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## THE ORIGIN OF SNAKES: MORPHOLOGY AND THE FOSSIL RECORD (1ST EDITION)

*Caldwell, Michael W.* 300 pp. CRC Press.

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### CRANIAL PATHWAYS IN NOTOUNGULATES

New morphological evidence supports that the internal carotid passed directly into the endocranium via the piriform fenestra, rather than coursing through the middle ear.

### AMORPHOUS SILICA MICROFOSSILS FROM THE SOUTHERN PAMPAS

Paleoenvironmental reconstruction based on microfossils indicates temperate humid paleoclimate during the pedogenesis of a hydromorphic paleosol.

### NEW BRYOZOANS FROM THE MIOCENE OF PATAGONIA

Two new species of cheilostomes associated with gastropod shells are described from the Monte León Formation.

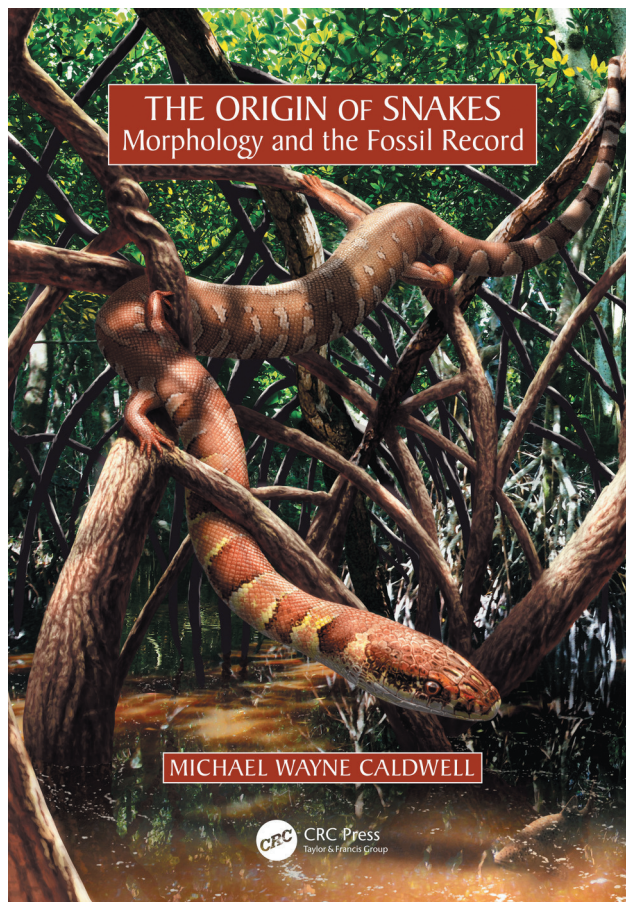
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The origin of snakes is one of the most intriguing and debated topics in vertebrate evolution. Two main reasons have obscured the evolutionary relationships of snakes with other squamates, creating difficulties to understand the acquisition of their unique skull and elongated, limb-reduced to limbless body. First, extant snakes are a highly derived group of lizards, which is problematic for identifying homologies with any potential close relative. Second, their long fossil record is considered quite scarce regarding informative specimens, with skull material or articulated remains, being isolated vertebrae the bulk of their fossil record. Despite limited interest given in the past to the fossil record to understand snake evolution, since the re-description of the Late Cretaceous squamate *Pachyrhachis problematicus* as the first known snake with well-developed hindlimbs (Caldwell & Lee, 1997), fossils have played a pivotal role to understand the origins of snakes. Also, it sparked a heated debate (still far from settled) about the relationship between snakes and mosasaurs and the ecological scenario in which the snake body plan originated. From that point to this volume, *"The Origins of Snakes: Morphology and the fossil record"*, the Mesozoic fossil record of snakes has undoubtedly been improved by many relevant findings, including taxa with hindlimbs, both marine and terrestrial.

The author, Michael W. Caldwell, is a leading expert in the evolutionary history of snakes and is more than qualified in the subject of the book. He has been personally involved in the area through field collections, original descriptions and critical revisions, along with many studies in fossil and extant squamates. In that sense, the contents of this book are written from a very personal point of view. This is evident in the Introduction, where the author explains his approach to science, philosophy, and scholarly criticism.

The content of the volume is well organized, following a logical order. Starting with the dedications, a detailed table of contents, a list of institutional abbreviations, a preface and a long list of acknowledgements followed by the

mentioned Introduction. After that, Chapter One ("Ancient Snakes, Modern Snakes") discusses the historical use of the term "snake", how often snakes are set apart from lizards (a similar problem with birds and dinosaurs) and explains the use of the term "snake lizards" that the author uses throughout the book. The first chapter also describes the basic anatomical organization of the skull in snake lizards, defining four basic skull types among living representatives of the group: Type I, Anilioid; Type II, Booid-Pythonoid; Type III, Colubroid; and Type IV, Scolecophidian-Viperid. These four general categories shake the traditional arrangement of extant snakes, considering scolecophidians as derived "regressed macrostomatans" and removing them from their basal position among extant snakes, supported by most researchers. Chapter Two ("Ancient Snake Lizards") summarizes the most relevant fossils of Mesozoic snake lizards currently known, providing an anatomical portrait of the most informative fossil taxa. These are treated in temporal (geological period and age) and geographical (paleogeographical context and modern place) order. Beginning with the oldest known snake lizards from the Middle Jurassic–Early Cretaceous of Laurasia, known from fragmentary cranial and postcranial material belonging to four taxa: *Eophis*, *Diablophis*, *Parviraptor*, and *Portugalophis*. From the Early Cretaceous of Gondwana, only a partial braincase from the Valanginian of South Africa is described, which is waiting for revision and formal description as an ophidian, as it was previously considered as an indeterminate squamate. Moving to the much better record from the Late Cretaceous, the Cenomanian marine snake lizards are presented, the simoliophiids: *Pachyrhachis*, *Haasiophis*, and *Eupodophis*. All of which are known from complete or almost complete and articulated specimens with evidence of hindlimbs from the Afro-Arabian platform. The similar but less-known *Pachyophis* and *Mesophis* from the Adriatic-Dinaric platform are described as well. Then, taxa from Late Cretaceous Gondwanan landmasses are presented. From Africa, the



**Figura 1.** Cover of the book "The origin of snakes: morphology and the fossil record" by Michael W. Caldwell, CRC Press.

partial braincase of *Menarana nosymena*. From South America, the snake lizards described are *Lunaophis* from the Cenomanian of Venezuela, which probably represent another independent lineage of marine forms, and *Najash* and *Dinilysia*, both terrestrial forms from the Cenomanian and Santonian of Patagonia, respectively. The two represent arguably the best-known fossil snake lizards (exceptional materials from the legged snake *Najash*, which are briefly mentioned as still undescribed, are now published). Given that the holotype of *Dinilysia patagonica* was the only Mesozoic snake lizard skull known from more than a century, a brief history of its study is included, since being first described in 1901 and from an interesting perspective on how it was overlooked for many years. From Gondwanan Asia, the snake lizards described are the embryonic/neonate *Xiaophis* preserved in amber from Myanmar and the large-sized madtsoiid *Sanajeh* from India, which was found associated with a nest of hatchling dinosaurs. All these snake

lizards, when possible, are assigned to the skull types described in Chapter 1. Two additional Cretaceous vertebral form taxa are discussed, *Simoliophis* (the first described and named Mesozoic snake lizard) and *Coniophis precedens*, recognizing only the type vertebrae as belonging to this taxon. The chapter ends with a revision of the purported four-legged snake fossil *Tetrapodophis amplexus* from the Early Cretaceous of Brazil, finding that it is not a snake lizard nor a fossorial animal. The proper re-description of this controversial taxon as an aquatic dolichosaurid lizard is now already published (Caldwell *et al.*, 2021). These anatomical portraits are interesting as they are not merely a summary from previous studies; but instead, they provide novel observations, and many aspects of these fossils are discussed. The specimens are illustrated, but the reader will need to search the source bibliography to see many aspects properly. Chapter Three ("The Anatomy of Ancient Lizards") deals in detail with several key anatomical characters seen in fossil and modern snake lizards. Long-debated primary homology concepts in lizard snakes osteology are discussed, at the end predicting the aspect expected to be found in ancestral snake lizards. This is the longest chapter in the book, and technical as it is, it can be hard to read for people without previous knowledge in reptile or lepidosaur anatomy. Nevertheless, many of the characters discussed are well-illustrated, with images mostly stemmed from previous contributions authored or co-authored by Caldwell. Chapter Four ("Ancient Snake Lizards Paleoeology") gives a review of the sedimentary settings interpreted for the rocks in which the fossils treated in Chapter Two were found, discussing the likely habitat and what can be inferred about the paleoeology of these ancient snake lizards, as well as the limitations. The chapter ends with a poetic account from the author's fieldwork experience in the Upper Cretaceous fossil Lagerstätten known as the Área Paleontológica de La Buitrera ("Paleontological Area of La Buitrera"), in Río Negro, Argentina, where the fossils of *Najash* have been found in rocks from the Candeleros Formation. Chapter Five ("Origins Myths as Opposed to Scientific Hypothesis") is dedicated to the burrowing origin scenario of snake lizards. The long history since Walls (1942) proposed a fossorial ancestral nature for snakes is revised and scrutinized, finally discarding the burrowing origin, remarking what the fossil record supports or not, and discussing misinterpretations about

the marine origin scenario of snake lizards. The chapter also serves as an example of the problems with the conceptualization of ideas in science. Chapter Six ("Ancient Snake Lizards Phylogeny") reviews the concepts of homology and character construction and compares molecular and morphological phylogenies, and presents a review of different hypotheses for ingroup and sister group relationships of snake lizards through history. Then, it ties concepts from previous chapters in an evolutionary framework, highlighting the importance of the unique morphology found in ancient snake lizards, with an experimental phylogeny built on a "fossil backbone analysis". The final chapter Seven ("Beginnings"), summarizes the ideas expressed and what future perspectives hold for big-picture studies of the evolutionary history of snake lizards. The book ends with references, a useful index and a brief biography of the author.

In sum, the book offers not only a review of the fossil record of snake lizards and a historical summary of essential research efforts dedicated to unveiling the still obscure origin of this remarkable group of reptiles but also a personal perspective from the author of the vast literature in the subject. Novel interpretations that challenge widely accepted notions add a new layer to a debate that remains contentious and will make the book an interesting reference point for future studies. For people not immersed in the topic or without deep knowledge of anatomy, many techni-

cal parts will not be easy to read. However, the book is still written in a comfortable, very introspective tone. The author goes beyond the origins and morphology of snakes, exploring philosophy and scientific thinking, compelling the reader to an eye-opening experience.

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