Facts, images, & animations for dinosaur breathing story

Main dinosaur: *Stegoceras* (note: this is NOT *Stegosaurus*, the dino with plates)
Family: Pachycephalosauridae (the "bone-headed" dinosaurs)
Time period: late Cretaceous, about 75 million years ago
Discovery: The *Stegoceras* specimen used in this study was discovered in 1921 in southern Alberta in Canada. It's currently housed at the University of Alberta and bears the catalog number UALVP 2.
The fossil: The skeleton is a relatively complete individual, one of the most complete pachycephalosaur specimens known.

***Stegoceras* at a glance:**

Age:	adult
Weight:	40 kg (90 pounds)
Length:	2 m (6.5 feet)
Skull length	212 mm (8.3 inches)
Lifestyle	bipedal herbivore
Claim to fame	head-butting

Major points:

a. Extraordinary preservation of soft tissue in the *Stegoceras* fossil skull, coupled with high resolution CT scanning, revealed (1) delicate scrolls of bone called "olfactory turbinates" in the back of the nasal cavity where smelling would have taken place, and (2) a long bony ridge running along the wall in the front of the nasal cavity.

b. The authors used an engineering approach called computational fluid dynamics (CFD) to simulate airflow under different anatomical conformations.

c. CFD of modern-day relatives of dinosaurs (birds, crocs, lizards) showed that some inspired air circulates around the olfactory turbinates before going down to the lungs.

d. When CFD of *Stegoceras* was performed, almost no air passed into the olfactory region. However, when a respiratory turbinate similar to those in modern-day dinosaur relatives was restored attaching to the bony ridge in *Stegoceras*, the computer simulations showed very natural-looking olfactory airflow. Therefore, the restored respiratory turbinate acts as a baffle to direct air around the nasal cavity.

e. The authors also restored the nasal blood vessels based on preserved canals and grooves. These findings suggested that the restored respiratory turbinate also functioned to provide increased surface area for blood to be cooled,

with the cooled venous blood flowing to the brain region to help regulate brain temperature.

f. Future directions: these advances will allow the authors to restore the nasal airflow and physiology in other dinosaurs with even more complicated airways.

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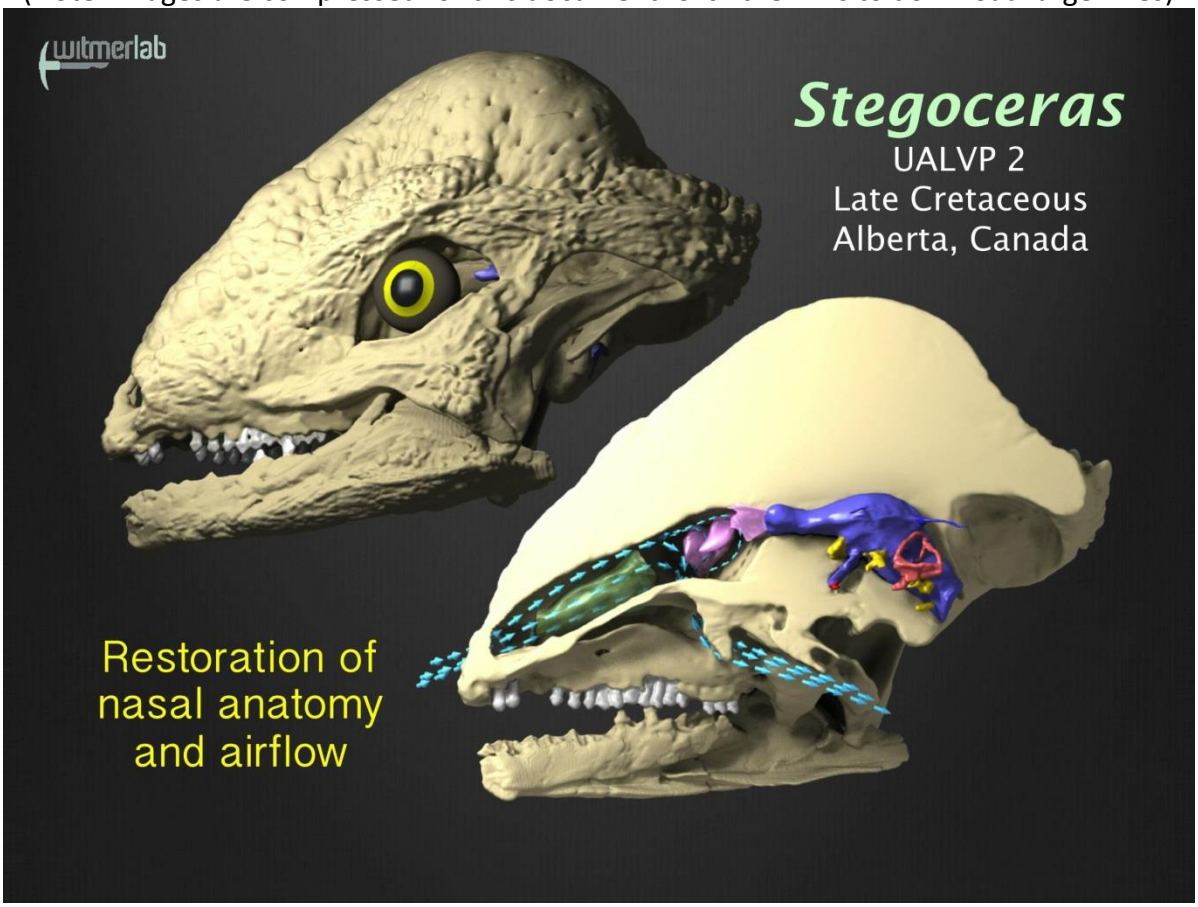
For downloadable graphics and animation, visit:
http://www.oucom.ohiou.edu/dbms-witmer/pachy_airflow.htm

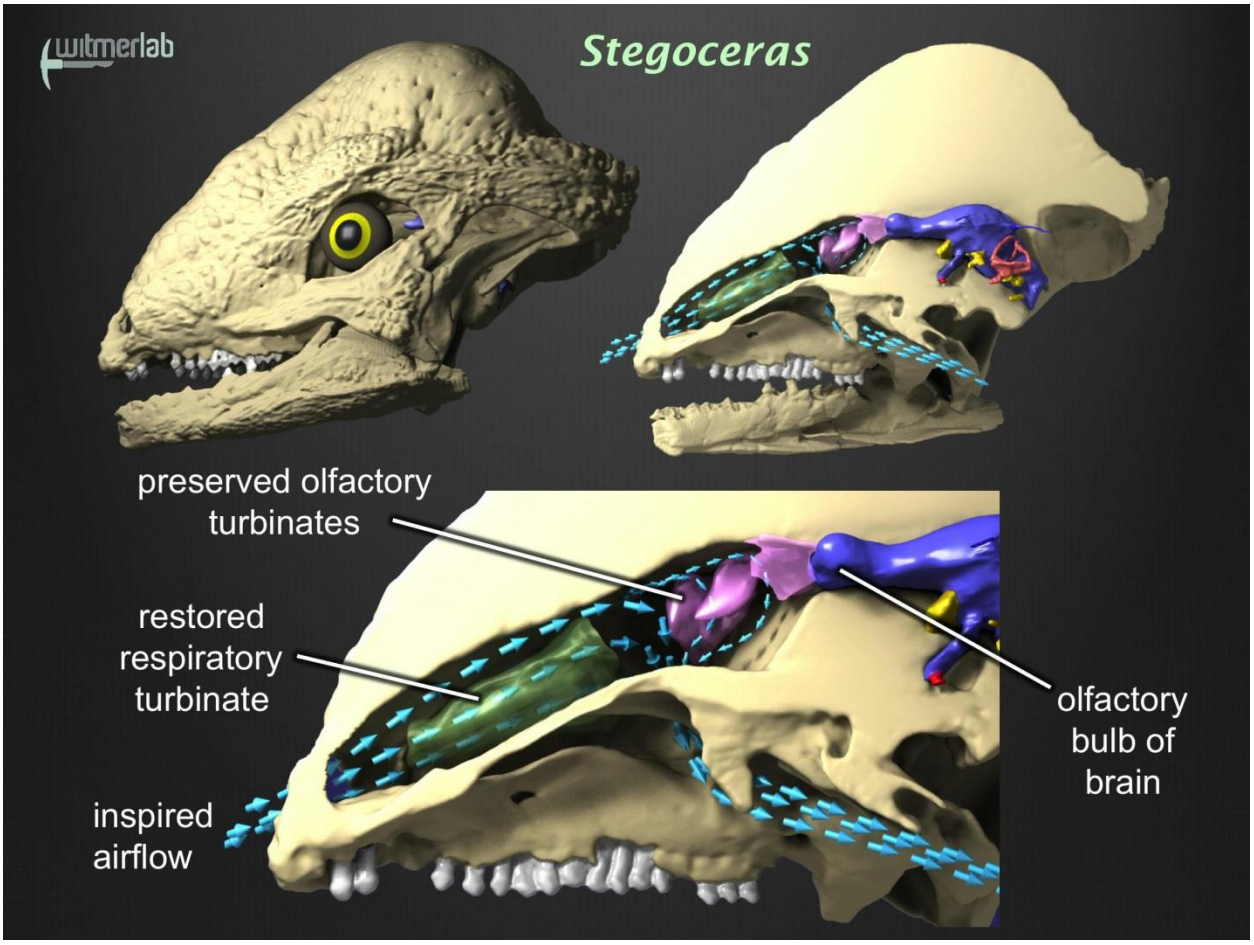
Images and animations

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



Airflow modeled through the nasal cavity of the Cretaceous pachycephalosaur *Stegoceras* based on restoration of nasal soft tissues and Computation Fluid Dynamics of nasal airflow. This is the first study to analytically model nasal airflow in any extinct animal. A very general key finding was that comparative anatomy can be combined with engineering to restore the nasal physiology of extinct species. Courtesy of WitmerLab at Ohio University.

Download the image: http://www.oucom.ohiou.edu/dbms-witmer/images/Stegoceras_skull_w_airflow.png



Airflow modeled through the nasal cavity of the Cretaceous pachycephalosaur *Stegoceras* based on restoration of a respiratory turbinate onto a long bony ridge preserved in the fossil. Simulations using computational fluid dynamics software revealed that a turbinate of at least broadly similar shape must have been present to act as a baffle to allow realistic airflow to the olfactory region. Courtesy of WitmerLab at Ohio University.

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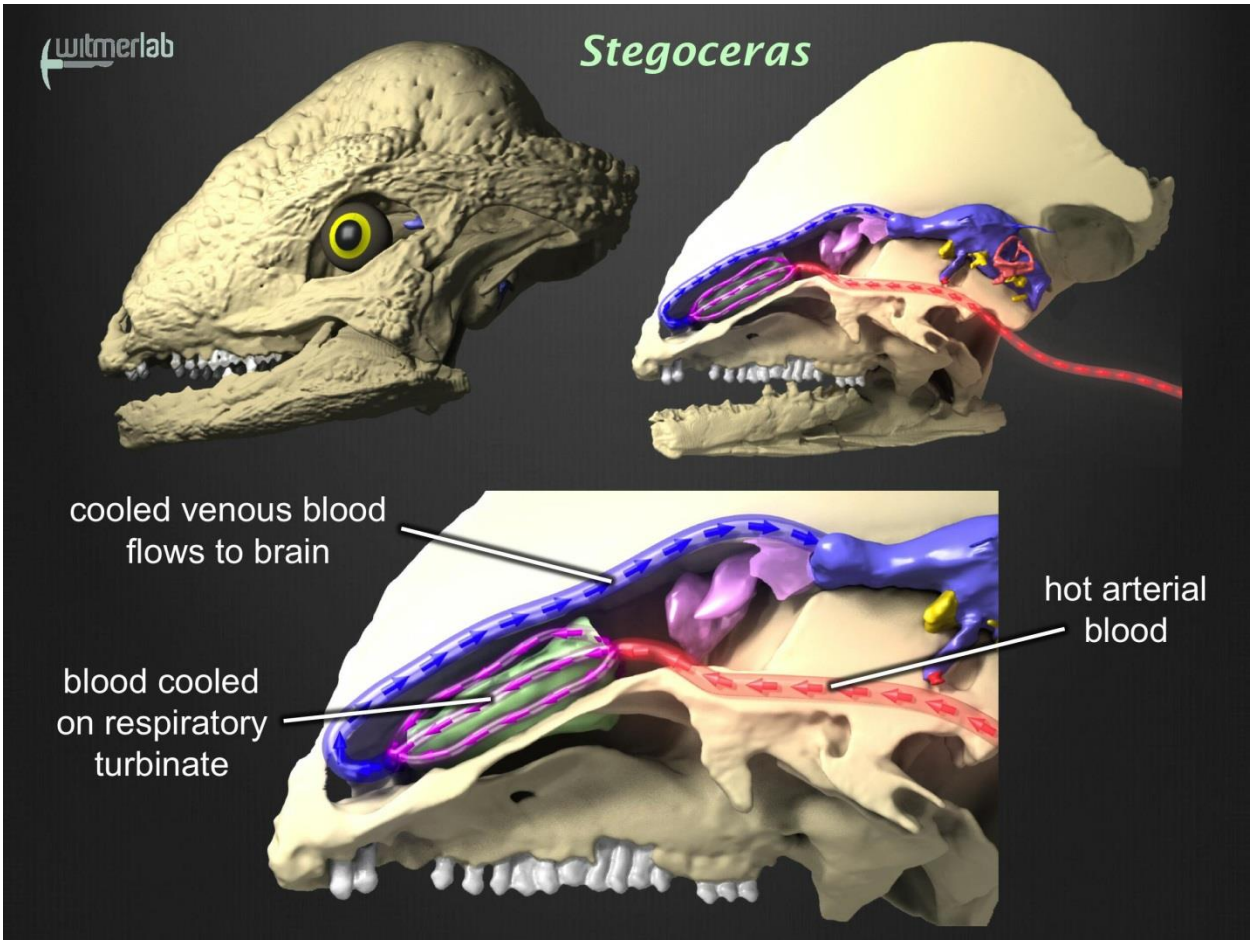

Restoration of blood flow through the nasal cavity of the Cretaceous pachycephalosaur *Stegoceras*. The restored respiratory turbinate increased the surface area of the nasal tissues. Hot arterial blood coming from the body core would have been cooled by evaporation on the respiratory turbinate, and the cooled venous blood would have then flowed to the brain region to moderate brain temperatures. Courtesy of WitmerLab at Ohio University.

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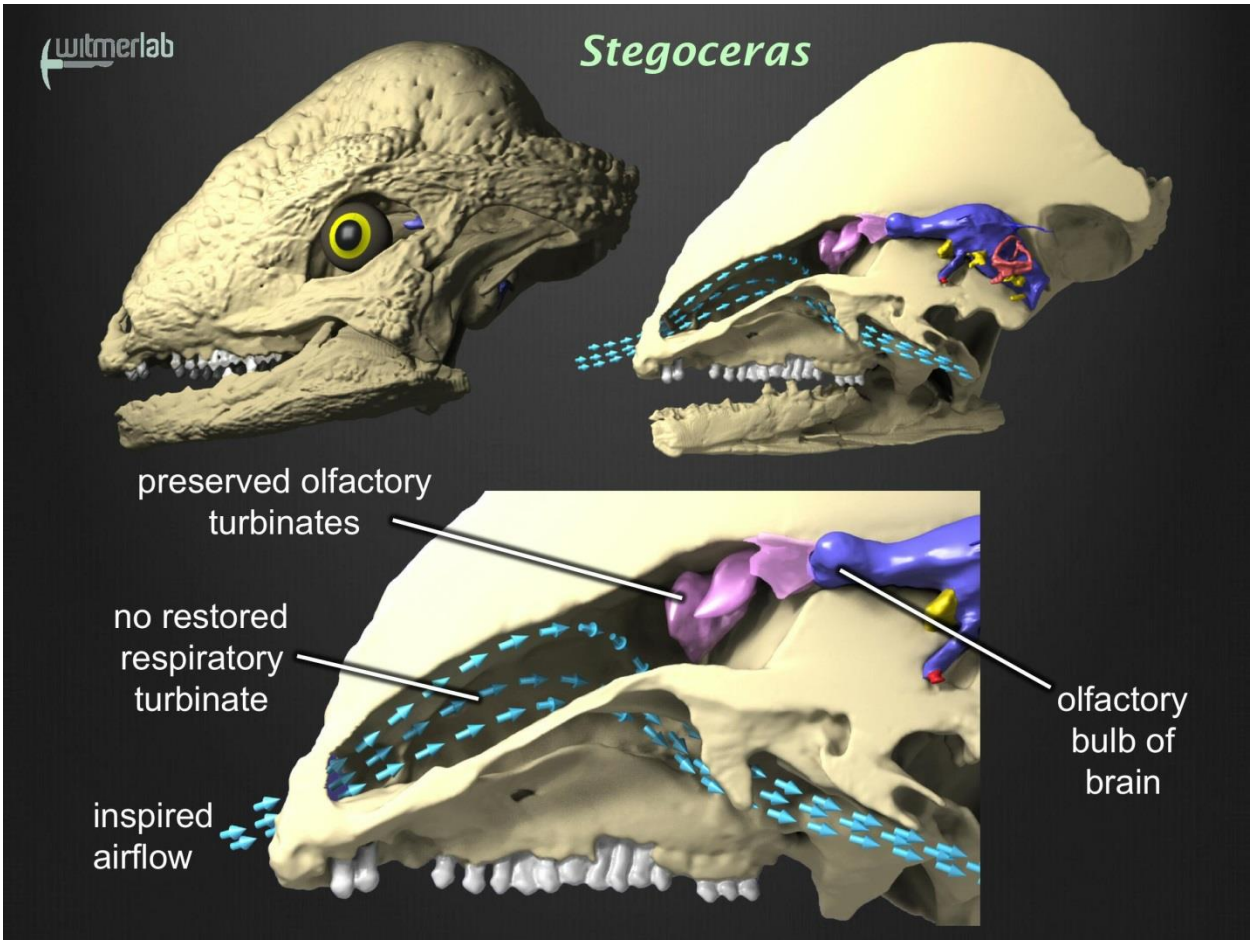

Airflow modeled through the nasal cavity of the Cretaceous pachycephalosaur *Stegoceras* in the absence of restoration of a respiratory turbinate. The fossil itself only preserves a bony ridge, not the respiratory turbinate itself. Simulations using computational fluid dynamics software revealed that, taking the fossil at "face value," absence of the turbinate produces unrealistic airflow patterns in that almost no inspired air reaches the olfactory region. Courtesy of WitmerLab at Ohio University.

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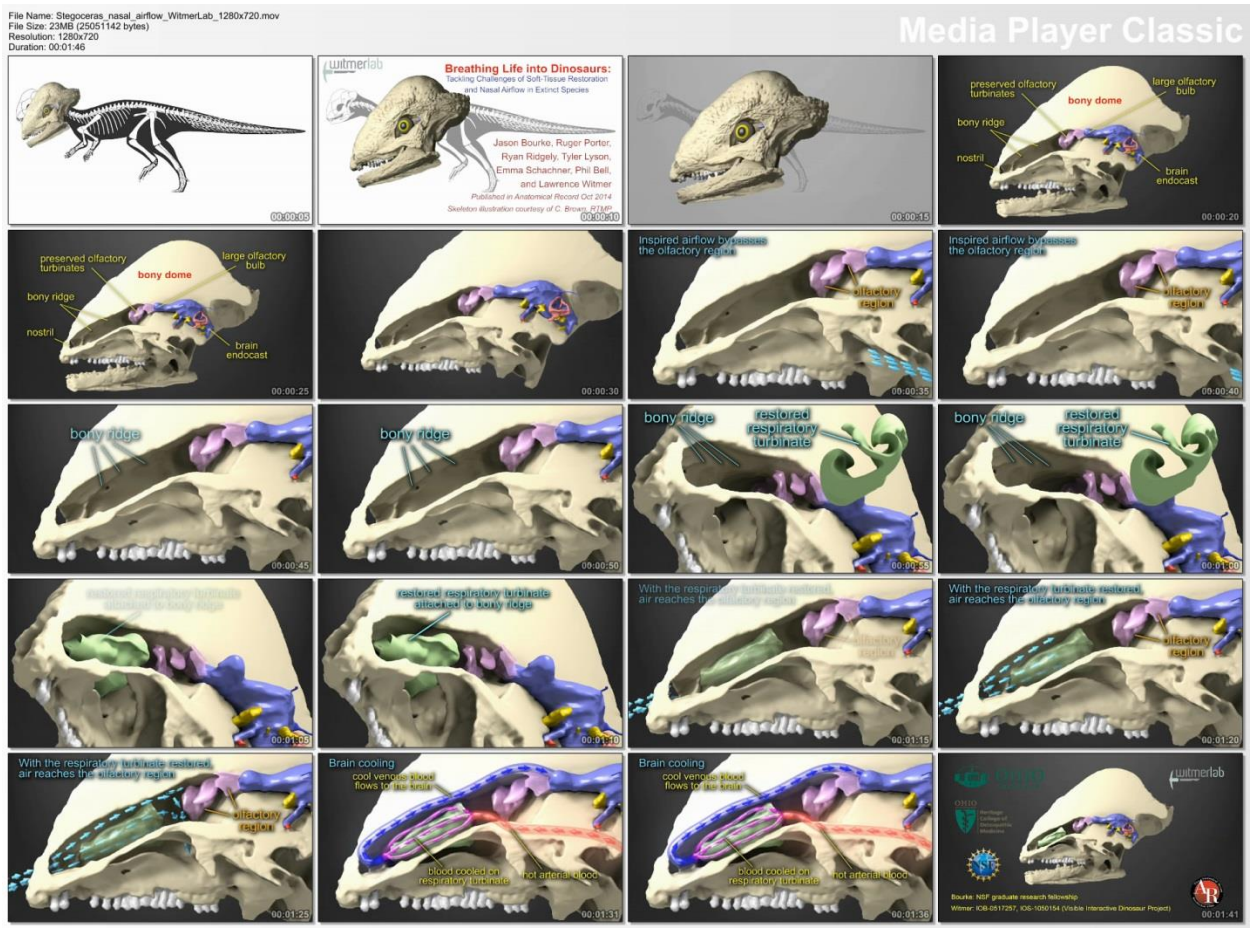

Animation of simulated airflow in the Cretaceous pachycephalosaurid dinosaur *Stegoceras* (UALVP 2) based on different models of restored nasal soft tissues. In the absence of any restored soft tissues, modeled airflow bypasses the olfactory region, which is not realistic. By modeling a respiratory turbinate (in this case, an ostrich-like branched concha) attaching to the preserved bony ridge, realistic olfactory airflow is modeled. It's also likely that the nasal structures functioned to cool blood that was destined for the brain region. This is largely the work of Jason Bourke (Ohio University) to accompany an article published in the Anatomical Record (2014) by Bourke, Porter, Ridgely, Lyson, Schachner, Bell, and Witmer. Research supported in part by the NSF-funded Visible Interactive Dinosaur project, WitmerLab at Ohio University.

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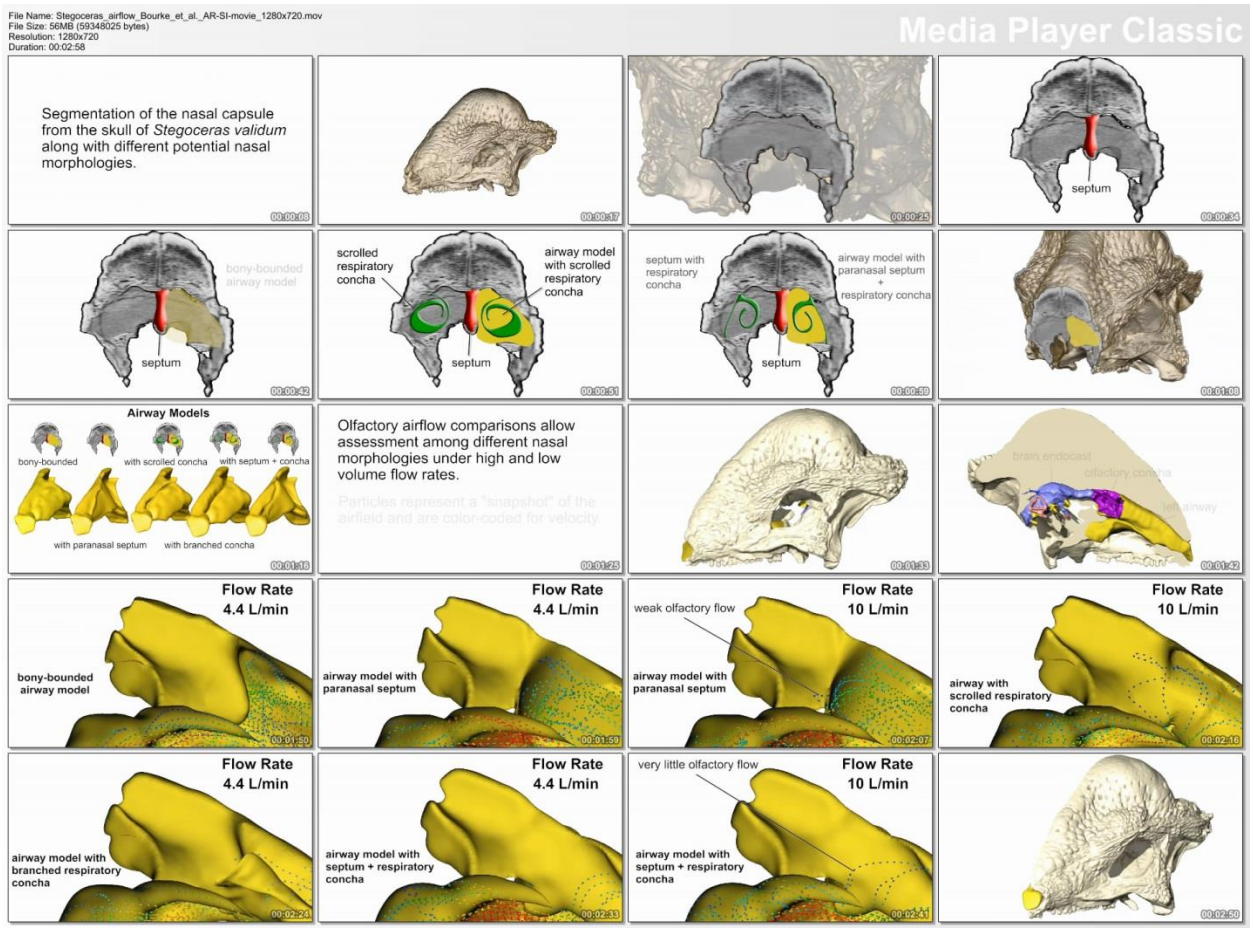

Animation of simulated airflow in the Cretaceous pachycephalosaurid dinosaur Stegoceras (UALVP 2) based on different models of restored nasal soft tissues. This is largely the work of Jason Bourke (Ohio University) to accompany an article published in the Anatomical Record (2014) by Bourke, Porter, Ridgely, Lyson, Schachner, Bell, and Witmer. Research supported in part by the NSF-funded Visible Interactive Dinosaur project, WitmerLab at Ohio University.

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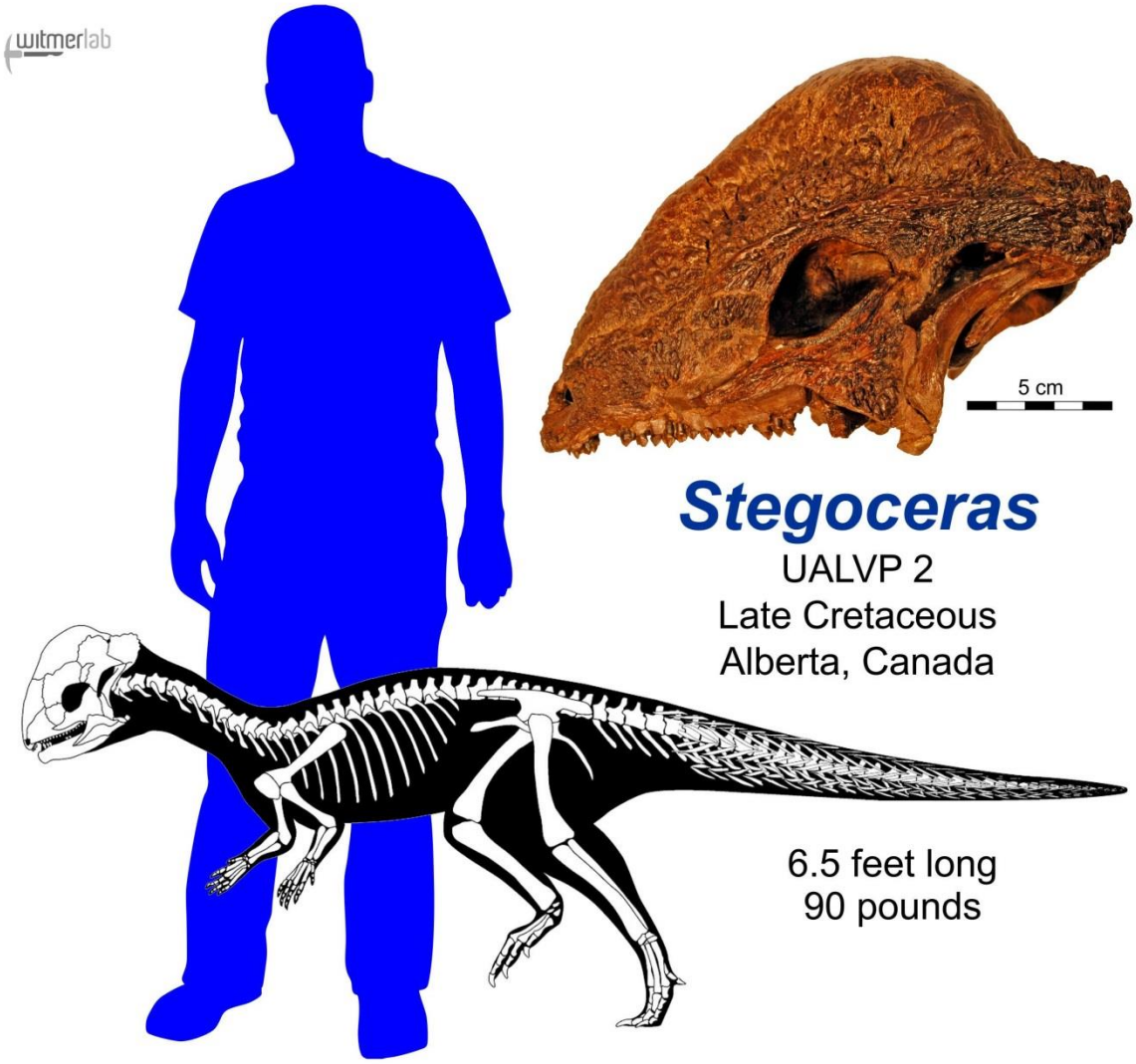

Skeleton of the Cretaceous pachycephalosaur *Stegoceras* with the silhouette of a human for scale. The original skull of *Stegoceras* is shown at top right. Skeleton and silhouette provided by C. Brown, Royal Tyrrell Museum of Palaeontology; photo of skull provided by P. Currie, University of Alberta. Courtesy of WitmerLab at Ohio University.

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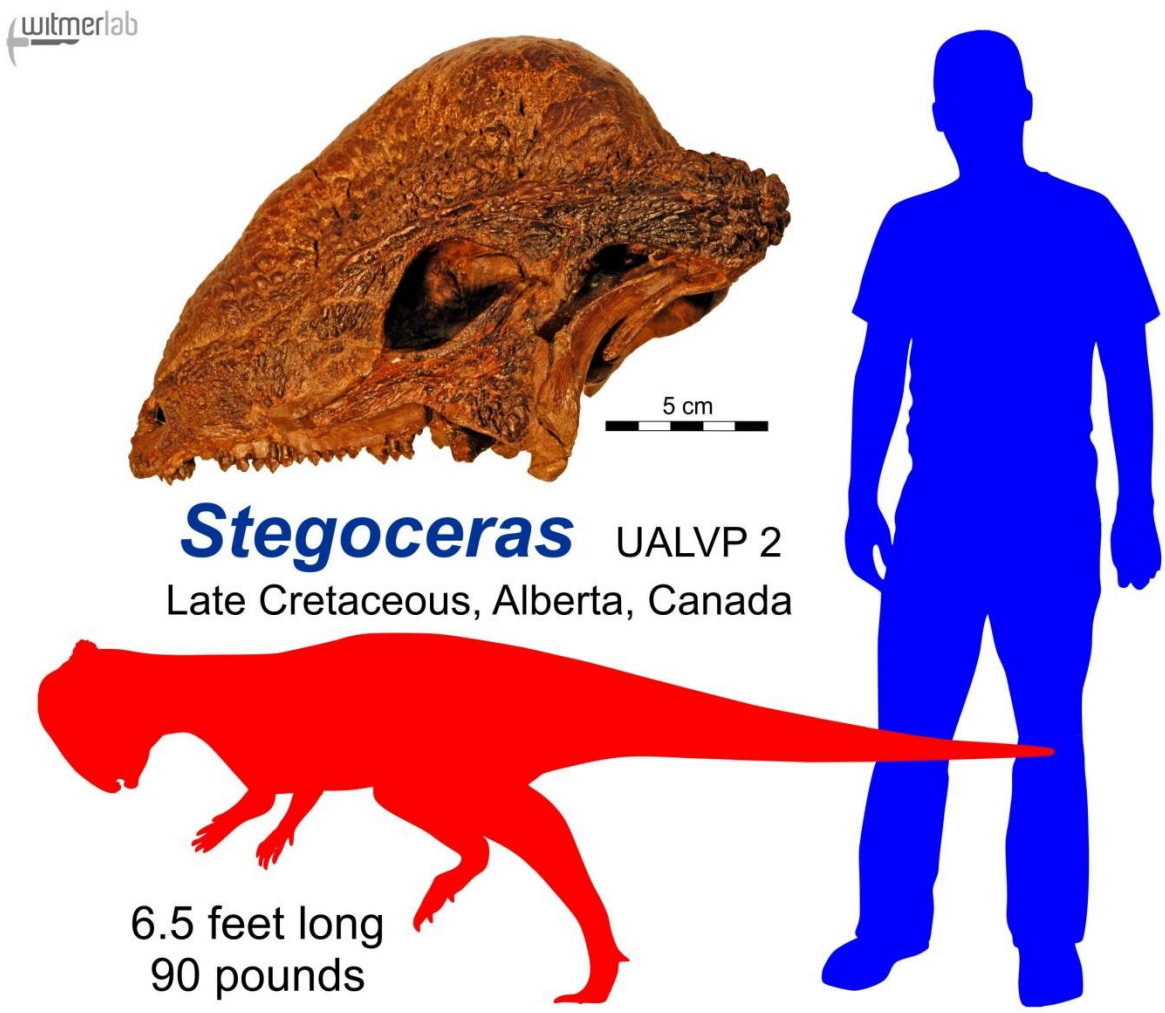

Silhouettes of the Cretaceous pachycephalosaur *Stegoceras* in head-butting posture and of a human, for scale. The original skull of *Stegoceras* is shown at top left. Silhouettes provided by C. Brown, Royal Tyrrell Museum of Palaeontology; photo of skull provided by P. Currie, University of Alberta. Courtesy of WitmerLab at Ohio University.

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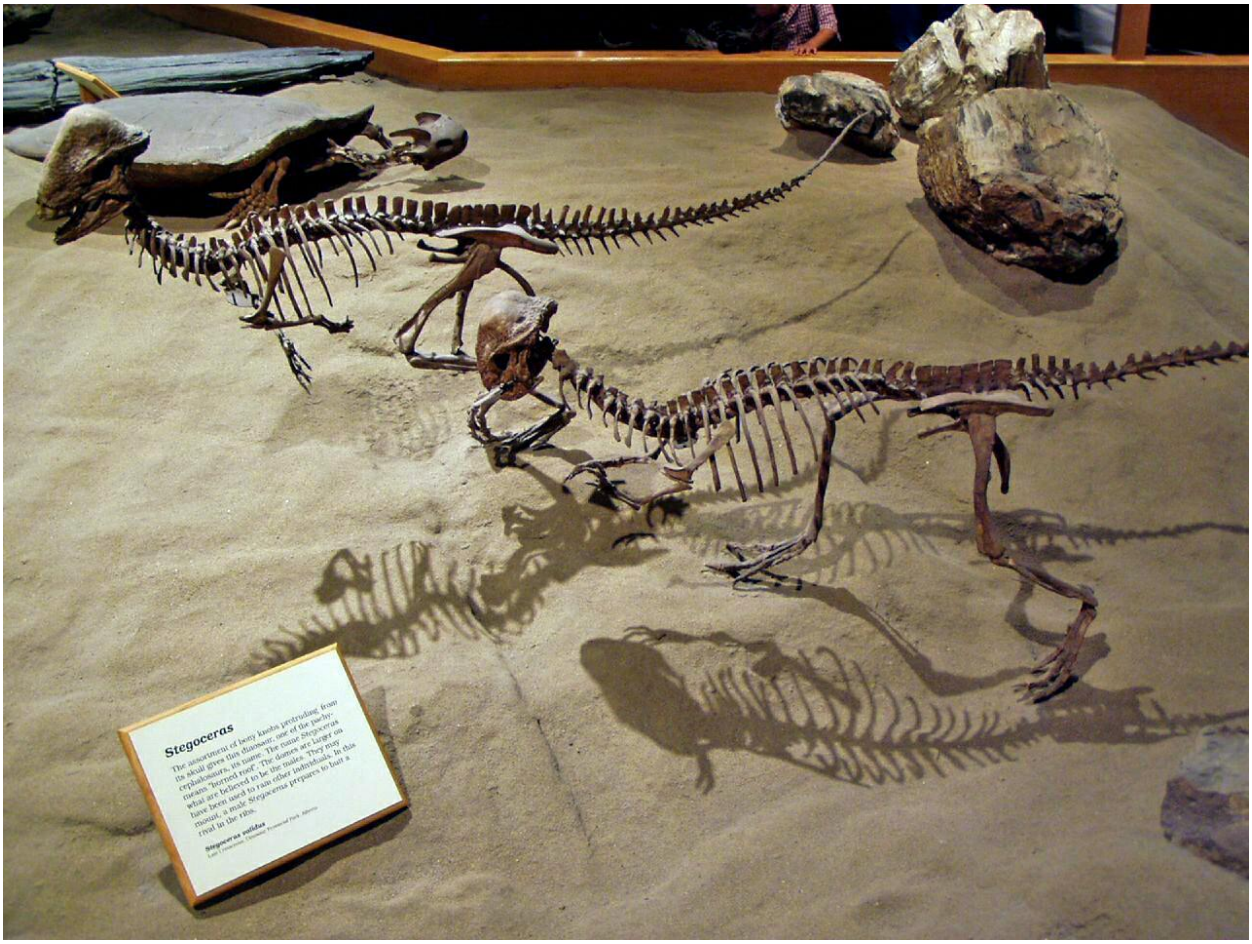
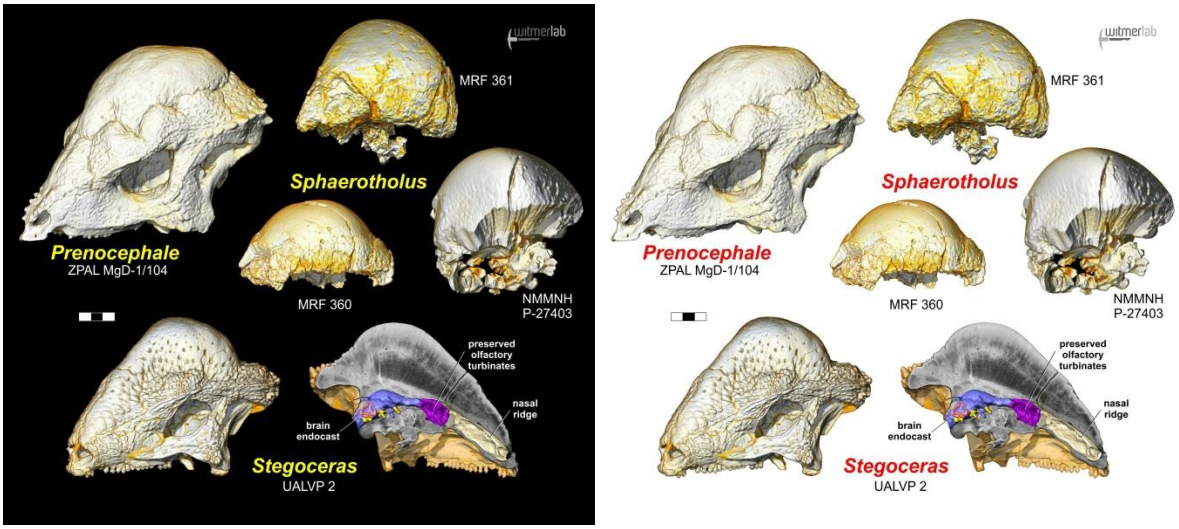


Mounted skeletons two *Stegoceras* in the gallery at the Royal Tyrrell Museum of Palaeontology in Drumheller, Alberta. Photo by S. Bergmann, Wikipedia.

Download the image: http://www.oucom.ohiou.edu/dbms-witmer/images/Stegoceras_Wikipedia_S.Bergmann.jpg



Skulls of pachycephalosaurid dinosaurs discussed in the scientific article, based on volume-rendered CT scan data. The three *Sphaerotholus* specimens are missing the facial part of the skull. Scale bar is 3 cm. Courtesy of WitmerLab at Ohio University.

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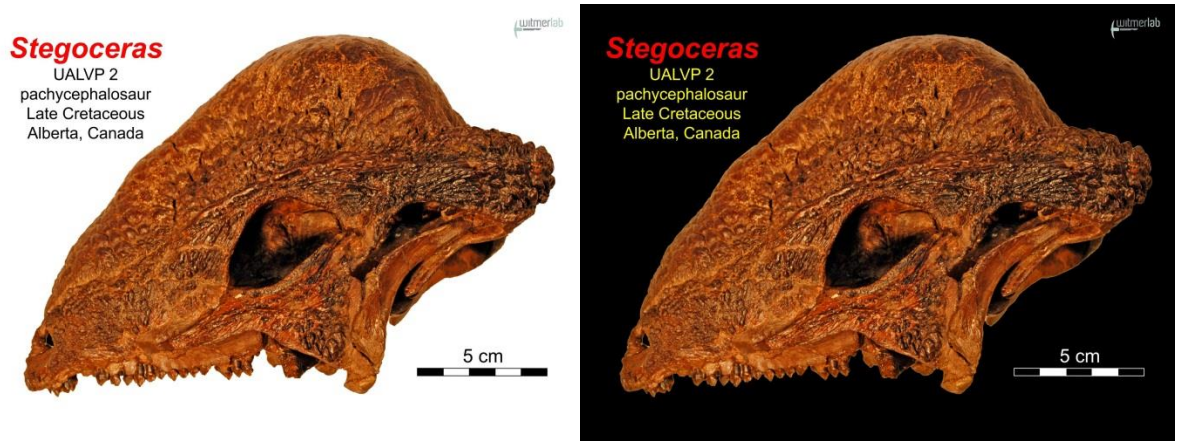

The original skull of *Stegoceras*. Photo of skull provided by P. Currie, University of Alberta. Courtesy of WitmerLab at Ohio University.

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