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Autonomic Nervous System Function in Extinct Giants

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Abstract

We measured published growth-lines in bones of two titannosaurs from images in the papers. We found that growth-lines in osteons in the anterior process of the rib grew faster than dense bone and juveniles grew faster than adults Power spectral analyses of growth intervals in osteons showed a ratio of 1.3 (LF/HF) and for bone 1.4 (LF/HF) NS.

We found additionally that the main drivers for blood flow to the brain were the physical aspect of flow in elastic tubes (blood vessels) and the smallness of their brains. These animals slept only ~3 hours/24 hours because of the need to sustain their enormous body mass (~80 tones) and they reached an age of ~100 years.

Keywords: T-test; Brachiosaurus; Fossils; Power spectra analyses; Autonomic nervous system function

Introduction

Independence and self-regulation are hallmarks of extant animals such as mammals and birds. The neural regulation and controls of these hallmarks of life is the province of the Autonomic nervous system (ANS). Because of the importance of these functions for survival and their complexity they are carried out automatically and are not entrusted to volition; they characteristically proceed autonomously such as breathing, temperature regulation, sleeping and feeding. All such ANS activities supply energy to sustain metabolism and are considered under the control of the ANS. These are self-evident truths according to the Free Dictionary by Farlex.

The titannosaurs became extinct at the time of a huge impact that hit earth 66 million years ago [1]. Because of their size they had constraints on locomotion, thermoregulation, blood supply to organs including the brain and especially autonomic nervous system function (ANSf).

Although the fossilized remains of these titans have been studied since their discovery in the late 19th and early 20th centuries their physiology has remained, for the most part, elusive.

To study ANSf in these fossils it is necessary to use modeling techniques and statistics. Such methods have been widely applied to elucidate physiology, size, metabolism and organ function from fossils; they have provided insights into prehistoric life, anatomy and physiology and metabolism.

In titannosaurs ANSf such as blood flow to the brain was aided by muscle contraction and special boney structures in the neck called cervical ribs which reached to approximately 1.8 meters along each side of their ~15 meters long necks [2]. These animals also had very high body temperatures which increased with activity. To preserve brain function they had cooling mechanisms along their carotid arteries [2].

Because of the inordinate demands to maintain metabolism their sleep times were drastically curtailed by the constant need to feed to provide fuel for the maintenance of body metabolism and ANSf.

Some of their fossil remains also imply that ANSf changed with age in keeping with the aging of the autonomic nervous system in extant animals including humans.

Materials and Methods

We measured growth-line intervals in histological sections of osteons (n = 19) and dense bone (n = 40) in published images of sections of cervical ribs from Diplodocus sp. (*Sauriermuseum Aathal*, Aathal SMA HQ2) and *Plateosaurus engelhardti* (STIPB R 620) [3] (Figure 1).

We modeled growth and metabolism in these animals using established methods. We used allometric methods to estimate size, weight and sleep-time in these animals.

ANSf was inferred, from power spectra analysis and measures of the sympathetic and parasympathetic control of neural activity during life. [4,5] (Supplementary material).

We then used allometry to model size, weight and sleep-time in these animals. [6] We adjusted statistically the allometric measures based on extant animals.

We estimated the ages of our subjects using exponential growth rates [7,8]. Annual growth rates were then converted to daily growth rates using the appropriate number of days in the Mesozoic era (186 million days) [9].

Lastly, we assessed ANSf over time in the Sauropods.

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Results

The growth-line intervals of osteons and dense bone are illustrated in Figure 1. Growth-lines in osteons in the anterior process of the rib grew faster than dense bone and juveniles grew faster than adults (juvenile bone 202 ± 44 microns/growth interval, adults 12 ± 4 microns/growth interval; osteons juveniles 129 ± 71 microns/growth interval, adults 62 ± microns/growth interval; in the tuberculum bone, juvenile 17 ± 3, microns/growth interval, adult 14 ± 5 microns/growth interval. Growth lines in Figure 1 are from references [6,8].

Power spectral analyses of growth intervals in osteons (the sum of low + mid frequencies 0.47/high frequency 0.36 with a ratio of 1.3) for areas under the curves. For bone Power spectral analyses of growth intervals (the sum of low + mid frequencies 0.56/high frequency 0.40 with a ratio of 1.4) for areas under the curves. The ratios between these tissues was not significantly different (P > 0.50) (Figures 2 and 3).

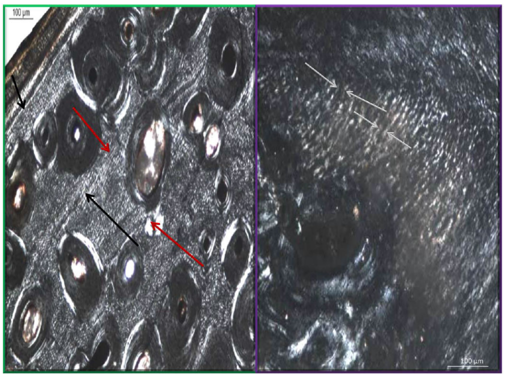

Figure 1: Growth lines in osteons (left) and dense bone (right). The growth intervals are indicated between opposing pairs of arrows (as measured from references [6,8]).

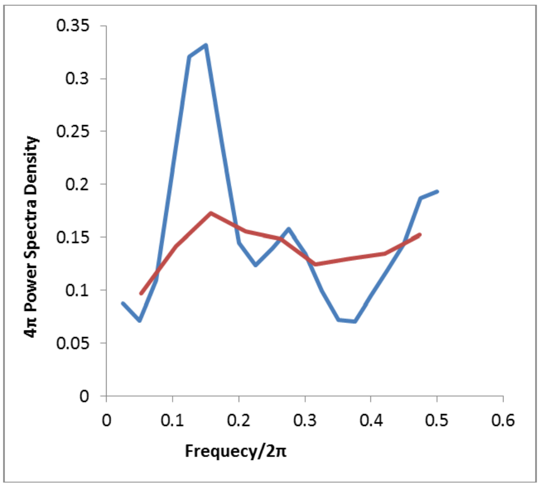

Figure 2: Cervical rib power spectra for dense bone (blue) and osteon (red). The growth line intervals in cervical ribs of Sauropods were standardized then pooled/by histology (dense bone and osteon).

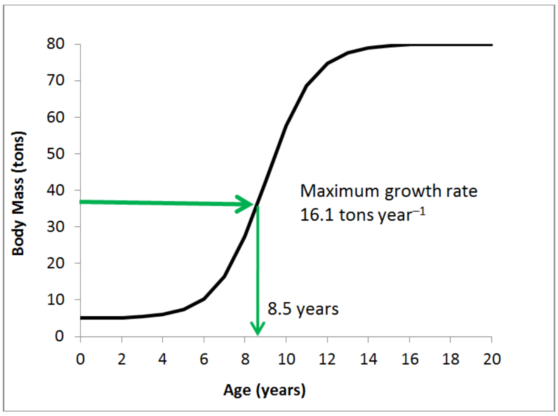

Figure 3: Growth functions for Brachiosaurus and age of Juvenile weighing 38 metric tons.

Based on rate of growth of Erickson's *Apatosaurus excelsus* and an assumed hatch weigh of 5 kg body mass of 38 tons is matching the figure given by Hanns-Christian Gunga et al. in their table derived by allometry and suggests an age of 8.5 years for this animal.

We further validated these values, given in a juvenile *Rapetosaurus krausei* from Madagascar which grew in its short life lifespan from 3.4 to 40 Kg in 38 days [10].

Blood Flow to the Brain

The physics of fluid flow would have aided blood reaching the brain and supplemented other mechanism [2,11].

Sleep-time

Our model predicted a sleep-time of ~3 hours/24 hours (Figure 4).

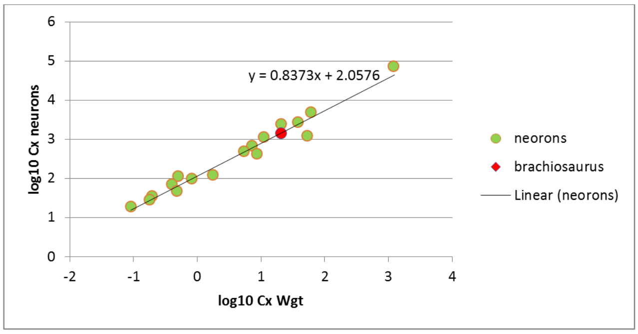

Figure 4: Logarithmic relationship across species of Brain Cortex Neurons (n) and Brain Cortex weight (g). The Brachiosaurus does not differ from other species (red circle).

Discussion

Saurопods were a group of saurischian dinosaurs; they were quadrupedal, herbivorous and some reached enormous sizes. A striking characteristic of these animals was their inordinately small brain that was housed in a small skull sitting on top of a very long neck which in some reached 15 m in length. Here we propose that their anatomy, body mass and brain size led to evolutionary adaptations including adaptations in ANSf.

Because of their body mass they needed to forage almost continuously to maintain metabolism. Thus sleep times in these extinct giants was severely curtailed as has been found in extant giants such as elephants and whales.

Titannosaur's growth rates have been difficult to gage because bone, the only remains of these animals, contains both slow and fast growth components [8], implying that components of bone tissue in the same animal may form and mature at different rates [8]. Previous analyses have consistently shown that the rate of growth changes with age in sigmoid relationships and that this is true throughout all taxa examined. Growth rate increases also exponentially with age [7]. Thus in *Apatosaurus excelsus*, an animal with a body mass of ~26 tons, the maximum annual growth rate was at ~5,466 kg year^{-1} [8]. Whereas *Brachiosaurus brancai*, had a maximum increase in body mass of ~16,100 Kg/year. The animal we examined was 8.5 years old and is classified as juvenile because these creatures may have reached an age of ~100 years.

Because of the enormous accretion of weight necessary in a short time to achieve their body mass the metabolism of these animals could have resembled the metabolism of contemporary cancer cells which replicate at enormous rates to form tumor masses in very short time intervals. Tumors use glycolytic metabolism even in the presence of sufficient oxygen rather than aerobic metabolism because aerobic metabolism is less efficient [10] Another similarity to tumor growth was the relative hypoxia of the cellular environment of these titans which could have led to the activation of the transcription factor HIF (hypoxia inducible factor) which up regulates glucose transporters and glycolytic enzymes.

Blood flow to the brain

The physical and mathematical aspects of fluid flow in elastic tubes, such as blood vessels, have been examined [11]. Equations for auto-oscillating flow enabled by a pulsating heart have been validated for the description of blood flow in major blood vessels of living animals. Fluid flows faster in a narrow tube which results in low pressure in smaller tubes and a high pressure in a larger tube [12] Thus blood flowing in the very small arteries supplying the extraordinarily small brain of titannosaurs would have aided blood flow because blood flow to the brain depends on the diameter of the carotid arteries and circle of Willis and on the hemorheology of the blood that is the flow properties of the blood; the blood viscosity. This varies with each systole; when shear stress is high the viscosity is decreased, during diastole the velocity decreases slightly because of lessening of the shear stress. In large Sauropods with long necks these mechanistic considerations must have had disproportionally large influences on the blood supply to the brain. There was additionally the anatomy based on brain size (only about the size of a walnut) [13] and neck length that assisted the blood supply to their brain. Moreover, cooling mechanisms in the form air sacks and cervical ribs aided blood propulsion to the brain and shielded the brain from high temperature exposure [2].

The organization of the adrenergic innervations of the carotid artery of the giraffe, the closest extant animal to the giganotosaurus shows this artery to be heavily innervated [14] This implies that during diastole when the blood would have a tendency to retreat in Sauropods because of the their long necks, the adrenergic tone would have maintained flow in addition to the other mechanisms mentioned in [1,2,11-13]

Another aspect of ANSf can be determined from power spectral analyses of recurring growth lines in growing tissues such as bone [5]. Here we used growth-line intervals of osteons and dense bone from published images [3] to infer ANSf in these extinct giants and predicted that these would differ because of the presumed different growth rate of these boney tissues. Nevertheless the power spectral ratios derived from osteons and dense bone growth intervals did not differ significantly.

Sleep

This animal's sleep was ~3 hours based on body size. There was no relationship to the cortical thickness brain weight ratios

The function of sleep has been intensively studied for decades but its physiological purpose has still not been elucidated. Almost all studies hitherto have been done in mammals or birds but recently [13-17] studies in sleeping Komodo dragons have revealed that the brain circuits underlying the electrical activity which accompanies sleep are very ancient and were likely also been present in extinct Sauropods. Thus the electrophysiological aspects of sleep in these sleeping giants must have been akin to extant sleeping giants.

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References

1. Hand E (2016) Scientists gear up to drill into 'ground zero' of the impact that killed the dinosaurs. Science 351: 1015-1016.
2. Switek B (2015) How Long-Necked Dinosaurs Pumped Blood to Their Brains. Smithsonian magazine, USA.
3. Preuschoft H, Klein N (2013) Torsion and bending in the neck and tail of sauropod dinosaurs and the function of cervical ribs: Insights from Functional Morphology and Biomechanics. PloS one 8: e78574.
4. Appenzeller O, Gunga HC, Qualls C, Furlan R, Porta A, et al. (2005) A hypothesis: autonomic rhythms are reflected in growth lines of teeth in humans and extinct archosaurs. Autonomic Neuroscience 117: 115-119.
5. Qualls C, Appenzeller O (2015) Modeling Metabolism and Disease in Bioarcheology Biomed Res Int 15: 548704.
6. Hanns-Christian G, Suthau T, Bellmann A, Stoinski S, Friedrich A (2008) A new body mass estimation of Brachiosaurus brancai Janensch 1914 mounted and exhibited at the Museum of Natural History (Berlin, Germany). Fossil Record 11: 33–38.
7. Monahan P (2016) The tiniest titan. Science Tanslational Medicine p: 352.
8. Erickson GM, Rogers KC, Yerby SA (2001) Dinosaurian growth patterns and rapid avian growth rates. Nature 412: 429-432.
9. Wells JW (1963) Coral growth and geochronometry. Nature 197: 948-950.
10. Rogers KC, Whtney M, Demie M, Bagley B (2016) Precocity in a tiny titanosaur from the cretaceous of Madagascar. Science 352: 450-453.
11. Volobuev AN (1995) Fluid flow in tubes with elastic walls. Physics-Uspekhi 38: 169-178.
12. Physics Forums (2014) Theory #1 on Jul 14, 2013.
13. Knoll F, Witmer LM, Ridgely RC, Ortega F, Sanz JL (2015) A New Titanosaurian Braincase from the Cretaceous "Lo Hueco" Locality in Spain Sheds Light on Neuroanatomical Evolution within Titanosauria. PloS one 10: e0138233.

14. Kimani JK, Opole IO (1991) The structural organization and adrenergic innervation of the carotid arterial system of the giraffe (Giraffa camelopardalis). The Anatomical Record 230: 369-377.
15. Shein-Idelson M, Ondracek JM, Liaw HP, Reiter S, Laurent G (2016) Slow waves, sharp waves, ripples, and REM in sleeping dragons. Science 352:590-595.
16. Vazquez A, Liu J, Zhou Y, Oltvai ZN (2010) Catabolic efficiency of aerobic glycolysis: the Warburg effect revisited. BMC systems biology 4: 1.
17. Eagle RA, Enriquez M, Grellet-Tinner G, Pérez-Huerta A, Hu D, et al. (2015) Isotopic ordering in eggshells reflects body temperatures and suggests differing thermophysiology in two Cretaceous dinosaurs. Nature communications 6: 8296.