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The Effects of Miniaturization on the Brain Case of Gymnopthalmodiea (Squamata)

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THE EFFECTS OF MINIATURIZATION ON THE BRAIN CASE OF GYMNOPTHALMODIEA (SQUAMATA)

by

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ABSTRACT

THE EFFECTS OF MINIATURIZATION ON THE BRAIN

CASE OF GYMNOPTHALMODIEA (SQUAMATA)

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The University of Texas at Arlington, 2011

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The concept of miniaturization states that as we go down the phylogenetic tree, species begin to become smaller in body size due to environmental pressures, especially within the Gymnophtalmoidea squamata. We question how the brain case morphology between different lizard species in the Gymnophtalmoidea squamata compares to one another when considering the differences in their body size. The brain cases of five lizard species were isolated using a 3D segmentation computer program, then reconstructed using an illustrator computer software and compared. The lizard studied includes one species from the Alopoglossidae family (*Alopoglossus embera*), one species from the Teiidae family (*Dracaena guanensis*), and three species from the Gymnophthalmidae family (*Lepasoma hexalepis, Bachia pyburni,* and *Oreosaurus luctuosus*). In general, every species' brain case shape differs, but will also have structures that are very close in resemblance, except for some variation in the structure size and shape.

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CHAPTER 1

INTRODUCTION

In the animal kingdom, we often see many examples of diversity that makes each species unique from one another. Specifically, diverse options are seen with each species' body in terms of morphology and body size. With body differences, there are bound to be differences in other physiological features such as the brain, heart, lung, etc.

1.1 The Gymnopthalmodiea Squamata

The Gymnopthalmoidea squamata is one of the most diverse orders within the animal kingdom that consists mostly of scaled reptiles. It consists of seven families, with the largest families belonging to Cercosaurinae, Gymnophthalminae, and Teiinae. It also consists of Alopoglossidae, Rachisaurinae, Riolaminae, and Tupinambinae, but only consists of a few species and is not as diverse as the other families (Hernandez Morales et al. 2019) (Fig 1.1). Regardless, this group of lizards presents an impressive morphological variation in different aspects. One of the most variable morphological traits in this group is the size ranging from the giant South American Tegus to the miniaturized Gymnophthalmids.

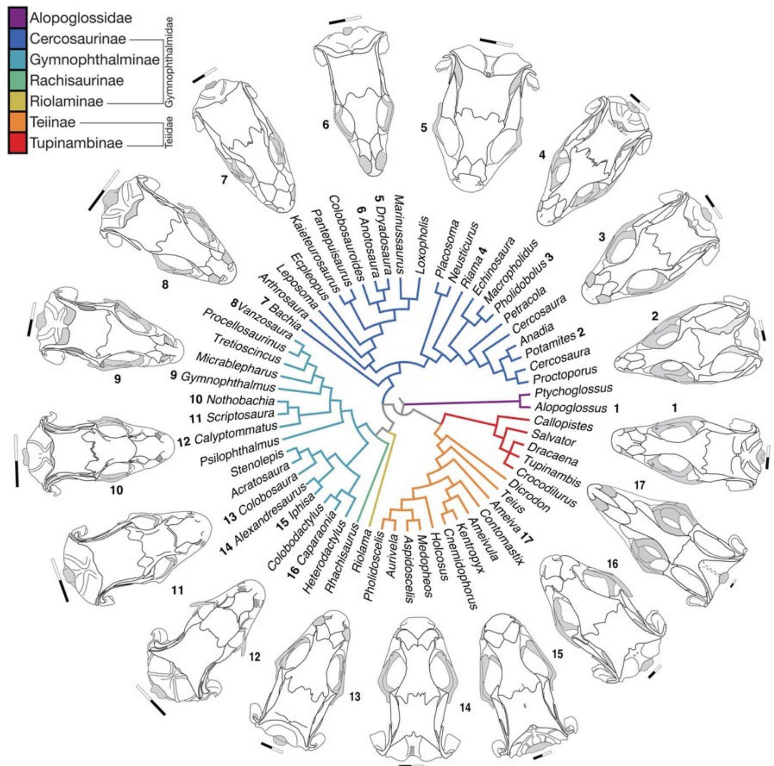

Figure 1.1: The Phylogenetic Tree of the Gymnopthalmoidea Squamata

1.1.1 Skull Differences within the Gymnopthalmoidea Squamata

Within the Gymnophtalmoidea squamata, there is a focus on three families that are known to have large variations in body size (Alopoglossidae, Teiidae, and Gymnophtalmidae). In their general skull morphology, there are differences in their shape that is reflected in body size difference, in where larger Gymnopthalmoidea genus' have more of an elongated skull with a narrow snout, while the smaller Gymnophtalmoidea genus' have a short length skull with either a broad or narrow snout. Functionally, larger areas of the skull provide relief from the external stress from their environment, while overlapping structures within the skull allow for less cranial-facial movement that could be beneficial to the specific species in terms of behavioral mechanisms (Hernandez Morales et al. 2019).

1.2 Miniaturization

The concept of miniaturization states that as we go down the phylogenetic tree, species begin to become more smaller in body size. This is mainly due to environmental pressures that favor being a small size. Keeping this in mind, we can assume that the smaller the lizard species, the smaller the brain will be to accommodate for the size and the different the skull structure holding the brain will be between these species. However, getting smaller presents some physiological challenges. For example, within the skull, there is threshold that cannot be over passed to maintain the functionality of elements related to the nervous system, such as the brain and the inner ear. This limitation produces that the braincase reduces its size at a different rate than the rest of the skull (allometry).

Even with the overall result of miniaturization being an overall change in the skull structure, there can also be individual variations that are observed within this phenomenon. It is observed that there can be variations in terms of their "overall proportions, the relative size of their components, the degree of constriction of the neck portion, and the number of major processes and foramina they bear." (Bhullar and Bell 2008).

1.3 Research Question

While there are numerous research studies on how skeletal structures, primarily with the skull, are affected by body size, the focus on the brain case is not focused on as much. As mentioned before, the Gymnopthalmoidea squamata consists of a variety of lizard species that will also vary heavily in their body size. This research study focuses on the question of how the brain case morphology between different lizard species within the Gymnopthalmoidea squamata compares to one another when considering the differences in their body size.

CHAPTER 2

METHODS

2.1 Gathering the CT Scans

Five species of lizards from three different families within the Gymnopthalmoidea squamata were chosen for this research project. These species were chosen by the criteria of large differences in body size between one another as well as the availability of the CT scans provided for our lab. Species that were chosen included one species from the Teiidae family (*Dracaena guanensis*), one species from the Alopoglossidae family (*Alopoglossus embera*), and three species from the Gymnopthalminae family (*Oreosaurus luctuosus, Bachia pyburni,* and *Lepasoma hexalepis*). All CT scans utilized were either provided from the Department of Geoscience at The University of Texas at Arlington or were obtained from Morphosource.com, an open online CT scan database.

2.2 Isolating the Brain Case

All CT scans per organism were compiled together in a 3D segmentation computer program to turn the slices into a workable 3D model. Once a 3D model was created, the brain case was isolated by removing any extra structures that were not needed. The general procedure consisted of first cutting the larger portions of the 3D model that were not needed, followed by observing each CT scan from different perspectives to be more precise when cleaning the structure. Extra care was taken to ensure that all extra structures not a part of the brain case were removed, and no part of the brain case was removed.

2.3 Data Analysis

Once the brain case was isolated, it was then uploaded to an illustrator software program that allowed us to easily compare the structures between each species. The basis of comparison includes setting the standard of identifying what structure is present, followed by comparing the morphology and size of the current structure being focused on.

CHAPTER 3

RESULTS

3.1 Anterior Differences

3.1.1 Basipterygoid Process

Within *D. guianensis*, the bastipterygoid process is shorter and thicker compared to the other species. We also see that it is ventrolaterally oriented rather than being directly underneath the vidian canal. There are also differences seen in *A. embera*, in which it is slenderer and oriented differently by being located anteriorly (Figure 3.1).

3.1.2 Processus Ascendens

Again with *D. guianensis*, another difference seen is the taller and thicker processus ascendens that is morphologically like the bottom half of the brain case. A thicker, wideset processus ascendens is also seen in *L. hexalepis* (Figure 3.1).

3.1.3 Other Differences

One of the other differences that can be seen anteriorly is the protruding supratrigeminal process within *D. guianensis* (Figure 3.1).

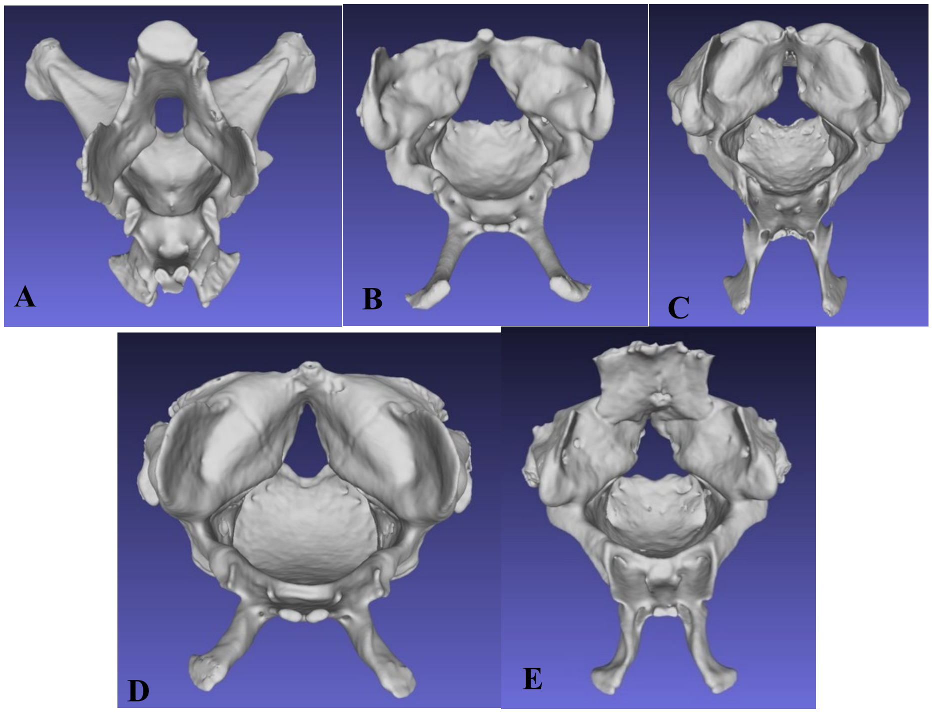

Figure 3.1: Anterior Views of the Brain Case (A) *Dracaena guianensis* (B) *Alopoglossus embera* (C) *Oreosaurus luctuosus* (D) *Bachia pyburni* € *Leposoma hexalepis*

3.2 Lateral Differences

3.2.1 LARST

For comparison, the size of the LARST was seen to be variable between each species. Smaller LARSTs were seen in *D. guianensis*, our biggest lizard, and in *B. pyburni,* which is an underground lizard. Larger LARSTs were seen in *A. embera*, *O. luctuosus*, and *L. hexalepis*, which are similar in size and habitat conditions (Figure 3.2).

3.2.2 Crista Tuberalis

Differences in the size and orientation of the crista tuberalis are seen with some similarities with some species. One orientation for the crista tuberalis can be straight oriented, as seen in *D. guainensis, A. embera,* and *B. pyburni*. We can also have it oriented to be perpendicular, such as *O. luctuosus and L. hexalepis* (Figure 3.2).

3.2.3 Crista Interfenestralis

Orientation and size variation is also to be seen with the crista interfenestralis in relation to the orientation of the crista tuberalis. Just like the crista tuberalis, orientation can include either being straight (*D. guainensis* and *B. pyburni*) or perpendicular (*A. embera, O. luctuosus,* and *L. hexalepis*). There are also differences in how this structure connects to the crista tuberalis near the posterior of the brain case, either being interconnected to each other (*B. pyburni*) or can be completely unattached (*O. luctuosus*) (Figure 3.2).

3.2.4 Other Differences

In *O. luctuosus,* we see the prootic alar process is oriented below the ampula as well as a larger fenestra ovalis compared to other species. We also see that in *B. pyburni*, there is no ridge present within the crisla sellaris. The prootic alar process is seen to be shorter than normal within *A. embera* (Figure 3.2).

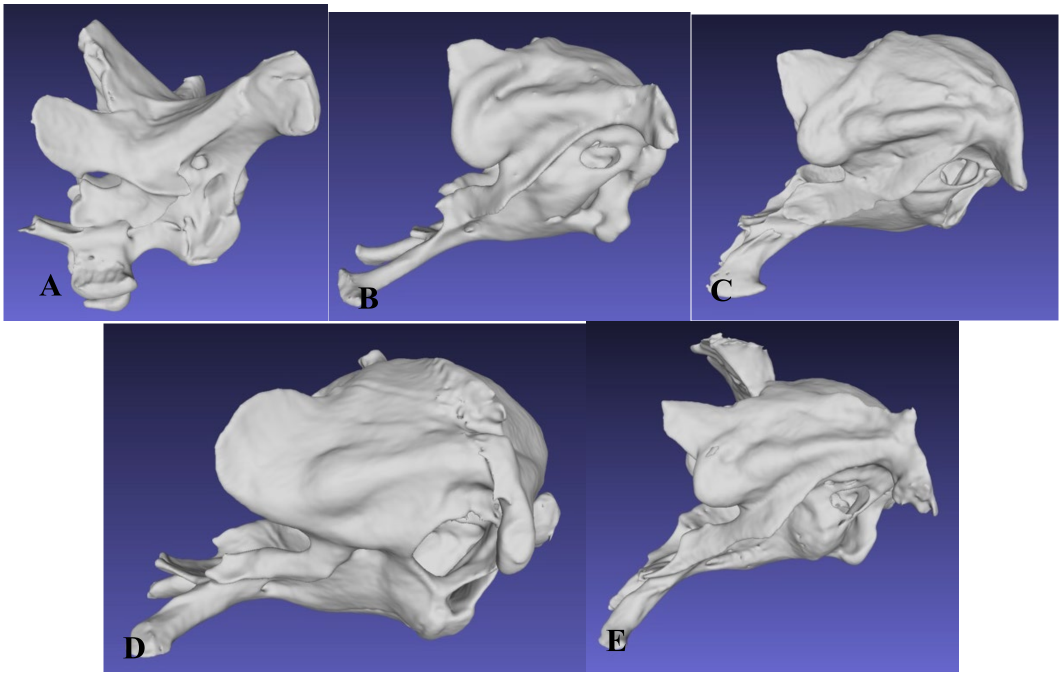

Figure 3.2: Left Lateral Views of the Brain Case (A) *Dracaena guianensis* (B) *Alopoglossus embera* (C) *Oreosaurus luctuosus* (D) *Bachia pyburni* (E) *Leposoma hexalepis*

3.3 Posterior Differences

3.3.1 Paraoccipital Process

One of the main differences seen within the paraoccipital process is going to be within D. guianensis and L. hexalepis. In D. guianensis, the paraoccipital process is the most prominent and protruding structure within the posterior view of the brain case. In comparison, L. hexalepis' paraoccipital process is oriented differently at a 90-degree angle rather than laterally (Figure 3.3)

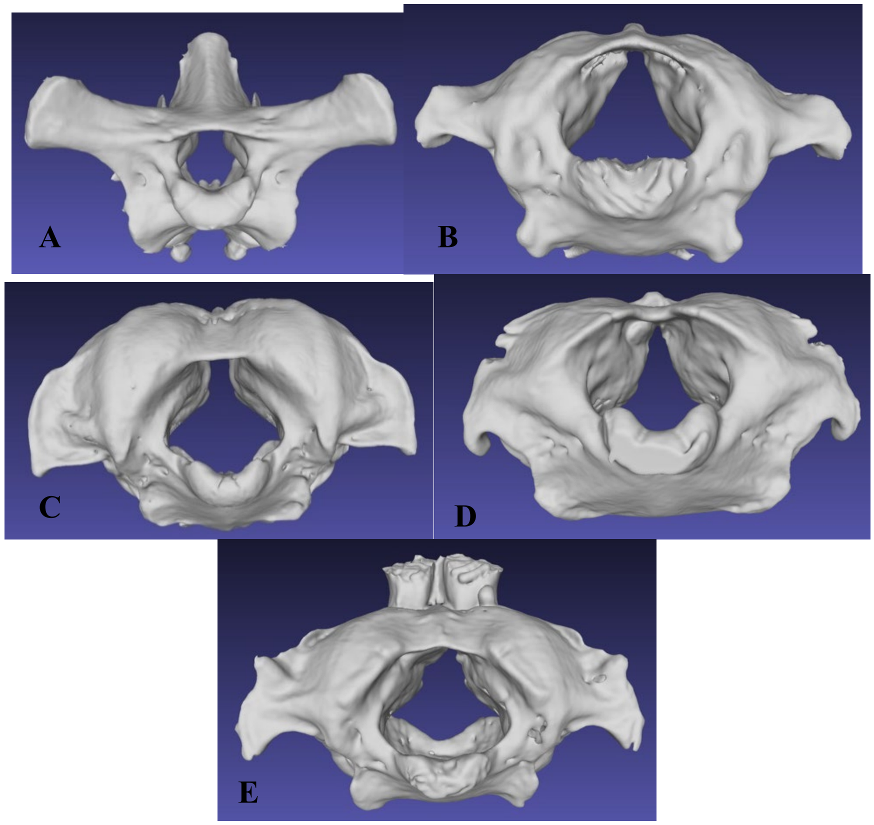

Figure 3.3: Posterior Views of the Brain Case (A) *Dracaena guianensis* (B) *Alopoglossus embera* (C) *Oreosaurus luctuosus* (D) *Bachia pyburni* (E) *Leposoma hexalepis*

CHAPTER 4

DISCUSSION

In general, every species' brain case shape differs, but will also have structures that are very close in resemblance, except for some variation in the structure size and shape. Differences are to occur to accommodate a large brain, the larger the species. Ossification within different areas of the skull is also seen, again correlating with the rearrangement of the brain case structures.

4.1 Size Implications

Out of all the lizard species studied, *D. guianensis* is seen to have the most differences in terms of the brain case structure. *D. guianensis* is known to be a two feet lizard compared to the miniaturized gymnopthalmids. As mentioned before, the larger the species is, the larger the brain is expected to be. To hold a larger brain, there needs to be more space present within the brain case, reflecting how different the rearrangement of structures is.

4.2 Environmental Implications

While the other species, except for *D. guianensis*, had a similar amount of brain case morphologies, it is to be noted how more compact the brain case for *B. pyburni* is. Even though these other lizards are known to be small in size, there is an exception with *B. pyburni*'s habitat in which it is an underground lizard. Since there is an increase in pressure from the surrounding environment, the brain needs to be more protected; henceforth, the more compact the brain case will have to be to provide that support. There are not that many differences in how the brain case structures are rearranged, but it is seen to be a little bit thicker in this species to withstand compression.

4.3 Advantages to Skull Rearrangement

Miniaturization allows for better ecological strategies within the environment so that these lizard species can co-exist and, in turn, leads to the evolution of the overall skull structure to better accommodate these behavioral modifications. As lizards become more miniature, the overall skull diameter is reduced to allow better jaw movement that correlates to the size of the prey. Due to the overall reduced body size, the skull structures are also modified in terms of their arrangement to have maximum movement in consideration of the lizard's size. For example, there are overlapping of some structures in a puzzle type of way that would allow for optimal jaw movement that is critical for its ecological survival. Also, considering behavioral modifications, the skull shape is also modified to allow for more burrowing behavior, which also increases the lizard's chance of survival due to their small size and easier ability to be preyed on (Rieppel 1984). This can all go back to the concept of natural selection, in which the variations of the skull will allow the environment to choose the skull shape that will allow the most optimal behavioral activity that increases the chance of survival, and with that allows those traits to be passed down to the offspring and leading to an overall evolutionary change.

Within the miniaturization phenomenon, there are some evolutionary patterns that can be seen. Throughout species, there is a constant pattern of fusion and disassociation of the bones and can be observed throughout the phylogeny as you go down the line. Also, individual skull bone loss is not correlated with the differences in body size. Still, however, the missing of some individual skull bones correlates with optimization for the frog and its survival. We can also consider the cell size comparison between the same size animal. A small animal with a large cell size will have a biologically smaller effect than a small animal with a small cell size. Larger differences in the skull are going to be seen in a once large animal being small than a small animal overall (Yeh 2002).

CHAPTER 5

CONCLUSION

Differences in overall brain case shape will occur with every species, but morphological variation in the same structure presents more explanation to the species' size that allows for accommodation for a larger brain. Miniaturization allows for better ecological strategies, allowing these lizard species to co-exist within the same environment. This leads to the evolution of the overall skull structure to better accommodate these behavioral modifications and can be directly represented within our study by the brain case morphology. The brain case will naturally rearrange its structures to fit the organism's needs and provide them with an advantage for better survival by modifying what actions can be performed. Ecologically, this can provide significance of how the environment can play a role in the evolutionary history of skeletal morphology within each species. Further field research can be performed to see how this phenomenon will compare with different structures within this same squamata or can be extended to other organisms that are not lizards as well.

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BIOGRAPHICAL INFORMATION

Britney Le was born in San Jose, California, but later moved to Mansfield, Texas, and has lived there ever since. She is the oldest daughter of Becky Tran and Brandon Le and has two younger siblings, Brianna Le and Brayden Le. She also lives with her grandmother Van Tran and is a proud pet owner of a miniature Australian Shepherd, Chewie. She graduated from Lake Ridge High School in 2019 with a 4.0 GPA and has also obtained her Pharmacy Technician Certification during her senior year. Because of her certification, she has been working as a certified pharmacy technician for three years and currently works for Kroger Pharmacy. Others see her as a healthcare hero for providing COVID-related services, such as testing and vaccinations, to the public throughout the pandemic.

Britney is currently a third-year student at the University of Texas at Arlington (UTA), majoring in both biology and interdisciplinary studies (biochemistry, psychology, and medical humanities). She is very active in many extracurriculars offered at UTA, such as the Minority Association of Pre-medical Students, the Leadership Honors Program, and the Honors College. She primarily enjoys being an officer for Global Medical Training and is currently the president for the 2021-2022 school year. One of her favorite parts of attending UTA is the opportunities to travel and serve in medical mission trips to Central America, where she has worked with other students to provide free medical and dental services to areas deprived of healthcare access. After completing her bachelor's degree, her main goal is to attend medical school and practice pediatric medicine.