# New research on sauropod gigantism summarized

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Replica of the reconstructed skeleton of Argentinosaurus huinculensis, on display as part of a special exhibition at the Senckenberg Natural History Museum, Frankfurt am Main. The fossil remains of this titanosaur that lived in the Early Cretaceous period were discovered in Neuquén province, Argentina.

Argentinosaurus huinculensis is currently the largest known sauropod with a total length of 38 meters and an estimated total body weight of 75 tons. Credit: Eva Maria Griebeler

Sauropods, the largest land animals in Earth's history, are still mightily puzzling the scientists. These plant-eating dinosaurs with their long necks and small heads could reach a height of 10 meters or more and dominated all other land vertebrates in terms of size. They could weigh up to 80 tons, more than any other known land vertebrate. One question that has been intensely debated is how these giants of the animal kingdom regulated their own body temperature. Dr. Eva Maria Griebeler of Johannes Gutenberg University Mainz has now shown that the hypothesis is inaccurate that their body size was limited only because the associated rise in body temperature could have resulted in potential overheating.

According to the calculations of the Mainz-based ecologist, the body temperature of these animals did not increase with body weight. Her estimates indicate that sauropods may have had an average body temperature of some 28 degrees Celsius. The upper limit for the body temperature that can be tolerated by vertebrate species living today is 45 degrees Celsius. The body temperatures that Griebeler postulates for the sauropods are thus well below those of today's endothermic vertebrates but consistent with those of ectothermic monitor lizards. Her calculations of sauropod body temperature take into account the relationship between the maximum rate of growth and the basal metabolic rate of an animal, whereby the latter is largely determined by body temperature.

Griebeler's work is part of a collection that brings together the results of recent research into sauropod gigantism. The gigantism of these

vertebrates, unique in the history of the Earth, raises many questions, such as why no other land creatures have ever achieved this size and what their bauplan, physiology, and life cycle would have been like. The collection put together by the leading open access journal *PLOS ONE* consists of 14 contributions from the fields of ecology, morphology, animal nutrition, and paleontology that all address the fundamental question of how the sauropods managed to become so extraordinarily massive. "We are pleased that this new research is freely accessible not only to other scientists, but also to sauropod fans," said PD Dr. Eva Maria Griebeler. She and Dr. Jan Werner are members of the research group "Biology of the Sauropod Dinosaurs: The Evolution of Gigantism (FOR 533)," funded by the German Research Foundation (DFG). The collection was initiated as a result of a related international conference on this subject. Both scientists from the Ecology division at the Institute of Zoology at Mainz University have been working for more than six years within this research group. They have written three of the 14 contributions in the collection.


Egg containing a titanosaur embryo, on display as part of a special exhibition at the Senckenberg Natural History Museum, Frankfurt am Main. This fossilized egg was discovered in Neuquén province, Argentina, and has an approximate diameter of 15 centimeters. Credit: Eva Maria Griebeler

In one article, Jan Werner and his colleague Koen Stein of the University of Bonn describe a new method of determining the density of bone tissue and juxtapose sauropod data and results extrapolated for comparable endothermic mammals. Although the bone structure and the density of certain tissues of sauropods were similar to those of today's mammals, the results do not conclusively demonstrate that sauropods were also endothermic animals. Other functional aspects, such as similar weight-bearing stresses, could have resulted in the development of convergent forms of bone tissue.

Another article looks at the reproductive biology of sauropods. Here Werner and Griebeler discuss the hypothesis that a high rate of reproduction contributed to the gigantism of the large dinosaurs. They discovered that the reproductive pattern of most dinosaurs was similar to that of modern reptiles and birds. The reproductive pattern of theropods, i.e., ancestors of the modern birds, turned out to be comparable with that of birds, prosauropods, and sauropods rather than reptiles. However, contrary to the assumptions of previous studies, the calculations of the Mainz scientists did not corroborate the hypothesis that the large dinosaurs would have laid a particularly large number of eggs. In terms of total eggs produced annually, this number could not have exceeded 200 to 400 eggs for a sauropod weighing 75 tons. Today's large sea turtles are known to lay clutches in this range.

**More information:** Eva Maria Griebeler Body Temperatures in Dinosaurs: What Can Growth Curves Tell Us? PLOS ONE, 30 October 2013 DOI: 10.1371/journal.pone.0074317

Koen W. H. Stein, Jan Werner Preliminary Analysis of Osteocyte Lacunar Density in Long Bones of Tetrapods: All Measures Are Bigger in Sauropod Dinosaurs
PLOS ONE, 30 October 2013 DOI: 10.1371/journal.pone.0077109

Jan Werner, Eva Maria Griebeler New Insights into Non-Avian Dinosaur Reproduction and Their Evolutionary and Ecological Implications: Linking Fossil Evidence to Allometries of Extant Close Relatives PLOS ONE, 21 August 2013 DOI: 10.1371/journal.pone.0072862

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