These air-filled structures form a single cavity with a resonant frequency that matches the main frequency of the song. This amplifies the fundamental frequency and suppresses overtones."

Suthers, biologist Tobias Riede, who is now at the National Center for Voice and Speech (Colorado), Purdue University veterinary scientist William Blevins, and Australian National University acoustic physicist Neville Fletcher used X-ray cinematography to observe and measure the shape and total volume (three-dimensional space, not loudness) of a cardinal's throat as it spontaneously sang. Explanatory video can be downloaded here:

http://www.iuinfo.indiana.edu/bem/mr/rsfb/north_cardinal_large.mov (10 megs)
http://www.iuinfo.indiana.edu/bem/mr/rsfb/north_cardinal_small.mov (4 megs)
(Modeling and animation by Eric Wernert, IU University Information Technology Services Advanced Visualization Lab; video courtesy of *PNAS*)

The scientists determined that note changes in birdsong are accompanied by controlled changes in the volume of the upper esophagus as well as the positions of the bird's larynx and hyoid skeleton (a U-shaped bone formation in the bird's throat). They also found that the volume of the upper esophagus goes up whenever the main tone produced by the bird goes down, and vice versa. These alterations of shape have the effect of increasing the main tone and suppressing the loudness of overtones.

Tobias Riede was a postdoctoral fellow in Suthers' IU Bloomington lab when the research was done. Riede, who also holds a position at Humboldt-University of Berlin, is the study's corresponding author. The report was funded with grants from the National Institutes of Health (National Institute of Neurological Disorders

and Stroke) and the German Academic Exchange Service.