Bones of Mammals' Ancestors Fleshed Out

Clues emerge for the transition from reptiles to the first mammals

The spectacularly diverse group of creatures that dominated the terrestrial animal world for 125 million years before the dinosaurs arrived, and, more importantly, gave rise to the first primitive mammals, has been relatively neglected by the scientific community and the public at large. This group, the mammal-like reptiles (subclass: Synapsida) was the subject of a recent conference held at the Smithsonian Institution's National Museum of Natural History and jointly organized with the National Institute of Mental Health.

"There's enormous potential interest in these animals," said Paul MacLean of NIMH, "because they are so close to the roots of our family tree." The focus of the interest is, of course, on the anatomical and behavioral changes that occurred in typically reptilian stock and eventually gave rise to typically mammalian characteristics. The meeting's organizers realized that they could formulate questions about this transition only if they invited biologists as well as paleontologists.

Reptiles evolved from amphibians some 325 million years ago. "They were small insect-eating lizard-like creatures," said John Ruben, of Oregon State University. "They differed from amphibians not so much in their anatomy but in their mode of reproduction." They laid eggs bounded by a protective membrane or shell. And so too did the mammal-like reptiles, which arose from the newly evolved reptiles.

The earliest mammal-like reptiles, of the order Pelycosauria, were distinguished from their ancestors principally in size and diet: many large species rapidly arose, some of which were specialized carnivores, while others were herbivores. Although not extensive, differentiation of tooth type has its origins in these early stages, "implying a more efficient preparation of food," explained Robert Carroll, of McGill University.

Several groups of pelycosaurs developed the large dorsal sails so beloved by Walt Disney. In the 700-pound *Dimetrodon grandis*, for example, the sail would have been an extremely impressive structure. The chances are, however, that the sail evolved not so much to impress as to act as a primitive temperature control apparatus, allowing heat loss through convection.

There were three major groups (suborders) of pelycosaurs: sphenacodonts, edaphosaurs, and ophiacodonts. It was the first group, to which *Dimetrodon* belonged, that gave rise to the second subclass of mammal-like reptiles, the therapsids.

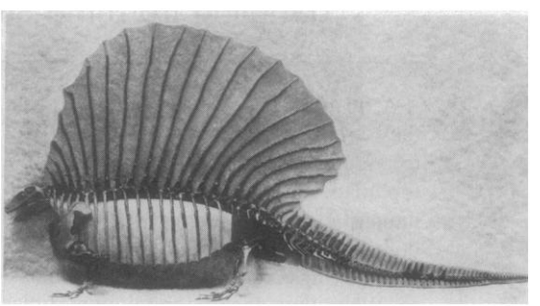
The pelycosaurs were hugely successful during their 50-million-year tenure but became extinct in the Early Permian, some 265 million years ago. Their issue, the therapsids (order: Therapsida), were equally fecund, giving rise to more than 300 genera, with species ranging in size from that of rats to rhinoceroses. Again, some were carnivores, some herbivores.

The line of advancing mammal-like features passes through the theriodonts, a diverse group mainly of apparently efficient carnivores, to cynodonts, from which the first true mammals evolved some 200 million years ago. The two major trends through the cynodont line were a reduction in size (they ranged from the size of a rat to that of a wolf) and an increasing elaboration of mammalian features. The last of the cynodonts were very small and were probably insect-eaters like the mammals that evolved from them. They may have been nocturnal too, like their descendants.

In addition to the steady specialization of teeth, other mammalian characteristics include limbs that move anterioposteriorly directly under the body rather than straddling horizontally as in reptiles, and the beginnings of an arched vertebral column. Alfred Crompton described the dramatic alteration of the reptilian jaw into the mammalian structure, which has a stronger joint and, through greater flexibility, permits much more effective food processing. "The change occurred as a secondary consequence of the evolution of a more sensitive middle ear containing three bones as against the reptile's one," said Crompton. The two extra bones derived from part of the reptilian jaw structure.

An important mammalian feature is the ability to generate heat and maintain body temperature within tight limits. Is this a mammalian invention, or did the therapsids develop it first? "The vascular structure of the bones, the possession of a secondary boney palate, and reduction in the rib cage all correlate with endothermy," said Albert Bennett, of the University of California at Irvine. More telling, though, is evidence in some therapsids of a wet membrane in the nasal cavity. And some of the later species would undoubtedly have had hair. "Although it is clear that some therapsids were warm-blooded, we can't say how precisely they were able to control their body temperature," added Bennett.

Neurological evidence, sketchily drawn in brain endocasts, also supports the notion of endothermic therapsids. But most strikingly portrayed in the fossil brain structure is the clear importance of a good sense of smell in these creatures. And this correlates very well with what David Duvall, of the University of Wyoming, sees in the nasal structure of late therapsids. "In animals that employ pheromones for social signaling you always find an important structure, the Veremo nasal organ," he said.



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Edaphosaurus, a *pelycosaur*

Duvall detects such structures in some of the late therapsids, which points to the emergence of a truly social animal.

Why be social? Possibly because these late mammal-like reptiles had also come close to inventing the family. Louis Guillette, of the University of Colorado, speculated on the origin of maternal care through a combination of egg guarding and the development of a brood patch in a warm-blooded animal. Glands of the brood patch might produce little more than an aggregation pheromone, or they might even yield milk. By its nature, fossil evidence for such processes is at best hazy. "But," suggested Guillette, "one can readily envisage some kind of situation like this."

The transition to the first mammal, which probably happened in just one or, at most, two lineages, is still an enigma.—ROGER LEWIN

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