

Embryonic anatomy and life history of the Early Jurassic prosauropod dinosaur *Massospondylus*

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The oldest known dinosaur embryos are preserved inside thin-shelled eggs in a partially preserved clutch from the Lower Jurassic Elliot Formation in the Golden Gate Highland National Park of Central South Africa. Embryos clearly pertain to the prosauropod dinosaur *Massospondylus carinatus*, and include articulated skeletons curled up and ready to hatch. The skeletal proportions of the embryo, although conforming to the ontogenetic trajectory provided by an extensive growth series, are dramatically different from those in the adult in having short rather than greatly elongated cervical vertebrae and very short rather than normal length caudal vertebrae. Embryonic proportions of the vertebrae are probably associated with the necessity of fitting the developing organism into the small egg. However, the unusually large forelimbs do not fit this pattern, and indicate

that the hatchlings of this prosauropod were obligatory quadrupeds. Adult prosauropods were at least facultative bipeds, the primitive condition for this clade. This has major implications for the origin of the quadrupedal gait in the giant sauropods, which appears to have arisen by a retardation of post-natal negative allometry associated with the forelimbs, rather than positive allometry through growth as may have been expected. The diminutive pelvis and the enormous head, and awkward body proportions suggest that this dinosaur may not have been able to move efficiently or feed itself when newly hatched. This implies a level of parent care, that if correctly inferred, would be the oldest known example of altricial behavior. *Massospondylus* provides the most complete picture of embryonic anatomy and ontogenetic development in an early dinosaur.