Spinosaurs as Crocodile Mimics

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Theropod dinosaurs (bipedal, primarily carnivorous forms) have received widespread attention in recent years owing to their importance in understanding the origin of birds (1). However, the evolution of theropods was more than a "bird factory": Indeed, these dinosaurs represent one of the most successful radiations of terrestrial predators in Earth history. On page 1298 of this issue, Sereno et al. report (2) the discovery of a new theropod belonging to the specialized lineage known as spinosaurs, which provides important new insights on the evolution and adaptation of this group and their place in Mesozoic ecosystems.

One of the most mysterious theropods ever discovered is Spinosaurus aegyptiacus, first described by Ernst Stromer in 1915 on the basis of skeletal material from the lowermost Upper Cretaceous Bahariya Formation (about 95 million years old) (3). Its mystery is in part due to the highly specialized nature of its anatomy. The neural spines of the vertebrae of the trunk of the body were highly elongate (up to 1.69 m), forming a tall "sail" reminiscent of the Early Permian synapsid Dimetrodon. The lower jaw was quite long and slender for a large theropod, and the teeth were conical, rather than the bladelike serrated teeth found in most theropods (such as Allosaurus or Velociraptor).

However, part of the mystery of Spinosaurus lies in the fact that it was twice lost: once because of extinction sometime in the Cretaceous Period and again because of the destruction of Stromer's collection during the bombing of Munich in World War II. For many decades, paleontology's sole knowledge of spinosaurs came from Stromer's monographs (3).

In recent decades, new specimens of Spinosaurus and those of related dinosaurs have been discovered in Lower Cretaceous and lowermost Upper Cretaceous formations of Africa (4), Europe (5, 6), and South America (7). Together, these fossils make up our knowledge of Spinosauridae, a radiation of unusual theropods known from the Barremian to the Cenomanian stages of the Cretaceous (about 125 to 95 million years ago). Although most of these fossils are only isolated teeth and bones, there have been some notable spinosaur specimens recovered during the 1980s and 1990s. Among these are Baryonyx Walkeri, known from one of the most complete dinosaur specimens ever recovered in England (5, 6) and Irritator challengeri and Angaturama ilmai, known from the main section of a skull and an isolated snout (possibility of the same species, or even the same individual, and published only a month apart) from Brazil (7). Sereno and colleagues report on the newest spinosaur fossil and one of the most complete ever discovered (2). Sereno et al. have named this new species from the late Early Cretaceous of Niger Suchomimus tenerensis, the crocodile mimic of Tenere Desert (see figure).

The relatively complete material of Suchomimus, combined with the discoveries of the 1980s and 1990s, increases our resolution of spinosaur anatomy, phylogeny, and functional morphology. By comparing this new discovery with previous specimens, Sereno et al. have determined which features of Spinosauridae are characteristic of the whole family (among them, the morphology of the lower jaws and teeth) and which are unique to that genus (including the eponymous elongated neural spines). Sereno et al. have combined knowledge of the skulls of Baryonyx and Suchomimus to discover that the heads of spinosaurs were even more narrow, slender, and crocodile-like than previously reconstructed (5). (Additional information from the relatively complete cranial material of Irritator, still under study, will help to fill in the elements missing in both Baryonyx and Suchomimus.)

The jaw and tooth morphology of spinosaurs is considerably different from that of typical theropod dinosaurs (for example, Ceratosaurus or Allosaurus). In the primi-
forces exerted on the skull during predation and feeding (8). The skulls of *Suchomimus*, *Baryonyx*, and their kin are long and narrow, and their teeth are subcircular in basal cross section, with either very fine serrations or none at all. The anterior end of a spinosaurus snout is expanded into a pincerlike “terminal rosette,” containing the largest teeth in the skull. As demonstrated by *Suchomimus* and other new discoveries, spinosaurus skulls had a substantial secondary palate (formed by medial extensions of the maxillae).

The cranial adaptations in spinosaurs parallel those of crocodilians. Early crocodylomorphs had skulls similar to those of typical theropods and bladelike teeth with serrations running along the parallel those of crocodilians. Early of the palate joined to form a solid roof of those of typical theropods and bladelike crocodilians nostrils, the mouth with rearward-placed internal through the water, and teeth with a round-

Baryonyx torsional loads generated by struggling of the species *Spinaxaurus maroccanus* and *Cristatusaurus* (appendent) Sereno et al. (2) provisionally consider the former of these species synony-
mous with *Spinaxaurus aegyptiaca* and the latter as a dubious taxon indistinguishable at present from *Baryonyx*.


**PERSPECTIVES: NEUROSCIENCE**

**Gathering Glycine Receptors at Synapses**

Stanley C. Froehner

**Synapse formation in the central nervous system is exceptionally complex. A single neuron may receive input from thousands of synaptic connections on its cell body and dendrites—some inhibitory, some excitatory. To integrate these signals rapidly and specifically, the correct receptor with the neurotransmitter released from the presynaptic terminal. Receptor-associated proteins are thought to be involved in forming these postsynaptic specializations, possibly by linking the receptor to the postsynaptic cytoskeleton (1). This idea has been most thoroughly studied at the neuromuscular junction, where nicotinic receptors are associated with the clustering protein rapsyn (2, 3). Now, the laboratories of J. R. Sanes and H. Betz have tested this theory on neurons in the central nervous system. In a report on page 1321 of this issue, they show by targeted gene disruption that gephyrin, a protein associated with the glycine receptors, is required for the formation of inhibitory synapses in the spinal cord and brain (4). Their results also reveal an intriguing link between gephyrin and neurological diseases related to molybdenum deficiency.

Glycine receptors are members of the pentameric family of ligand-gated ion channels, which also includes nicotinic acetylcholine receptors, γ-aminobutyric acid (GABA) receptors (another type of inhibitory receptor), and, more distantly, NMBA- and AMPA-type glutamate receptors. In earlier experiments, Betz and colleagues found that a 93-kilodalton peripheral membrane protein, now called gephyrin, was localized at inhibitory synapses on motor neurons in a complex with the glycine receptor (5). A clue to gephyrin’s function came from experiments in which depletion of gephyrin with antisense oligonucleotides

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