Interspecific Variation in the Bony Labyrinth (Inner Ear) of Anurans.

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Introduction

The semicircular canals of the inner ear serve positional information of the body and angular acceleration of the head during movement. It is widely accepted that birds and mammals with agile and spatially complex movements will have a canal morphology that maximizes sensitivity to these behaviors. More specifically, agile animals have canals with larger radii of curvature and ipsilateral canal pairs that closely approximate 90°. However, it is not well understood if changes in canal functional morphology in mammals are broadly applicable across vertebrates, or if morphological responses to movement have evolved independently. Interestingly, recent documentation of inner ear variation in caecilians and fossorial snakes, a group of predominantly limbless vertebrates, indicates that both groups may have adopted novel morphological traits thought to enhance sensitivity to movement below ground.

We present a survey of the morphological diversity of the bony labyrinth of anurans, to further investigate the potential influence of habitat and phylogeny on inner ear morphology in the clade Lissamphibia. Using 3-dimensional endocasts generated from high resolution CT scans, we document substantial variation in the size and shape of the semicircular canals and sacculus across species. Implications regarding locomotor behaviors and phylogeny are discussed.

Methods

Data Collection

All specimens were housed at the Florida Museum of Natural History. CT scans were generated at the University of Florida’s Nanoscale Research Facility using a GE V-TOME X M 240 ultra-high resolution CT scanner. All specimens are listed in Table 1.

Materials

VIStudio MAX 3.0 was used to gather 3D volumes of the right inner ear of each specimen. Landmark data was then collected in R retains (Figure 1a and 1b) and for the purpose of this study, only focused on the semicircular canals. A total of 16 (9 fixed and 7 sliding) landmarks were placed on each specimen. Points shown in blue are fixed landmarks, points shown in orange are sliding landmarks. Fixed landmarks were chosen according to the most identifiable points consistent through each specimen. The sliding landmarks were then chosen to best show the range of curvature of, and between, each of the semicircular canals.

Analysis

A Principal Component Analysis (PC) of semicircular canal variation was performed using Procrustes tangent coordinates (16 landmark variables corrected for variation in position, orientation, and size). The Procrustes-aligned specimens were plotted (Figure 2 and 4) and grouped by ecological category (color) and clade membership (shape). Allometry was examined by assessing the multivariate regression between semicircular canal shape and canal centroid size. Additional analyses were performed using Procrustes distances.

Images

Each figure (with the exception of Pseudacris ornata) corresponds with one of the inner ears expanded in either the PCA plot or the allometry plot. The image of P. ornata (right) corresponds with the expanded image of the skull showing the placement of the inner ear.

Photo credit: US Geological Survey; William Quattm; John W. Wilkinson; Thai National Park; Morten Van Weerl; Mike Buckman; Imagery Work; Ryan Photograph. All photos were altered from their original format.

Conclusions:

• Taxonomic relation appears to have very little influence over specific morphological variation of the semicircular canals.
• Some ecological patterns exist particularly for the arboreal ecological group as it is separated from most other ecological categories.
• There appears to be significant correlation between the shape of the semicircular canals and the relative size of the inner ear.

Moving Forward:

• increase taxonomic breadth
• Gather data on the variation seen in the sacculus
• Examine the effects on inner ear morphology on hearing

Fig. 1. A Principal Component Analysis (PC) of semicircular canal variation was performed using Procrustes tangent coordinates (16 landmark variables corrected for variation in position, orientation, and size). The Procrustes-aligned specimens were plotted (Figure 2 and 4) and grouped by ecological category (color) and clade membership (shape). Allometry was examined by assessing the multivariate regression between semicircular canal shape and canal centroid size. Additional analyses were performed using Procrustes distances.

Fig. 2. PC 1 represents changes in the relative length of the semicircular canals with large canals having positive PC scores and small canals having negative PC scores. PC 2 represents changes in the arc of the anterior semicircular canal, with small arcs having positive PC scores and large arcs having negative PC scores. Most variation occurs on PC 1 (25%) which tends to separate arboreal specimens from most other ecological categories. PC 2 exhibits 17% variance. Taxonomic taxa have the largest range of variation of any ecological category.

Fig. 3. Bivariate plot of log(centroid size) regressed against shape regression scores. A strong positive relationship is indicated.

Fig. 4. Same PCA as Fig. 2, but with specimens labeled for identification and comparison with Fig. 3 and Table 1.

Fig. 5. PCA Plot of PC1 vs. PC2 with Labeled Specimens

Fig. 6. PCA Plot of PC1 vs. PC2 with Labeled Specimens

Table 1. List of Anurans studied

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Florida Museum of Natural History: Department of Herpetology

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