Fact sheet for dinosaur nasal air-conditioning story

Main species studied:

Panoplosaurus (pan-OH-plo-SORE-us)
Euoplocephalus (YOU-oh-plo-SEF-alus)

Members of dinosaur group: Ankylosauria
Time Period: Late Cretaceous, approximately 76–75 million years ago
Location: Both species lived in Alberta, Canada, although *Euoplocephalus* specimens have been found as far south as Montana.
Habitat: Swampy coastal plains
Descriptions:

Panoplosaurus

Age: adult
Estimated weight: 1500–2000 kg (3300–4400 lbs), hippo-sized
Estimated length: 5 m (16 ft)
Diet: Herbivore
Body: Quadrupedal, barrel-shaped, armored body with spikes over the shoulders and a long skull

Euoplocephalus

Age: adult
Estimated weight: 2000–3500 kg (4400–7700 lbs), rhino-sized
Estimated length: 5–6 m (16–20 ft)
Diet: Herbivore
Body: Quadrupedal, barrel-shaped, armored body with a short, wide skull and a tail that ended in a thickened club of bone

Major points:

a. Main problem addressed by the research: Large-bodied dinosaurs like *Panoplosaurus* and *Euoplocephalus* would have had very hot bodies because of (1) their low surface area compared to their huge volume and (2) the warm Cretaceous climate. For comparison, a large pot of soup takes a long time to cool whereas it seems your cup of coffee gets cold as soon as you turn your back on it. These dinosaurs were very large pots of soup! Hot blood from the body core would flow to the brain, potentially damaging the sensitive neural tissue. This research discovered a mechanism that could allow the large bodies of big dinosaurs to be hot without causing heatstroke.
b. Extensive armoring of the body in these dinosaurs resulted in calcification of nasal structures that would normally be made of soft tissues, resulting in amazingly well-preserved nasal passages.
c. The authors used an engineering approach called Computational Fluid Dynamics (CFD) to simulate the flow of air and heat within the nasal passages of these dinosaurs.
d. Multiple anatomical conformations were tested and compared to nasal heat-transfer data collected from modern-day animals
e. Nasal passages—as preserved, meaning just bony passages—revealed nasal heat transfer abilities that were on par with modern-day animals. When soft tissues were accounted for—a more life-like situation—these heat-transfer abilities increased.
f. Removing convolutions and artificially reducing the length of the nasal passages to match the length of the skull, saw substantial decreases in heat-transfer abilities in these dinosaurs

(~50%), indicating that a long, winding tube was necessary for effective heat transfer during breathing.

g. When the authors reconstructed the paths of blood vessels, they found a large supply of blood traveling to the nose and back towards the brain. As air passed over the moist nasal mucous membranes, there would be evaporative cooling of the mucous membranes (this same mechanism is what allows sweating to cool us). The venous blood in the mucous membrane would have been cooled, providing a constant source of cool blood to the brain.
h. Almost all large dinosaurs show nasal expansion, suggesting that these animals enhanced the cooling ability of their noses to keep their brains from overheating inside ever larger bodies.
i. Future directions: The authors are now looking at small to mid-sized dinosaurs to better understand how this nasal elaboration happened.

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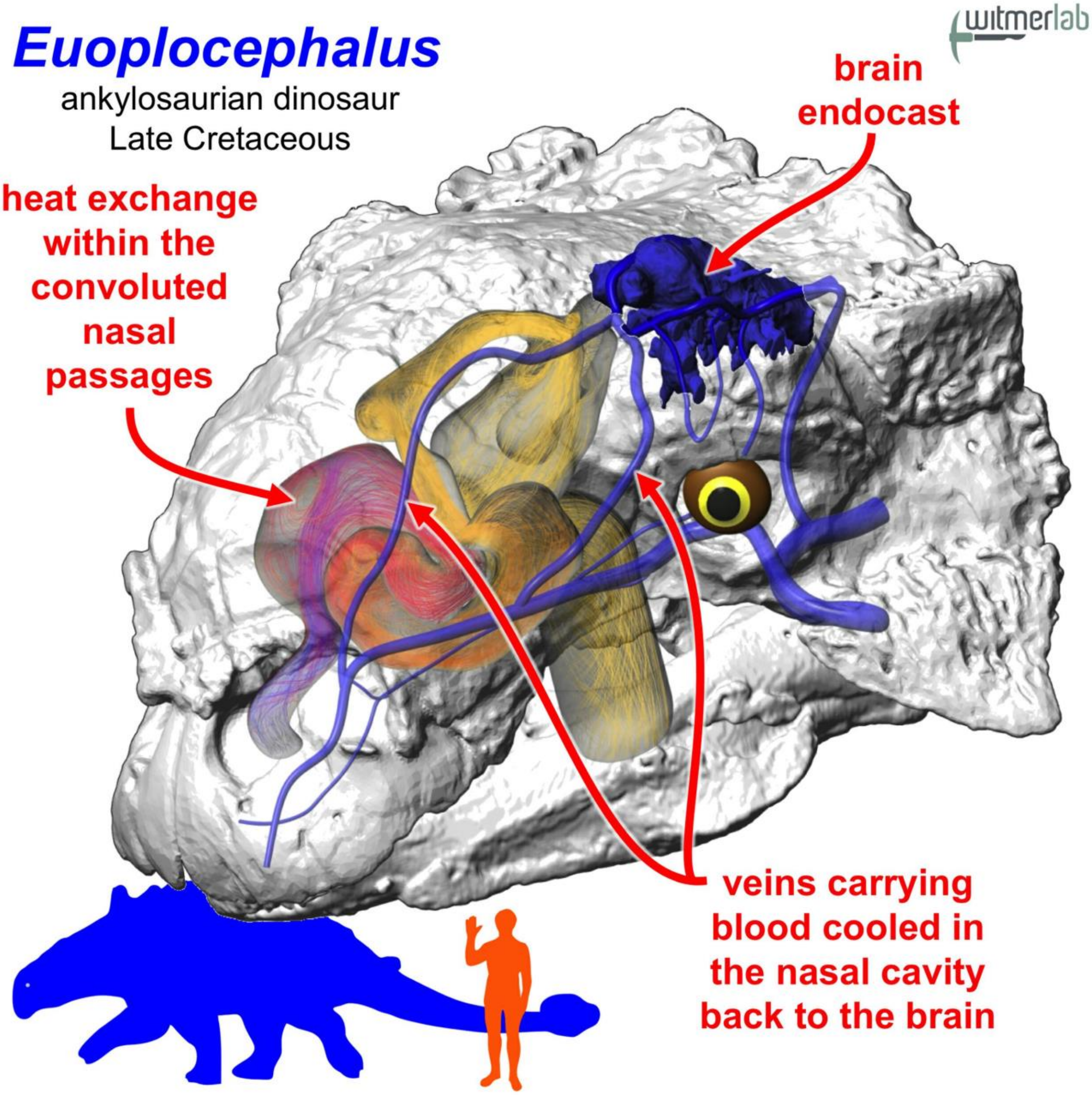
For downloadable graphics and animations, visit: https://people.ohio.edu/witmerl/ankylosaur_brain-AC.htm

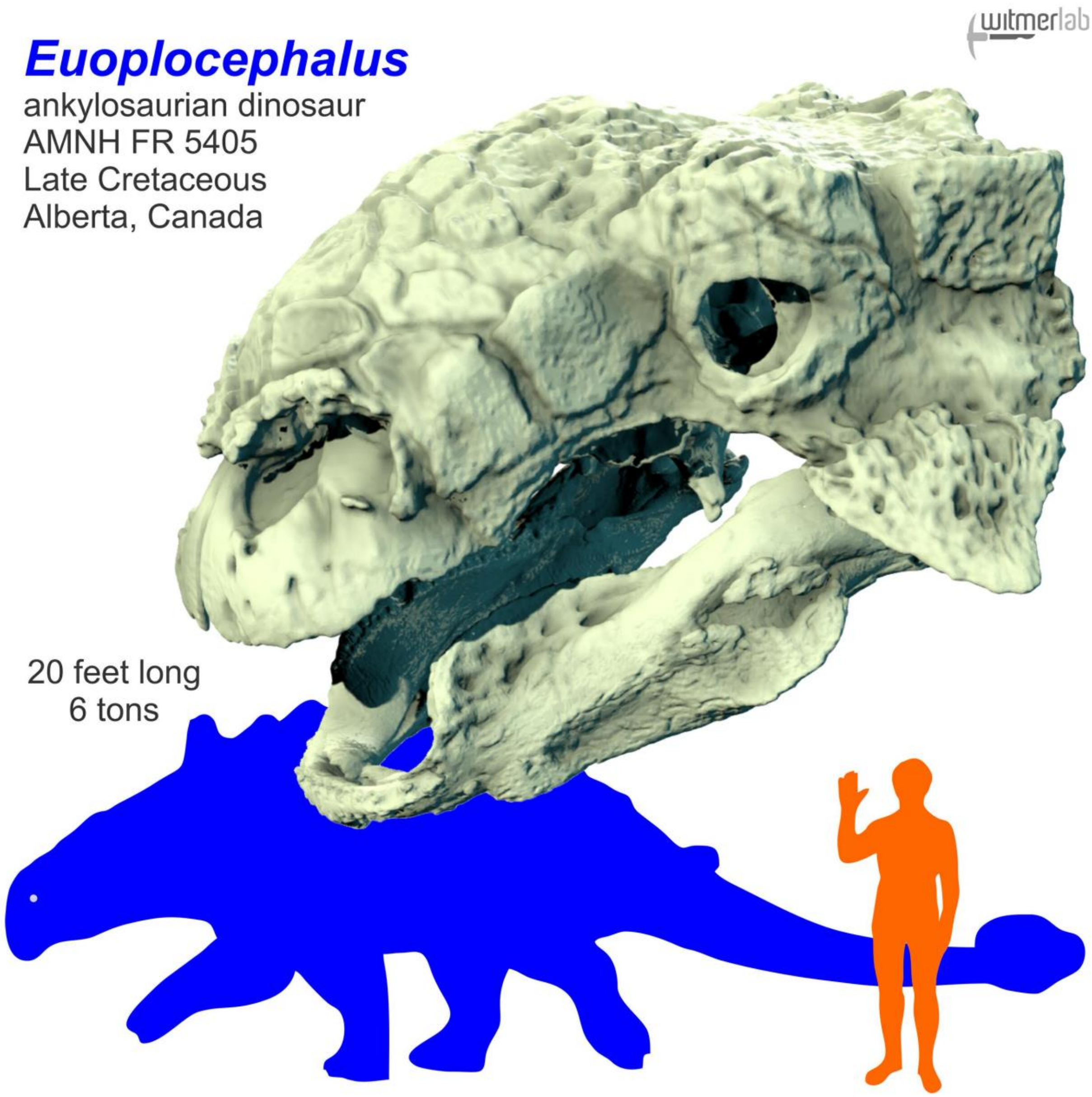
Images and animations

(Note: Images are compressed for this document. Click the links to download larger files).

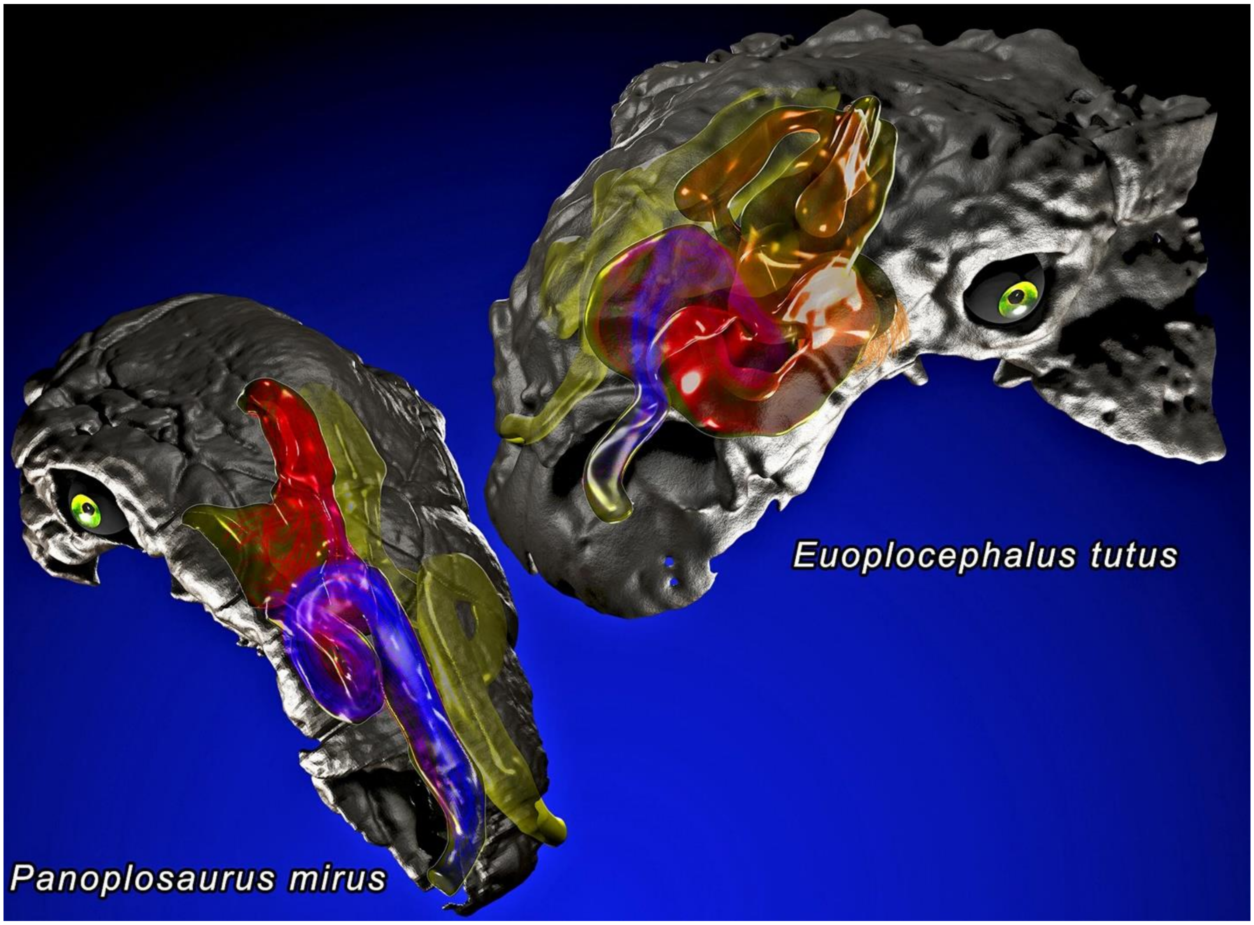


Heat exchange through the highly convoluted nasal passages of the Cretaceous ankylosaurian dinosaur *Euoplocephalus* not only efficiently warmed and humidified the inspired air on its way to the lungs but also cooled the blood running through the nasal veins, much of which was destined for the brain. In this way, the brain was protected from the high temperatures of the hot arterial blood coming from the body core. Courtesy of WitmerLab at Ohio University. (Silhouettes: Marmelad - CC-BY-SA-2.5)

https://people.ohio.edu/witmerl/images/Euoplocephalus_nasal_air-conditioning.jpg

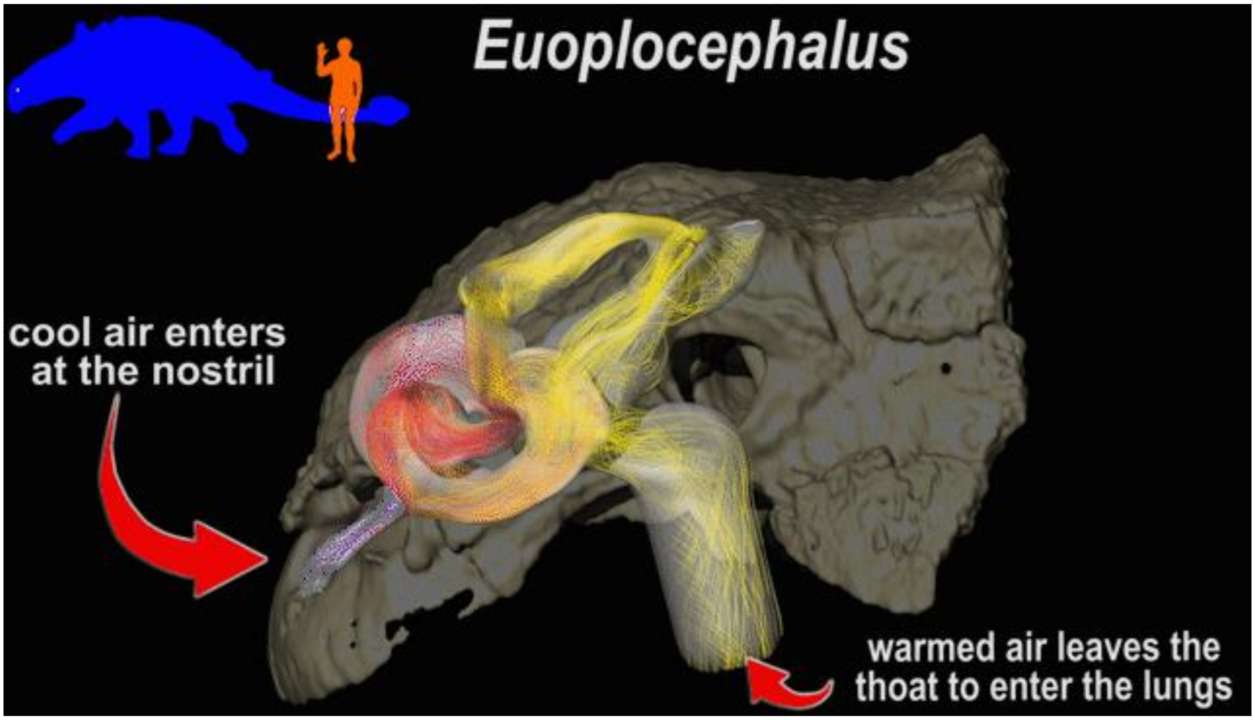


This study of dinosaur thermal physiology focused on the Cretaceous ankylosaurian dinosaur *Euoplocephalus* (illustrated here), as well another less specialized ankylosaur called *Panoplosaurus*. Both dinosaurs were found in Late Cretaceous fossil deposits of Alberta, Canada. The research team used CT scanning, soft-tissue reconstruction, and engineering analyses (computational fluid dynamics) to simulate air and blood flow and calculate heat exchange in the nasal passages. Courtesy of WitmerLab at Ohio University. (Silhouettes: Marmelad - CC-BY-SA-2.5)
https://people.ohio.edu/witmerl/images/Euoplocephalus_skull_&_silhouette_human.jpg

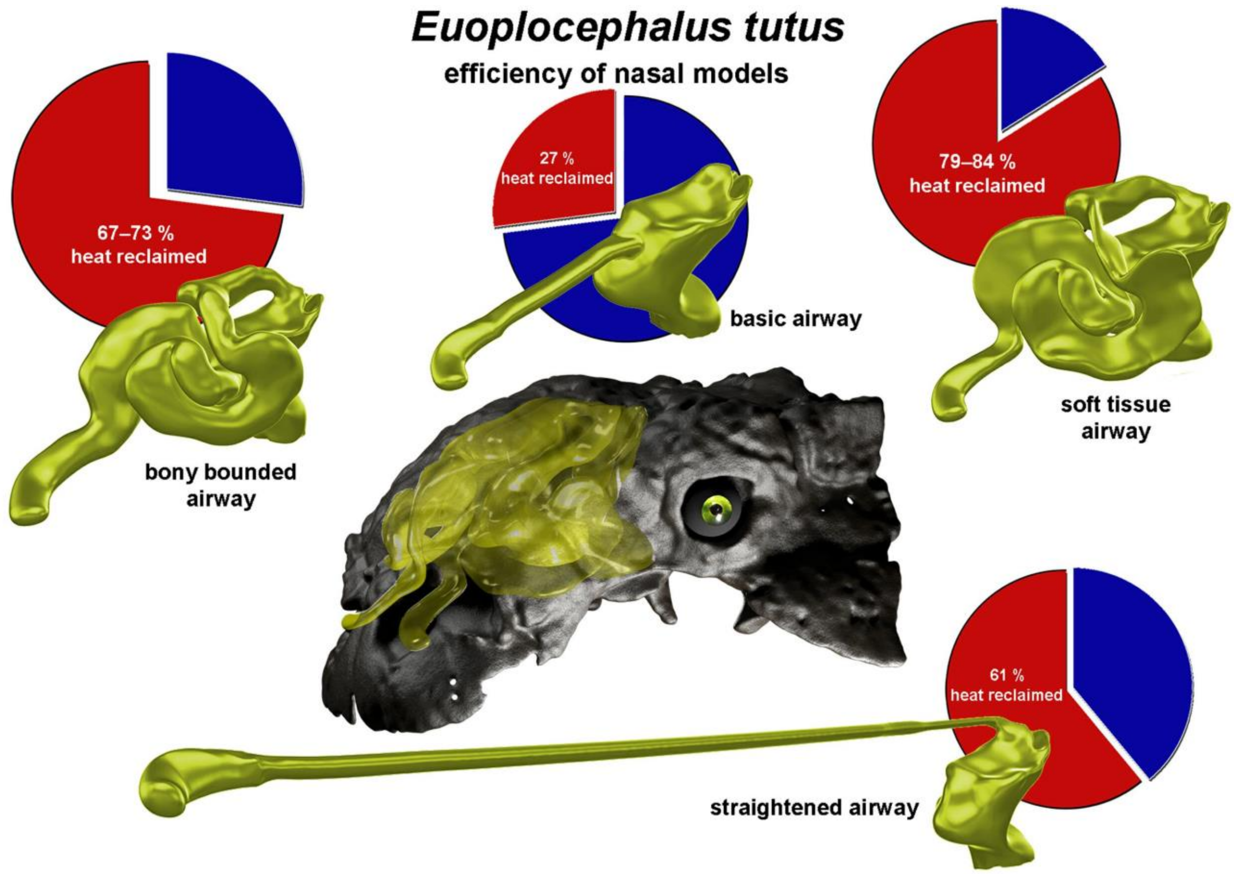


The skulls of the two ankylosaurian dinosaurs—*Panoplosaurus* and *Euoplocephalus*—that were the focus of the research. The skulls are rendered semitransparent, revealing the convoluted "krazy-straw" nasal passages coiled within their snouts. Colors within the nasal passages show the heat exchange modeled by the computational fluid dynamics analysis. The heat exchange allowed efficient warming and humidification of the inspired air. The more elaborately coiled nasal passages of *Euoplocephalus* were more efficient than the simpler ones of *Panoplosaurus*. Courtesy of WitmerLab at Ohio University.
https://people.ohio.edu/witmerl/images/ankylosaur_dinosaur_airways.jpg

Authors of the article investigate key features in the skulls of ankylosaurian dinosaurs in WitmerLab at Ohio University. From left: Jason Bourke, Ruger Porter, and Lawrence Witmer. Courtesy of WitmerLab at Ohio University.
https://people.ohio.edu/witmerl/images/WitmerLab-Team_Ankylosaur_Bourke-Porter-Witmer.jpg

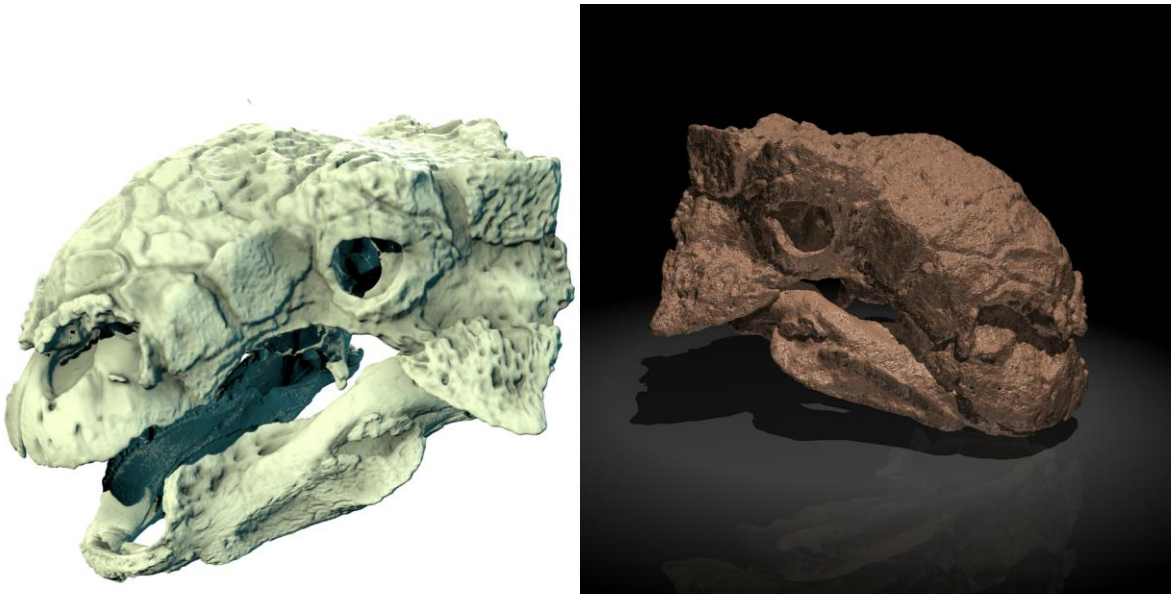


Animated GIF: Heat exchange of inspired air as it passes through the tortuous nasal cavity of the Late Cretaceous ankylosaur *Euoplocephalus*. The computational fluid dynamics analysis shows the flow of air during inhalation, with color—i.e., gray to red to orange to yellow—indicating progressively warmer temperatures. *Euoplocephalus* has a very efficient nasal cavity, fully warming and humidifying the inspired air before it reaches the lungs. *Panoplosaurus*, with its simpler nose is somewhat less efficient but still impressive. Likewise, on exhalation, the long convoluted airways cool the expired air, saving heat and energy. Courtesy of WitmerLab at Ohio University.
https://people.ohio.edu/witmerl/images/Euoplocephalus_nasal_air-conditioning_360p.gif
https://people.ohio.edu/witmerl/images/Euoplocephalus_nasal_air-conditioning_720p.gif

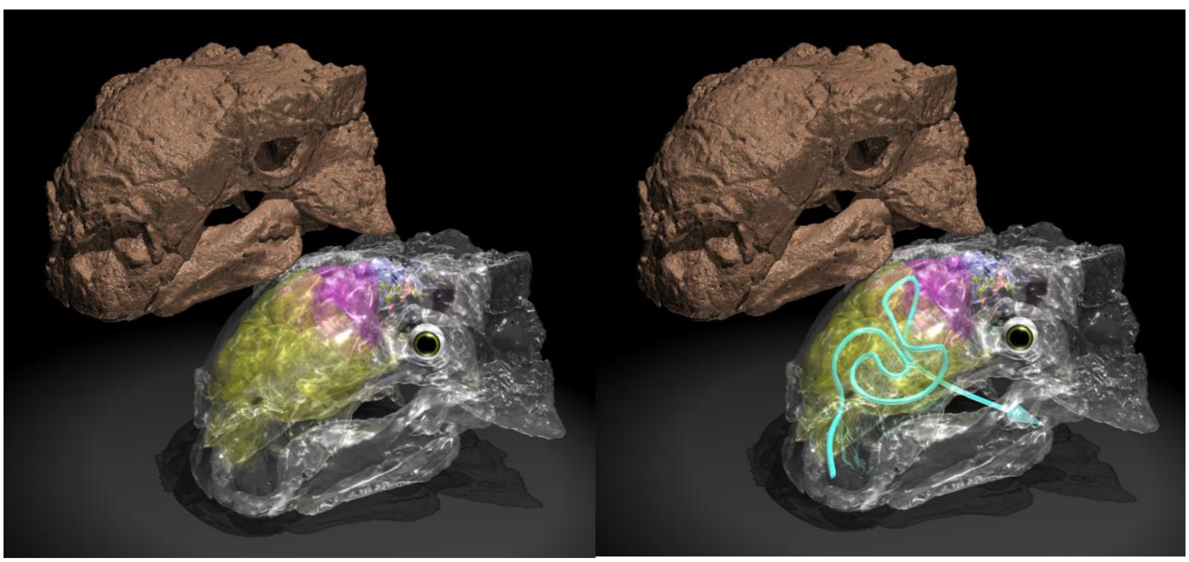


Bourke et al. 2018. Convoluted nasal passages function as efficient heat exchangers in ankylosaurs (Dinosauria: Ornithischia: Thyreophora). PLOS ONE

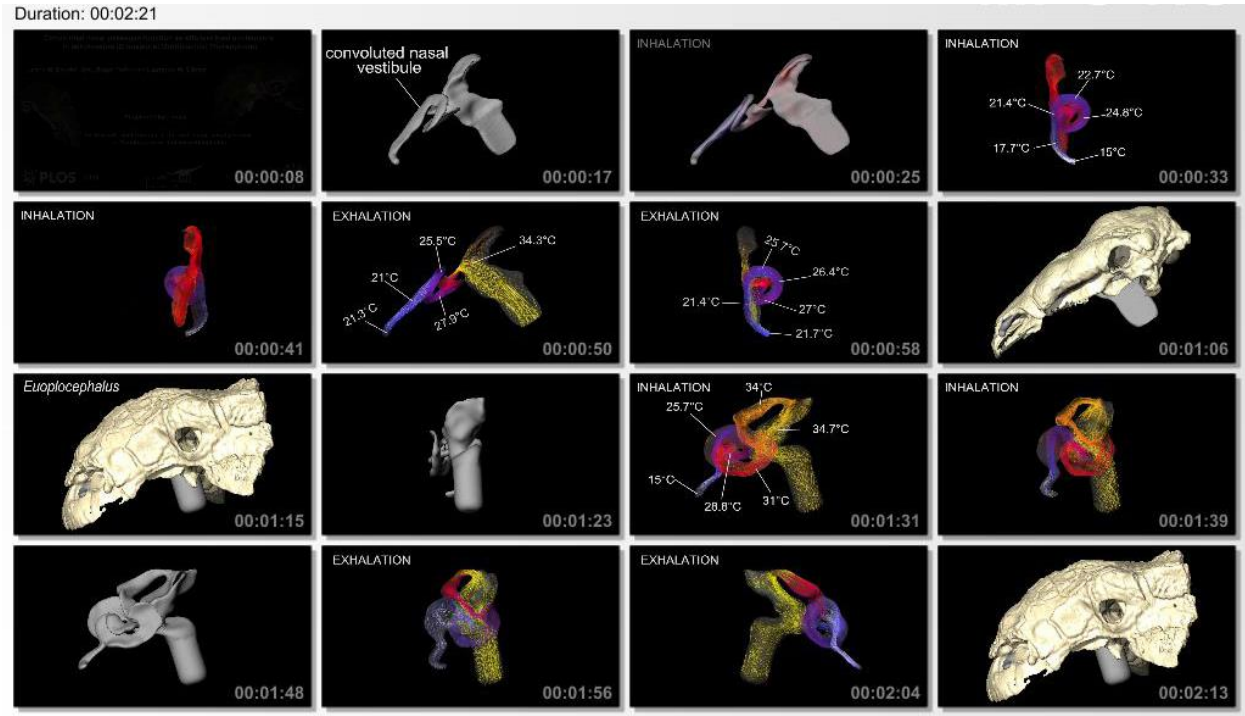
The Late Cretaceous armored dinosaur *Euoplocephalus* (center) had a long, highly convoluted nasal passage coiled up in its snout. The physiological efficiency of heat exchange was tested by computational fluid dynamics analyses that compared the (top left) “bony bounded” airway (i.e., as preserved in the fossil), (top right) the “soft tissue” airway (closer to real life due to restored nasal mucous membrane), (top middle) the “basic airway” (short and simple, as in many animals, including humans), and (bottom) the “straightened airway” (same length as bony-bounded and soft-tissue airways but without convolutions). The basic airway is the least efficient, and the long convoluted soft-tissue air is the most efficient as well as the most realistic. The long straight airway was also very efficient but less so than the convoluted airway, indicating that the twists and turns contribute significantly, probably due to the increased vorticity that slowed down the airstream and increased the chance for heat transfer. Courtesy of WitmerLab at Ohio University.
https://people.ohio.edu/witmerl/images/Euoplocephalus_skull-three_airway_models.jpg



The skull of the Late Cretaceous armored dinosaur Euoplocephalus that was used in the study.
https://people.ohio.edu/witmerl/images/Euoplocephalus_skull_01.png
https://people.ohio.edu/witmerl/images/Euoplocephalus_skull_02.png

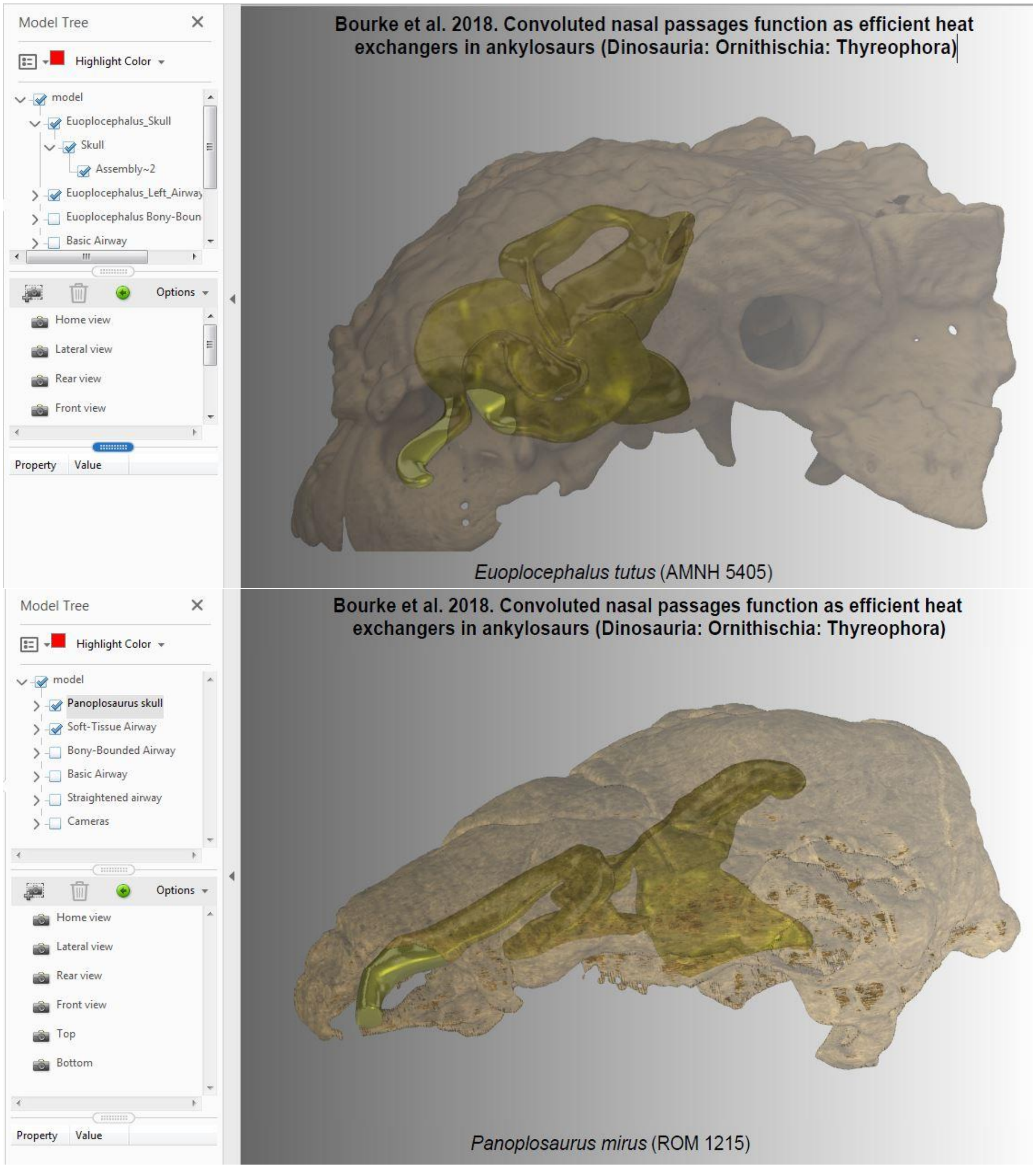


Skulls of the Late Cretaceous armored dinosaur Euoplocephalus represented as a solid skull (left) and as a transparent skull (right), revealing the long convoluted nasal cavity within the snout.
https://people.ohio.edu/witmerl/images/Euoplocephalus_skull_03.png
https://people.ohio.edu/witmerl/images/Euoplocephalus_skull_04.png



This movie is associated with an article published in PLOS ONE on 19 December 2018 (http://bit.ly/2rzFudE) by Jason Bourke, Ruger Porter, and Lawrence Witmer. Nasal airflow was modeled using Computational Fluid Dynamics analyses for two Late Cretaceous ankylosaurian dinosaurs, *Panoplosaurus* and *Euoplocephalus*. The video demonstrates how the highly convoluted nasal cavity in both species warms the inhaled air on its way to the lung and then cools the exhaled air, resulting in a highly efficient system of air conditioning that conserves both heat and water. For more in this project, visit the WitmerLab project page: http://bit.ly/2EwOzMO.

• YouTube version: https://youtu.be/xqJw5JcEeB0
• Download a 48 MB 1920x1080 QuickTime .mov: https://people.ohio.edu/witmerl/Movies/Ankylosaur_nasal_air-conditioning_WitmerLab_1920x1080.mov
• Download other sizes on the website: https://people.ohio.edu/witmerl/ankylosaur_brain-AC.htm



3D-PDF of the skull and nasal passages of the ankylosaurian dinosaurs *Euoplocephalus* and *Panoplosaurus*, showing the four different shapes of the airways tested: “bony bounded” airway (as preserved in the fossil), “soft tissue” airway (closer to real life due to restored nasal mucous membrane), “basic airway” (short and simple, as in many animals, including humans), and “straightened airway” (same length as bony-bounded and soft-tissue airways but without convolutions). 3D-PDF files should be saved and then run on your computer; they will not run in a browser window. Courtesy of WitmerLab at Ohio University.

https://people.ohio.edu/witmerl/Downloads/Euoplocephalus_airway_3D-PDF.pdf

https://people.ohio.edu/witmerl/Downloads/Panoplosaurus_airway_3D-PDF.pdf