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Review of the member of the dissertation council for the dissertation of Ivan Timurovich Kuzmin on the topic: "Anatomy, development and evolution of braincase in Crocodylomorpha (Diapsida: Archosauria)", submitted for the degree of candidate of Biological sciences in a scientific speciality 1.5.12 Zoology.

The dissertation of Ivan Timurovich Kuzmin deals with the evolution of the crocodylomorph neurocranium and the utility of its characters for phylogenetic analyses. The solid, akinetic nature of the crocodylomorph neurocranium is highly derived and constitutes a prerequisite for the ability to generate strong bite forces. This capability in turn contributed significantly to the great evolutionary success of the clade. In spite of this, the neurocranial evolution of crocodylomorphs has hitherto attracted surprisingly little attention in the scientific literature. Ivan Kuzmin's dissertation thus closes a gap in the scientific study of crocodylomorph evolution and morphology. The dissertation is clearly structured and consists of the following parts: Introduction, Chapters 1-5, Conclusions and Supplementary Files 1-2.

The Introduction contains a useful survey on crocodylian evolution and explicitly delineates the topic of the dissertation with its goals and objectives. In Chapter 1, the different lineages of fossil and extant crocodylomorphs are introduced and previous phylogenetic hypotheses are critically discussed.

Chapter 2 provides an overview of the studied specimens and the methods of investigation and analysis. A large and diverse sample of neurocrania of extant crocodylians is considered, consisting of 75 specimens encompassing all nine extant genera. The data are compared with 72 fossil specimens representing all main clades of crocodylomorphs, and 26 archosauromorphs that fall outside crocodylomorphs for outgroup comparison. A variety of established and innovative methods and approaches are applied. They encompass classical comparative morphology, CT-scans with subsequent production of 3D-models, computer-based phylogenetic analyses, and study of neurocranial ontogeny in extant crocodylians. An important achievement presented in this chapter is the substantial revision of the inconsistent anatomical terms of the crocodylian neurocranium. This nomenclatural unification will give direction to further studies and will greatly facilitate comparison of crocodylomorph neurocrania. Additionally, new anatomical terms for a number of neurocranial structures are proposed. Finally yet importantly, the exhaustive literature research spanning scientific studies on crocodylomorphs from the beginning of the 19th century to present is an impressive piece of work.

Chapter 3 is a comparative morphological description of the neurocrania of extant crocodylians mainly based on CT-scans. Numerous superb illustrations present the resulting, highly informative 3D-models. The outer morphology of each neurocranial element is shown for adults and hatchlings in unprecedented detail. Additionally, semitransparent models depict the canals for vessels and nerves as well as pneumatic structures. A detailed comparison between the different taxa is made and phylogenetic signals are highlighted. This chapter is written in the best tradition of the Great Russian morphologists.

Chapter 4 contains a phylogenetic analysis of crocodylomorphs and their relatives. This work is highly original because not only it is the first analysis of crocodylomorphs that is solely based on neurocranial characters, but also because 53 of the 167 characters are completely new and 33 are adopted from earlier studies but fundamentally modified. The results of this analysis form the base for our understanding of neurocranial evolution in crocodylomorphs, but also serve as independent test of previously published, often conflicting phylogenetic hypotheses. The resulting tree is well resolved and supports previously recognized major clades. This clearly shows the utility of neurocranial characters for the reconstruction of crocodylomorph phylogenetic relationships. The tree topology and the supporting derived characters of each clade are described and discussed in detail. Ivan Kuzmin worked again very carefully with these data and conducted various tests of how certain characters and taxa affect the resulting tree topology.

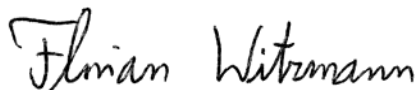
Based on the morphological investigations outlined in Chapter 3 and the phylogenetic results described in Chapter 4, evolutionary trends of the crocodylomorph neurocranium are identified and discussed in Chapter 5. These trends encompass the development of the akinetic skull and other modifications in the architecture of the neurocranium and the configuration of its elements. Also their impact on pneumatization and the course of major cranial nerves and vessels are discussed in detail. Ivan Kuzmin points to the fact that these evolutionary alterations, which occurred already at the base of the crocodylomorph phylogenetic tree, resemble the early ontogeny of the neurocranium in extant crocodylians. This leads to the hypothesis that modifications in ontogeny formed the basis of the observed evolutionary changes in the crocodylomorph neurocranium.

The Conclusions chapter provides a summary of the main results of the dissertation, highlights still unresolved problems, and gives perspectives on future studies. In Supplementary File 1 the investigated extant crocodylian specimens and their respective ontogenetic stages are listed, whereas Supplementary File 2 consists of the character-taxon matrix of the phylogenetic analysis.

In summary, the methodology and content of Ivan Kuzmin's dissertation are at the highest level, what is reflected by the fact that it gave rise to five publications in high-quality scientific journals. The results about evolution, anatomy and ontogeny of the crocodylomorph braincase are highly novel and significantly increase our knowledge about the evolutionary history of extant crocodiles and their fossil relatives. Ivan Kuzmin's dissertation sets the standards for future studies of braincases, not only those of crocodylomorphs, but of archosaurs and reptilians in general.

Dissertation of Ivan Timurovich Kuzmin on the topic: "Anatomy, development and evolution of braincase in Crocodylomorpha (Diapsida: Archosauria)" meets the basic requirements established by Order No.11181/1 dd. 19.11.2021 "On the procedure for awarding academic degrees at St. Petersburg State University". The applicant Ivan Timurovich Kuzmin deserves to be awarded the academic degree of candidate of Biological sciences in a scientific speciality 1.5.12 Zoology. No violations of paragraphs 9 and 11 of the specified Order have been detected.

Sincerely,



Dr. Florian Witzmann, Associate Professor (*Privatdozent*),
Member of the Dissertation Council
Curator at the Museum für Naturkunde Berlin, Germany