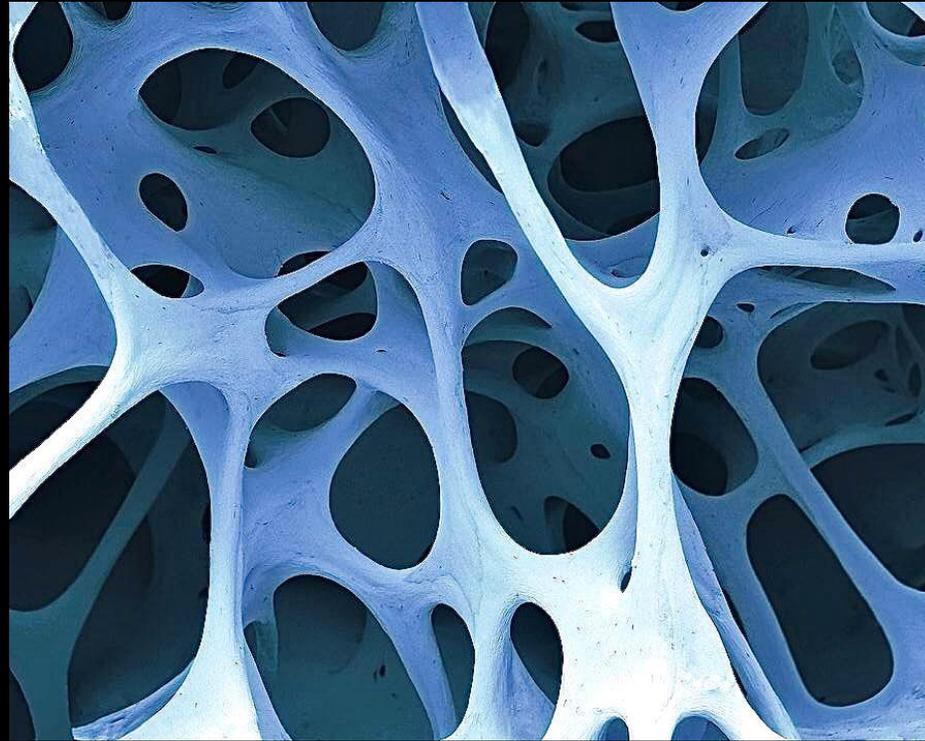


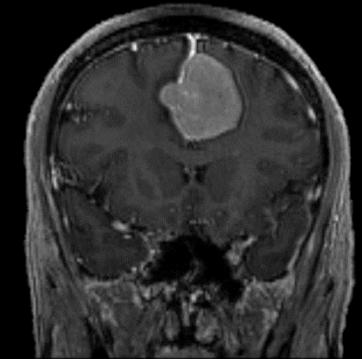
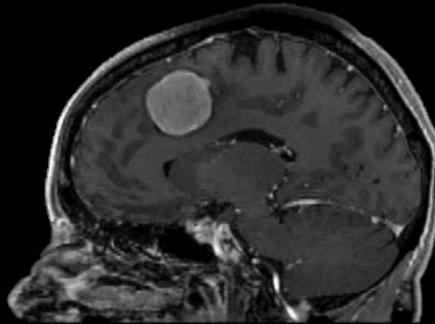
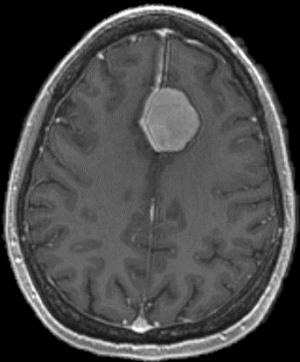
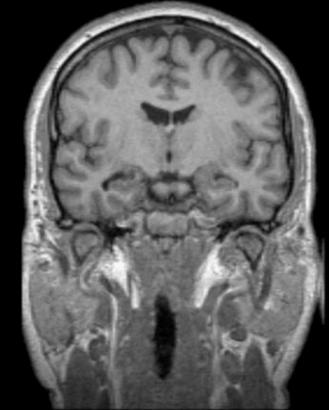
Assessing trabecular bone architecture at the divergence of bird-line (Aves) and croc-line (Pseudosuchia) archosaurs to reveal cardiopulmonary evolution and soft tissue relationships

Paul J. Byrne

X-ray Micro Computed Tomography Seminar and Workshop; Rigaku

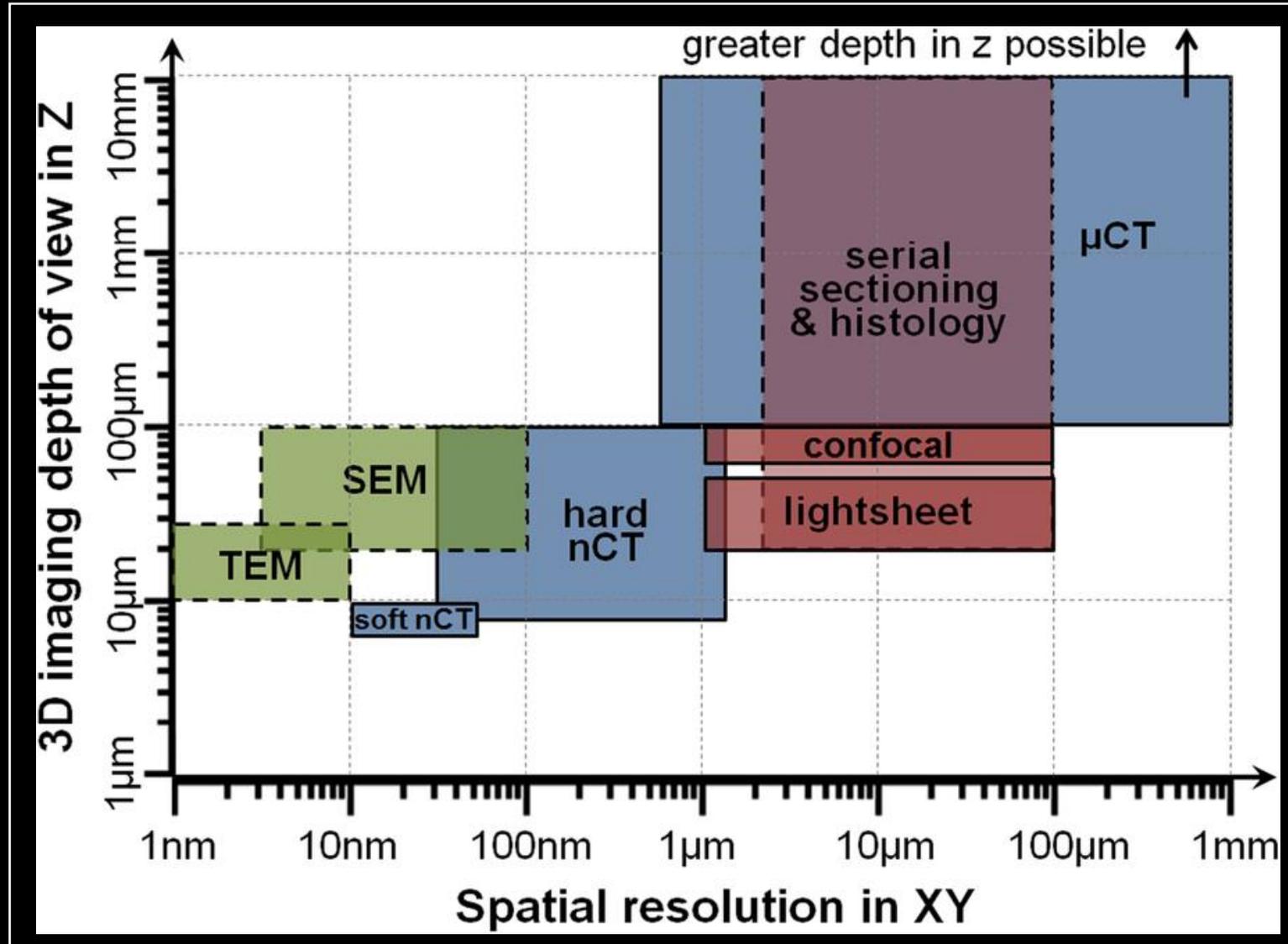


CT Scanning in Medicine



“Allows non-invasive imaging of a large field of view, even for optically opaque materials, across a range of resolutions”

General Applications

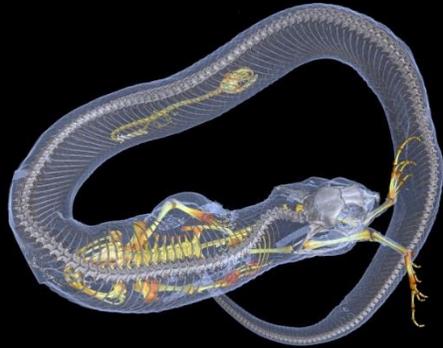


Offers:

1. High resolution in 3D
2. Non destructive!

CT Scanning in the Biological Sciences

- *Osteology and Morphology*



Eastern Hognose Snake, NSF

- *Interplay between genetics, morphology, and function (seed dispersal)*



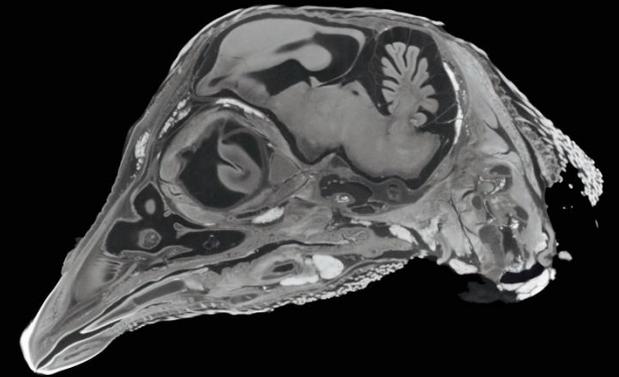
False-colored, sliced rendering of a blackberry, Haley O'Brian

- *Embryology*



Fetal Badger color-enhanced via diceCT, Haley O'Brian

- *Biological pathway of bone formation, host tissue interaction, fracture repair process*



Chicken color-contrasted via diceCT, Aki Watanabe

True or False: Fossils are always this well preserved.....



Longipteryx sp. HGM-41HIII0319



Boreopelta markmitchelli



Araganasuchus dutuiti ALM 404

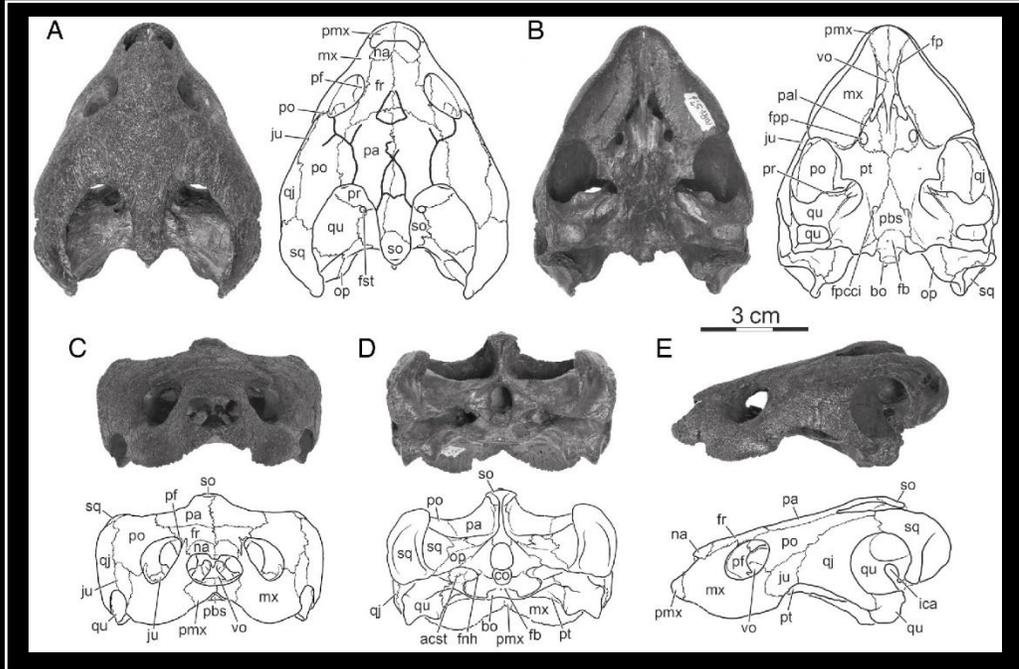
Chiappe & Meng, 2016; photo by Stephanie Abramowicz

False: Often times, fossils look more like this.....



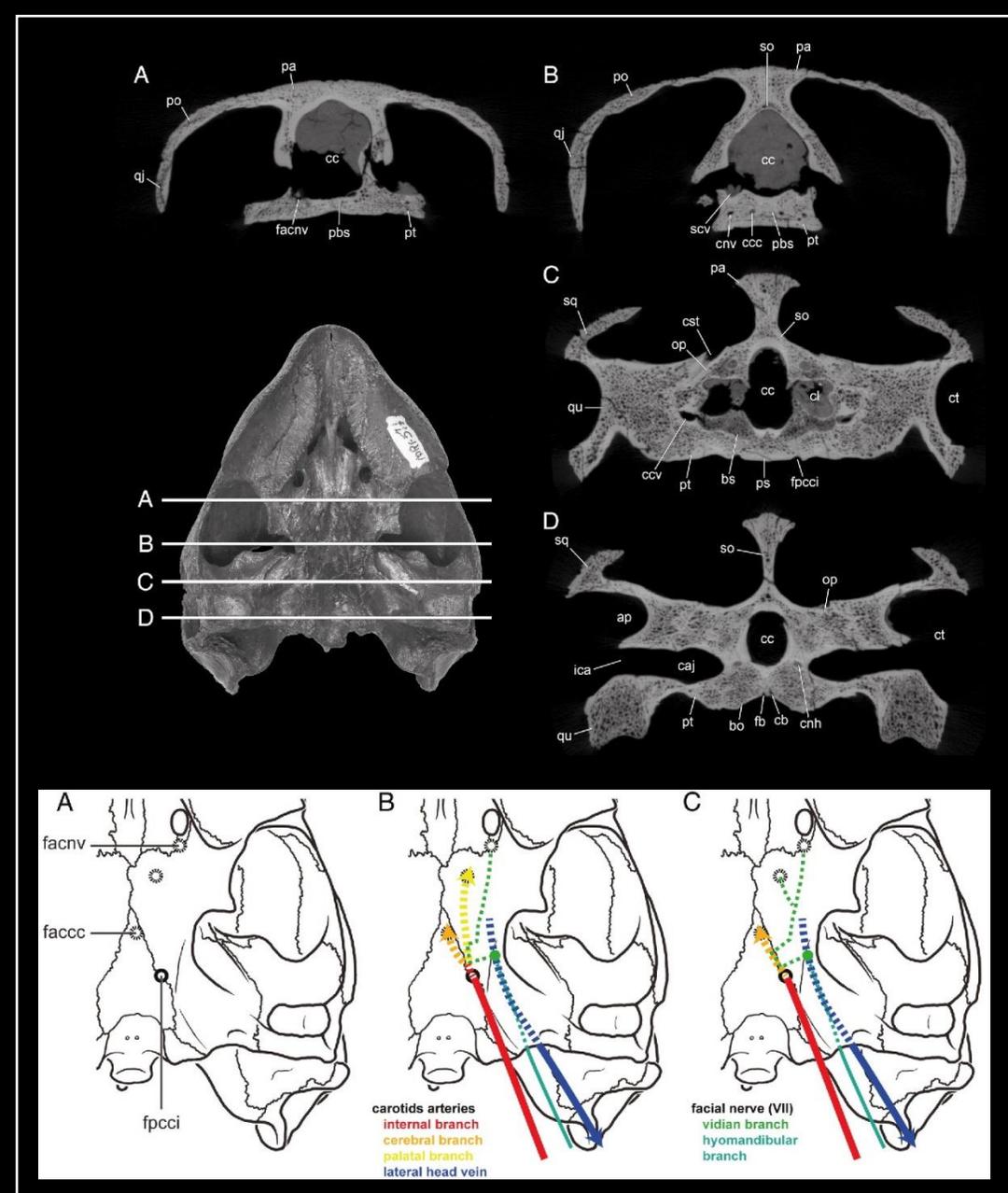
The question becomes.....How can we extract as much data from fossils as we can?

CT Scanning in Paleontology



Eubaena cephalica DMNH 96004, an upper Cretaceous turtle

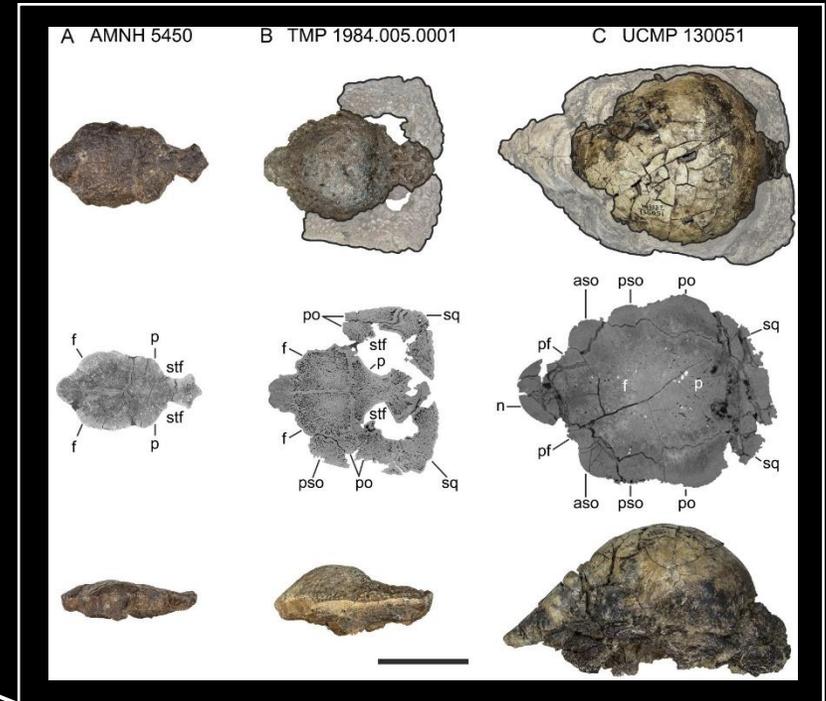
Mapping neuroanatomy and vasculature



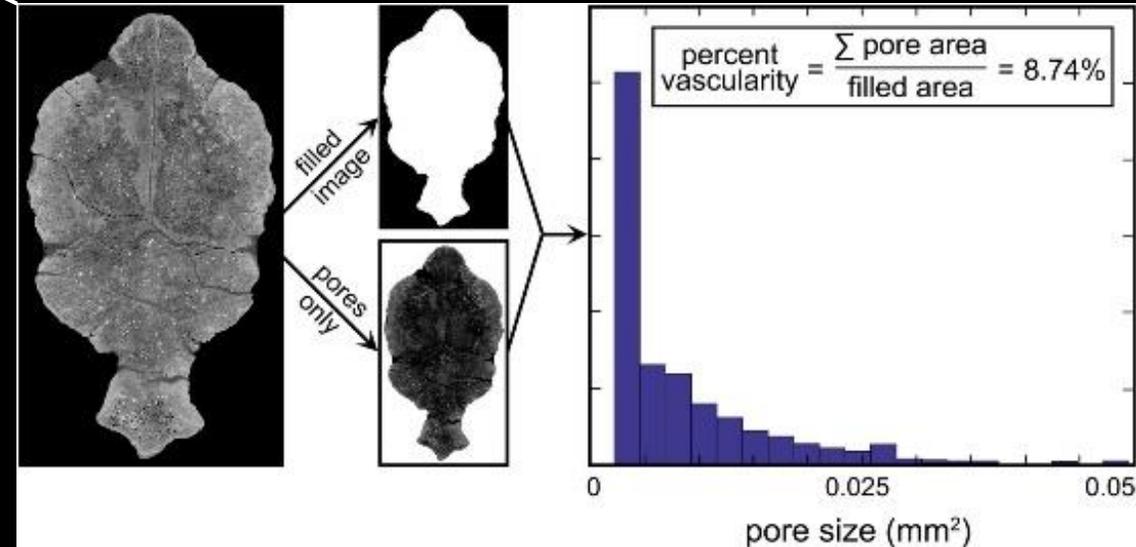
CT Scanning in Paleontology



External



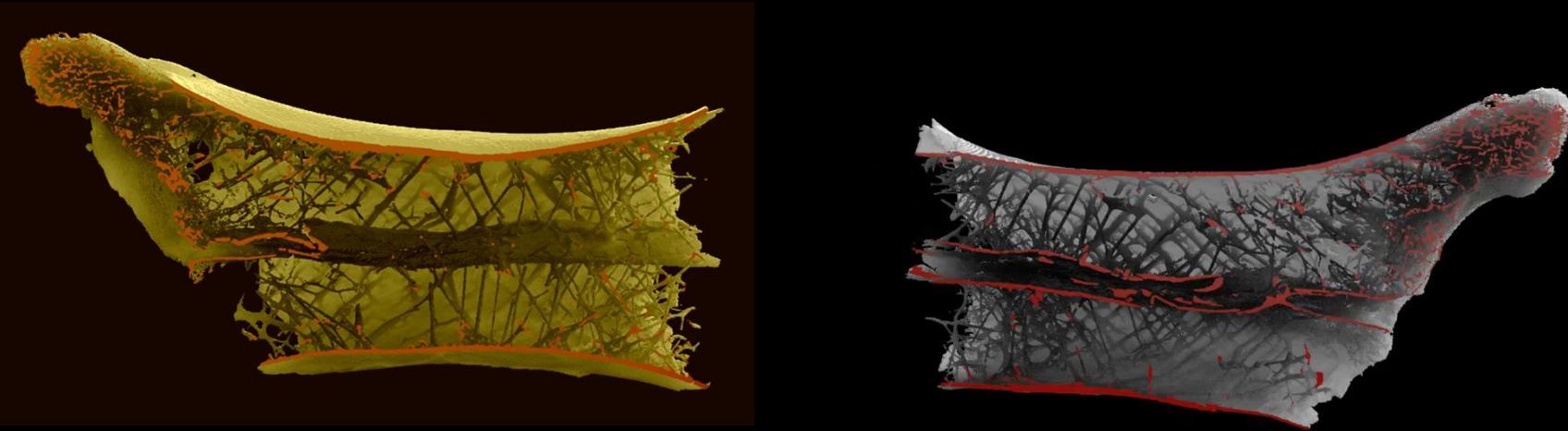
μ CT



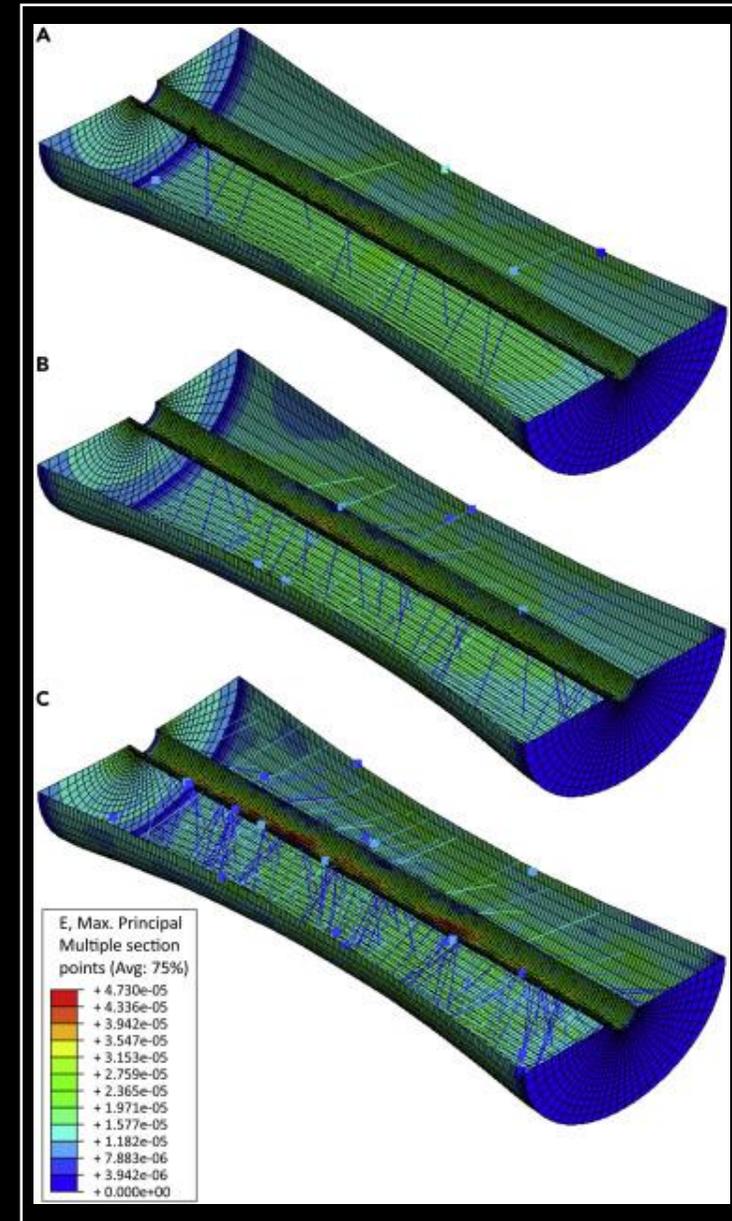
Quantifying vascularity in the frontoparietal dome of Stegoceras validum, and implications for bone growth and ontogenetic validation

-Nirody et al., 2022

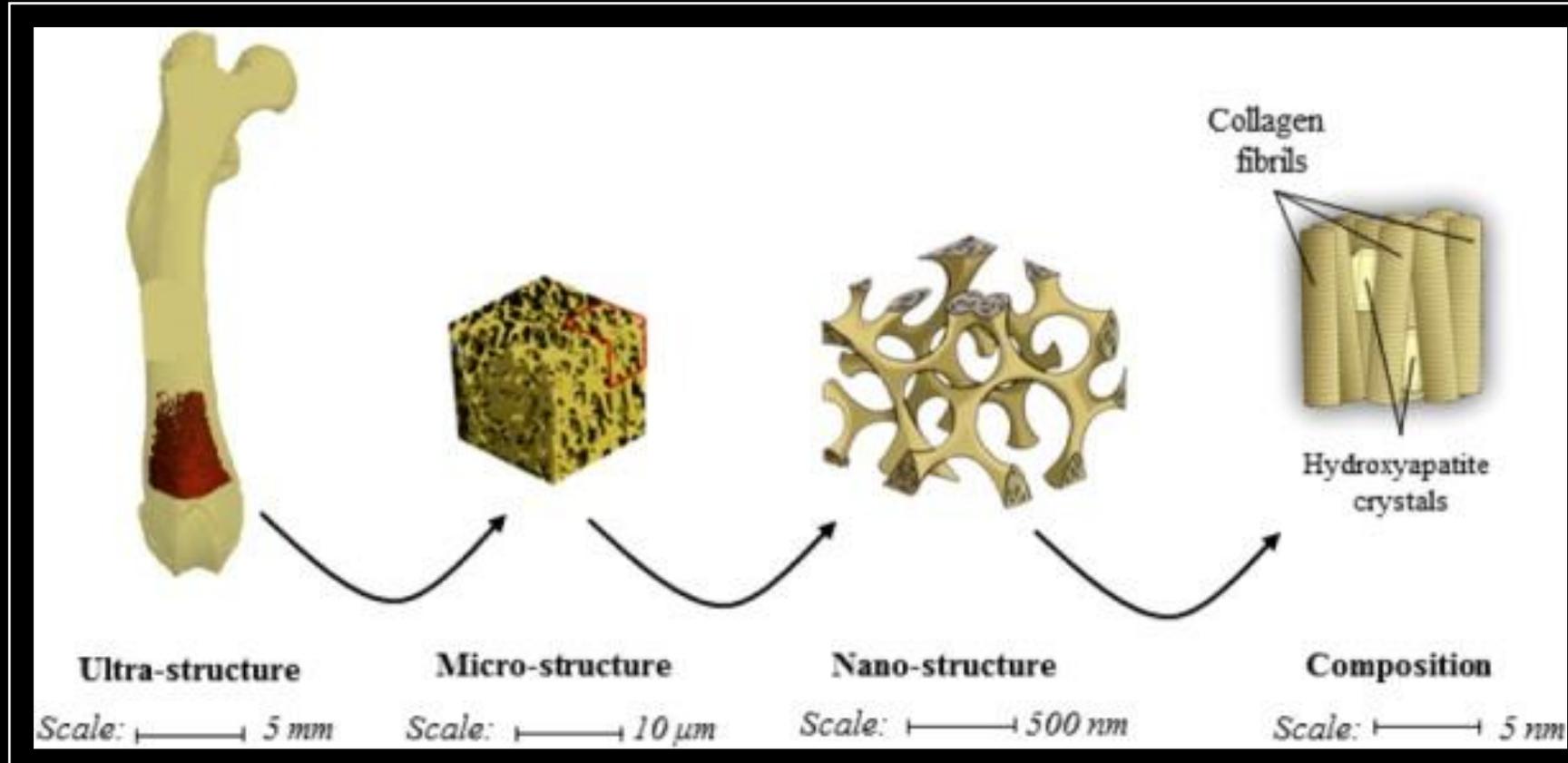
CT Scanning in Paleontology



Helically arranged radial, spoke-like trabeculae act to equally distribute stress in thin-walled pterosaur vertebrae; strengthening the bone while maintaining minimal weight



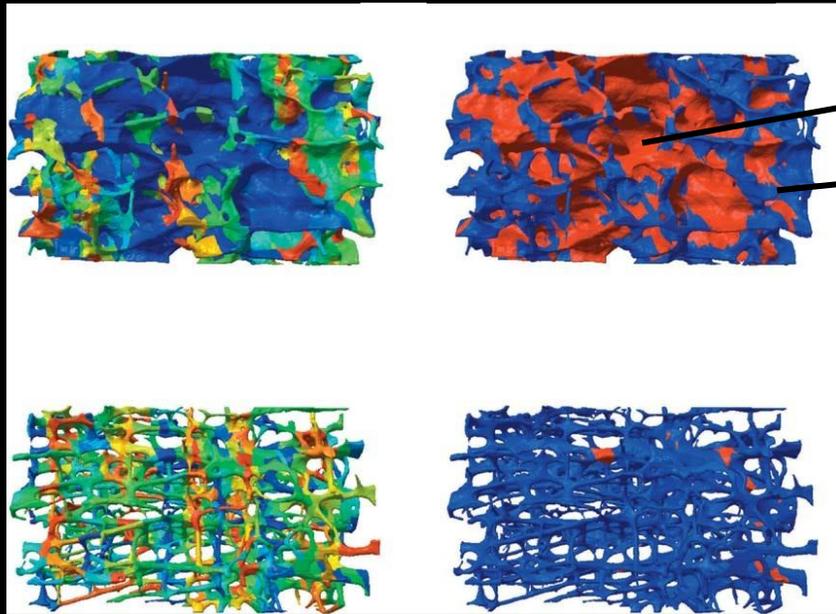
Trabecular Bone Microanatomy



“Highly porous, heterogeneous, and anisotropic material found in the epiphyses of long bones and vertebral bodies”
-Oftadeh et al., 2015

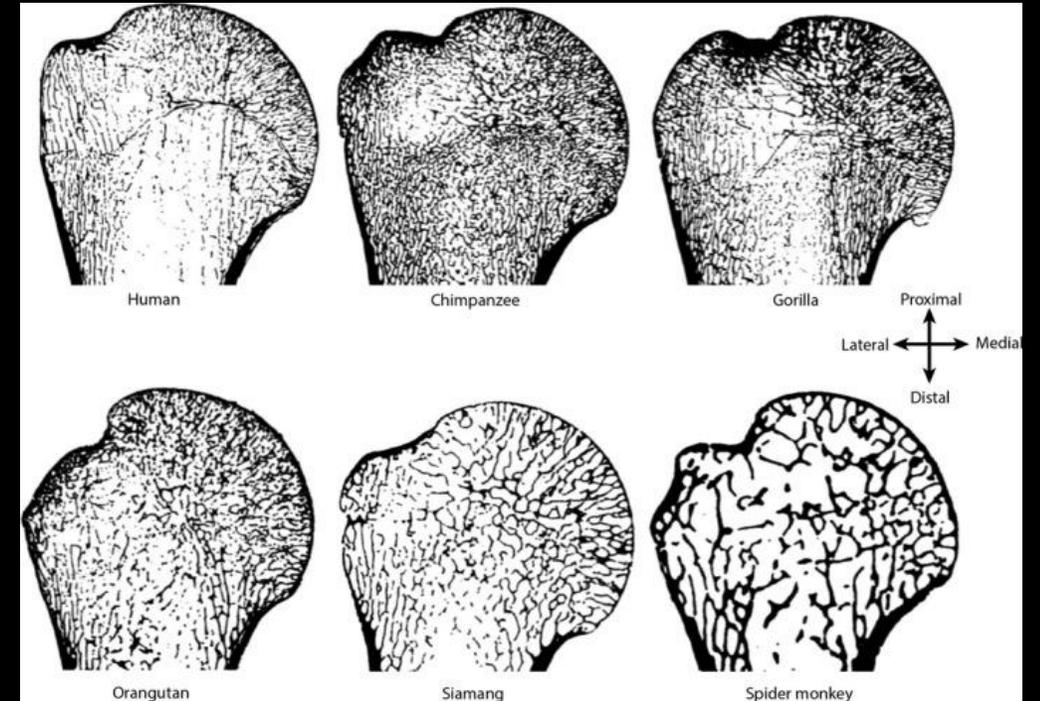
Trabecular Bone Microanatomy

Microscopic



Plates
Rods

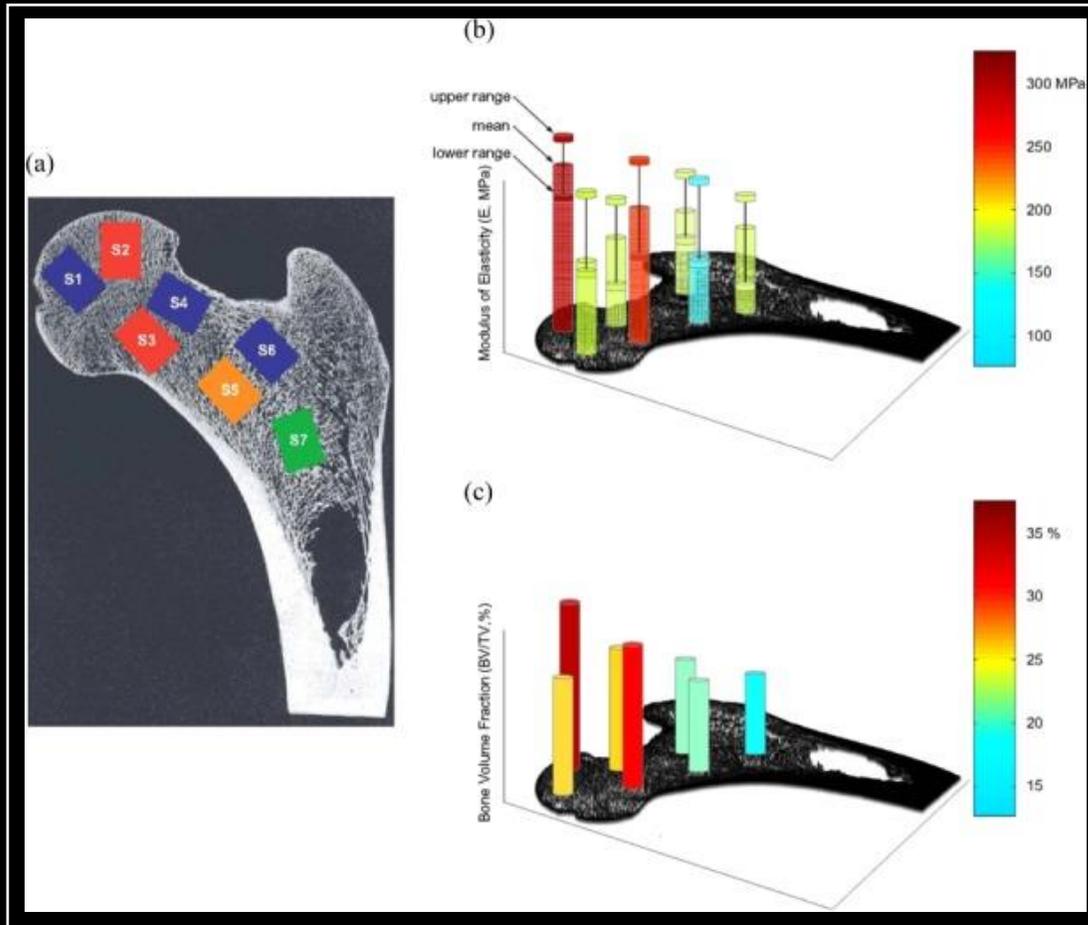
Macroscopic



Composed of rods and plates, trabecular bone forms a stiff structure that provides framework for bone marrow within intertrabecular spaces –Stauber et al., 2009

Trabecular architecture organized to optimize load transfer –Kivell, 2016

Mechanical Properties of Trabecular Bone

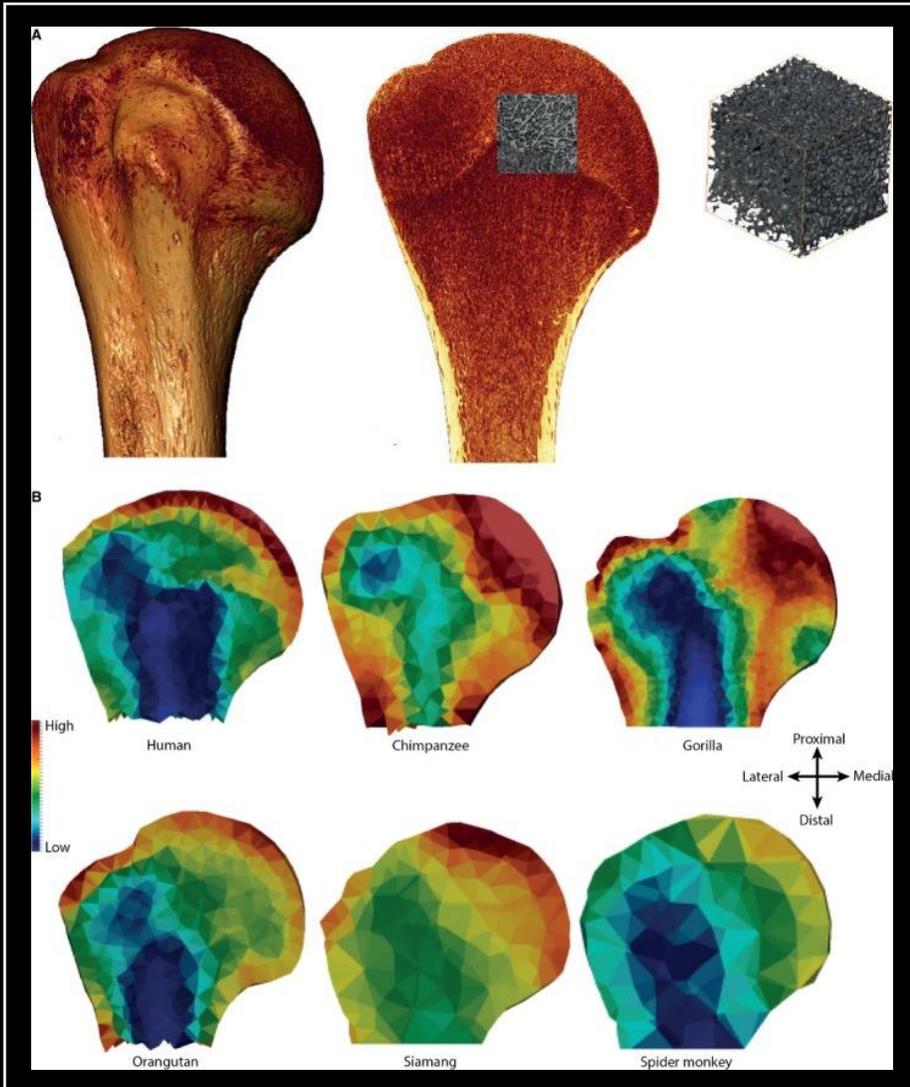


The plasticity of trabecular bone to mechanical loading means that trabecular bone architecture can reveal how the bone was used in life -Kivell, 2016

“Mechanical performance of each region of the femur is dependent on the trabecular architecture”

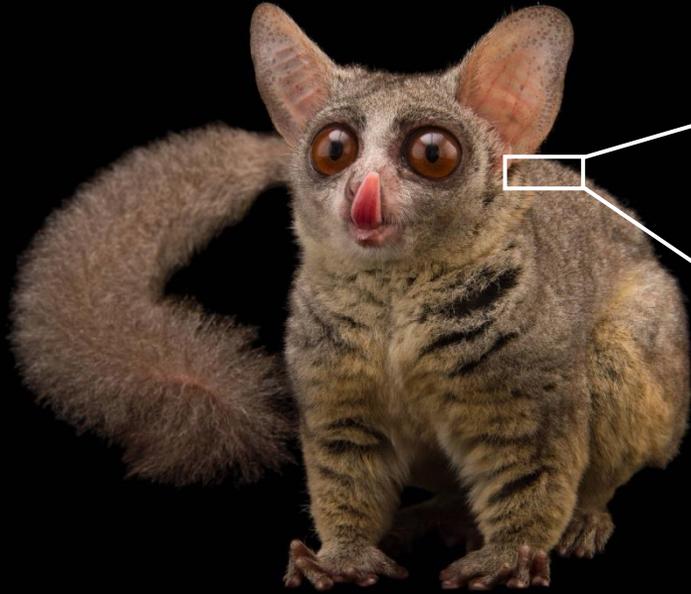
-Nazarian et al., 2007

Methods to Measure Mechanical Properties



- Bone volume fraction (BV/TV): Proportion of trabecular bone voxels relative to total number of voxels in given region/VOI
- Degree of anisotropy (DA): Trabecular orientation in 3D space (orientation of trabecular struts)
- Trabecular thickness (Tb.Th): Mean thickness of trabecular struts in a given region/VOI
- Trabecular separation (Tb.Sp): Mean width of spaces between adjacent trabeculae
- Structure model index (SMI): Measure of relative proportion of plate-like vs. rod-like structures
- Inter-trabecular angle distribution: Angling of trabecular networks modeled via nodes

Vertebral Bodies



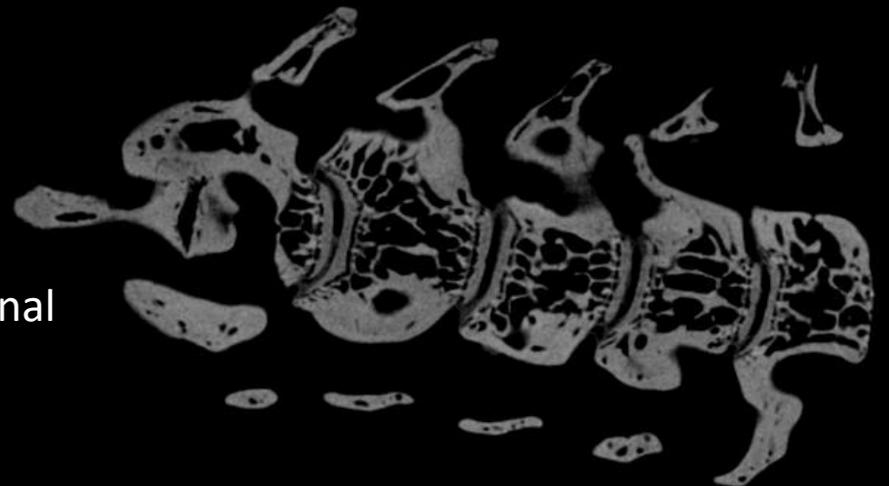
Galagoides senegalensis

Main load-bearing structure; varies based on an organisms' locomotor style and ecology

External



Internal



1 cm

Trabecular Bone in Archosaurs



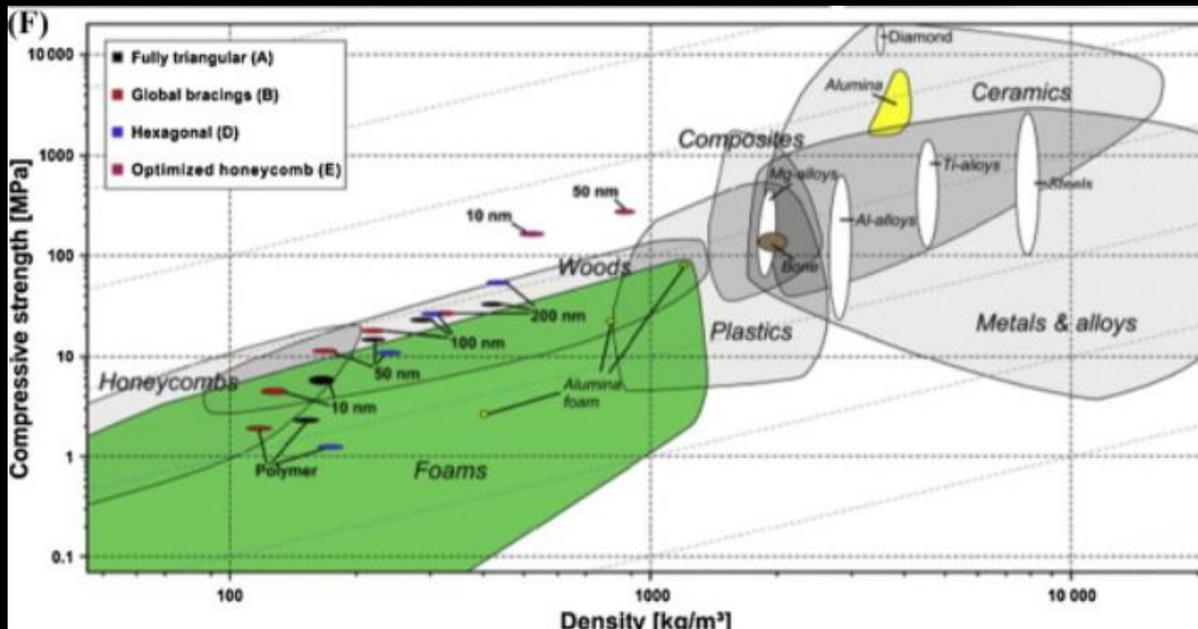
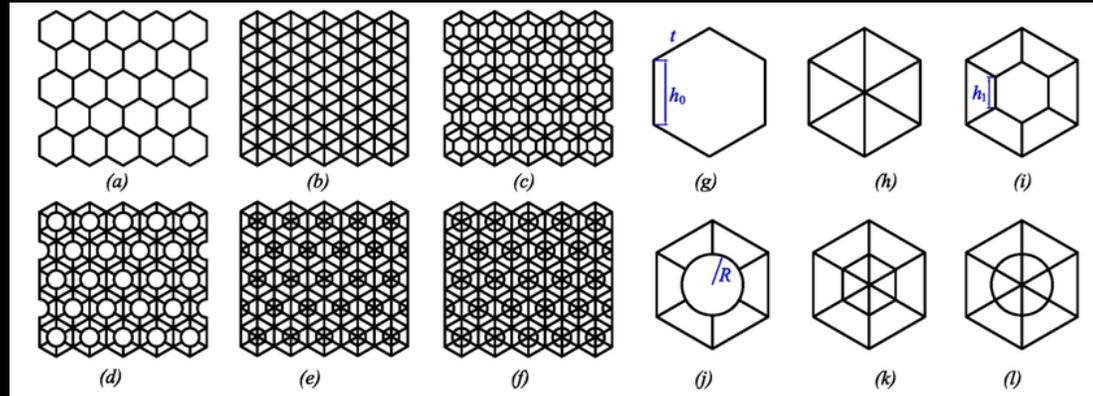
Ophisthocomus hoazin



Trabecular rods are arranged in a honeycomb-like arrangement; creating large intratrabecular spaces

Honeycomb Structures and Mechanical Performance

Wang et al., 2015



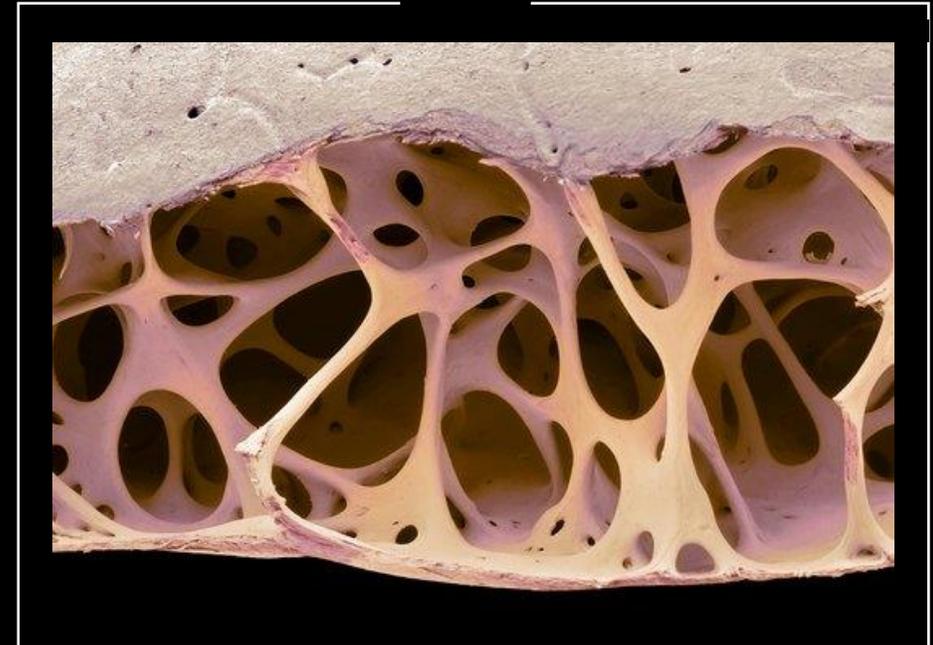
Zhang et al., 2015

Honeycomb Structures and Mechanical Performance

Zhang et al., 2015

Things Trabecular Bone Must Accomplish:

- 1. Structural support*
- 2. Protection for body and blood cell formation*
- 3. Mineral storage*



Honeycomb Structures and Mechanical Performance

Zhang et al., 2015

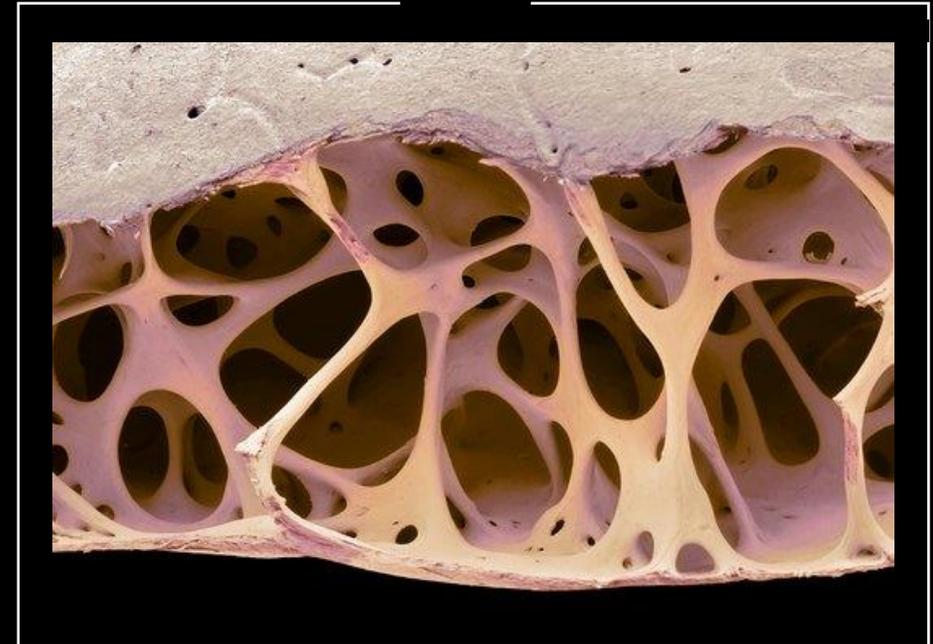
Things Trabecular Bone Must Accomplish:

- 1. Structural support*
- 2. Protection for body and blood cell formation*
- 3. Mineral storage*

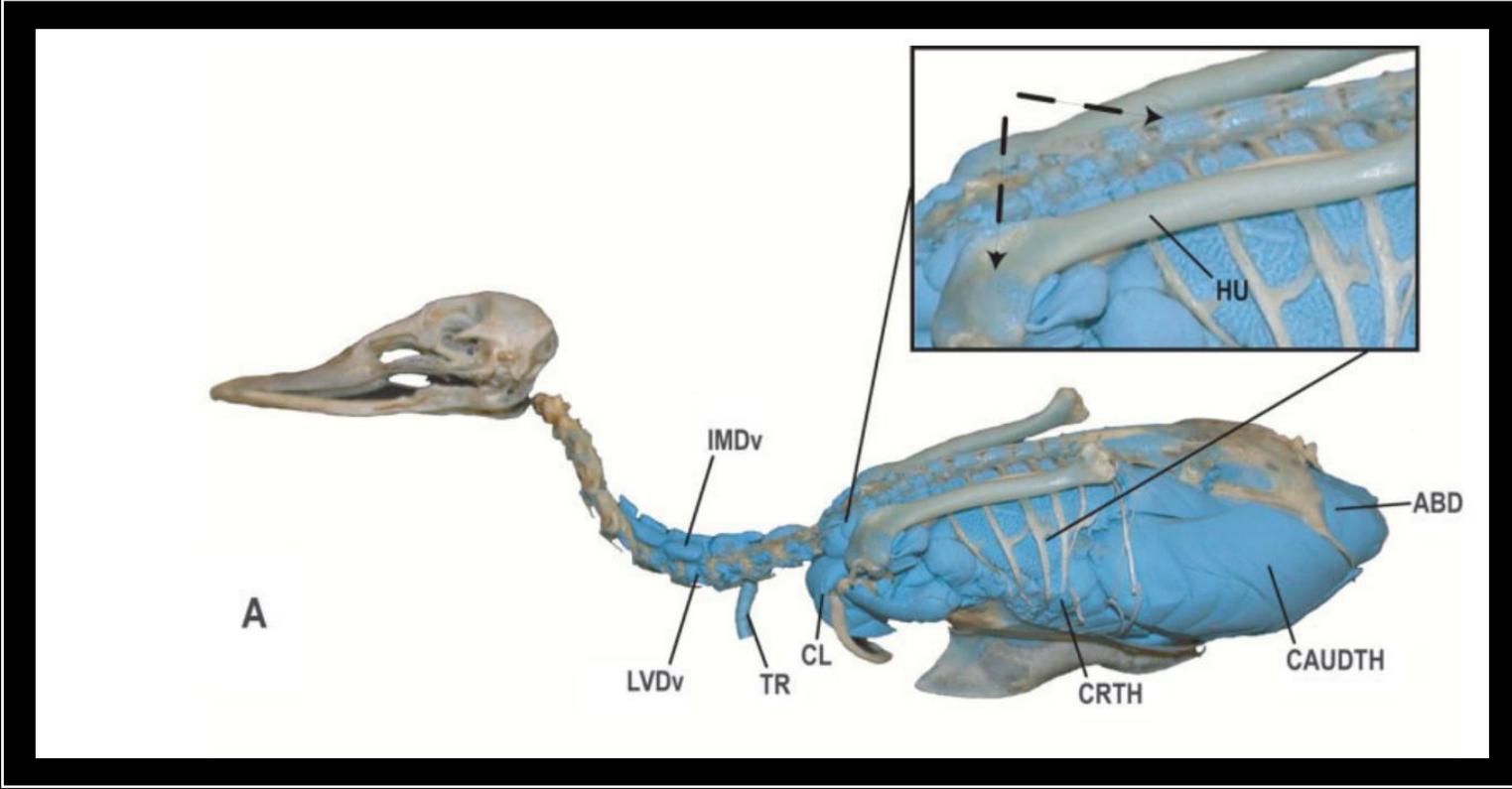


However:

- Attachment sites on endosteal surface determined by distribution of stress. However, rods and plate boundaries + angling seem randomized*
- What causes this to occur?*

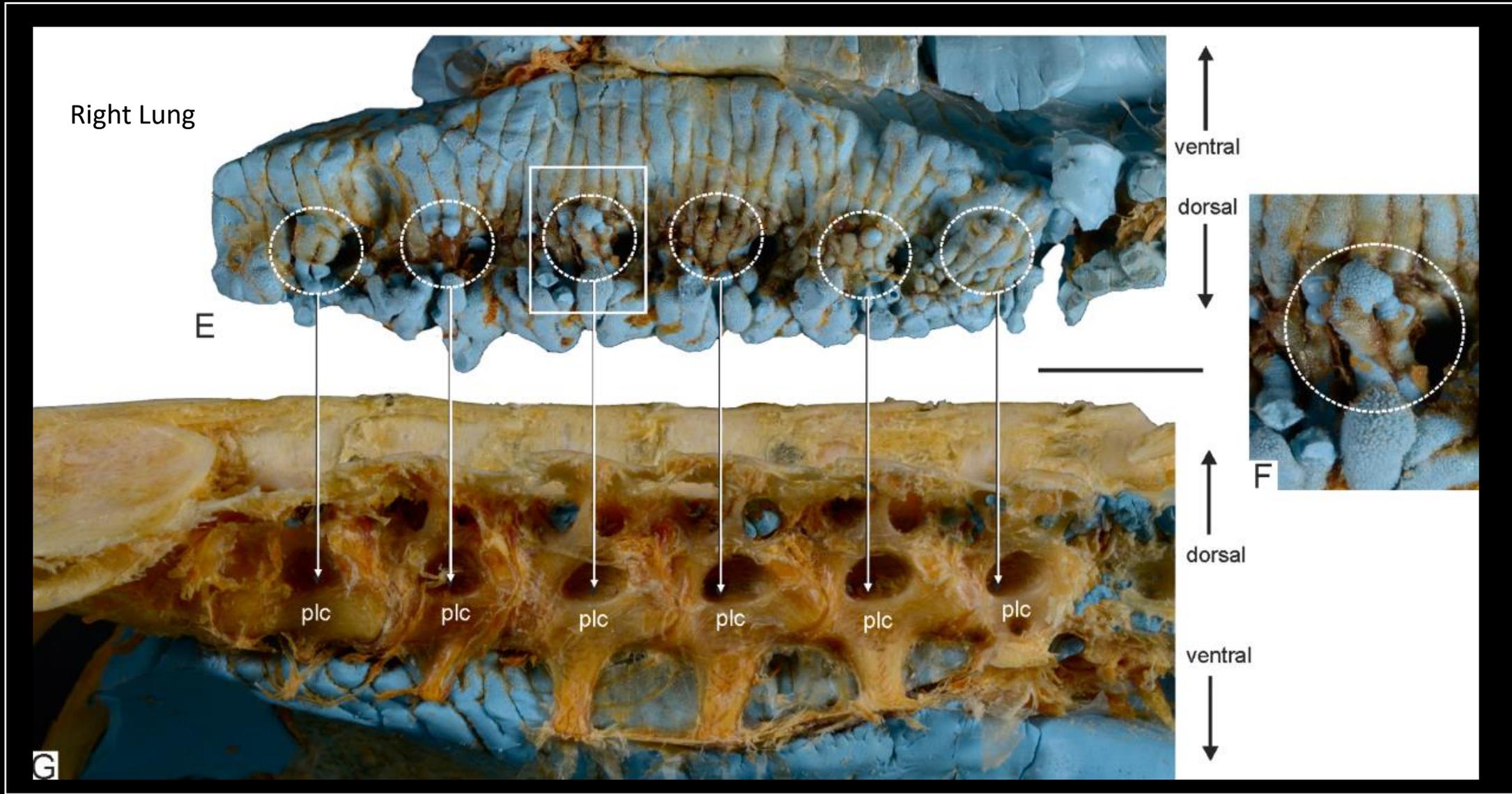


The Avian Style Respiratory System



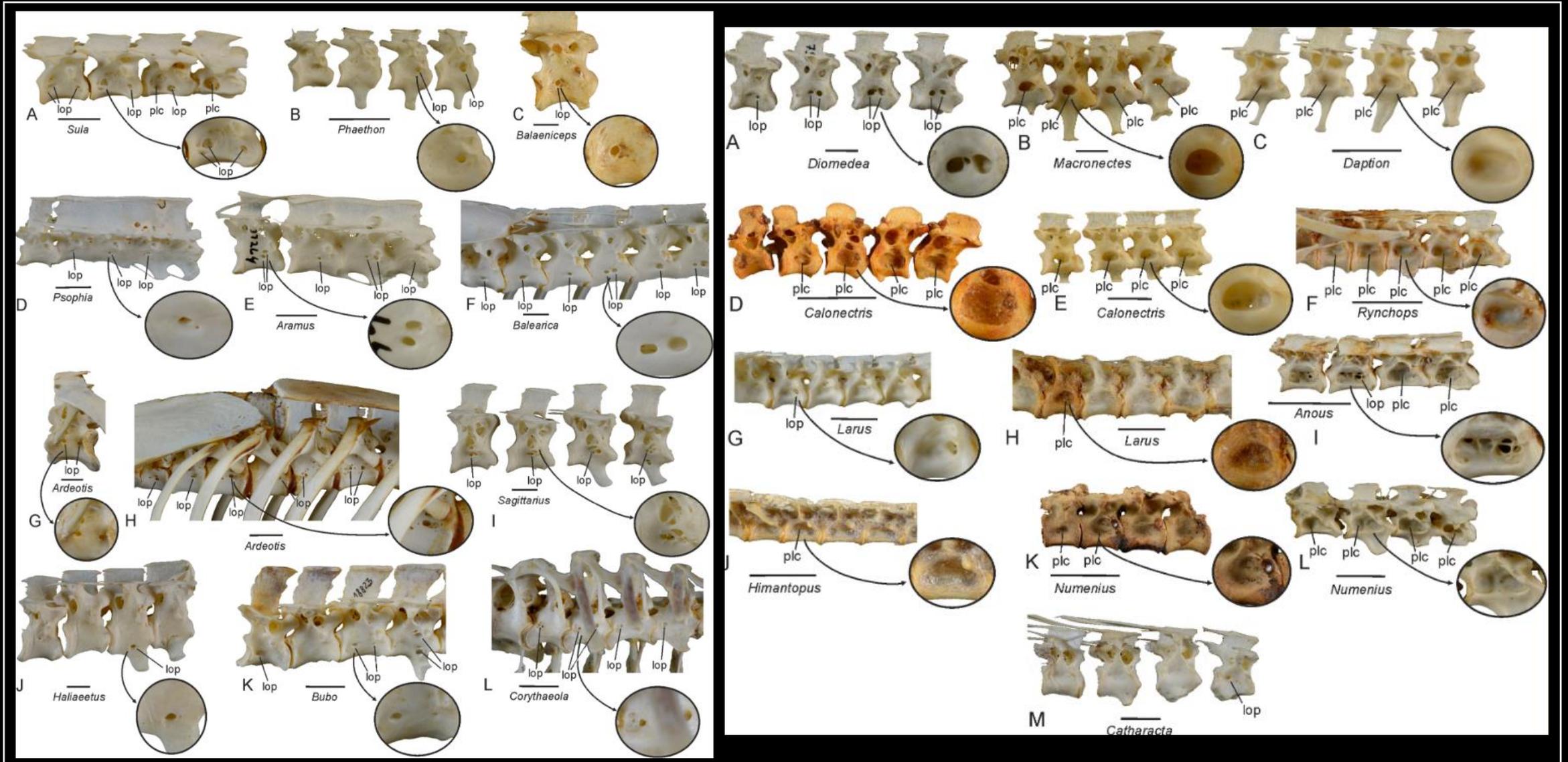
Green-winged teal *Anas crecca*

The Avian Style Respiratory System



The Avian Style Respiratory System

Mayr, 2021



LACM 164166 *Alligator mississippiensis*

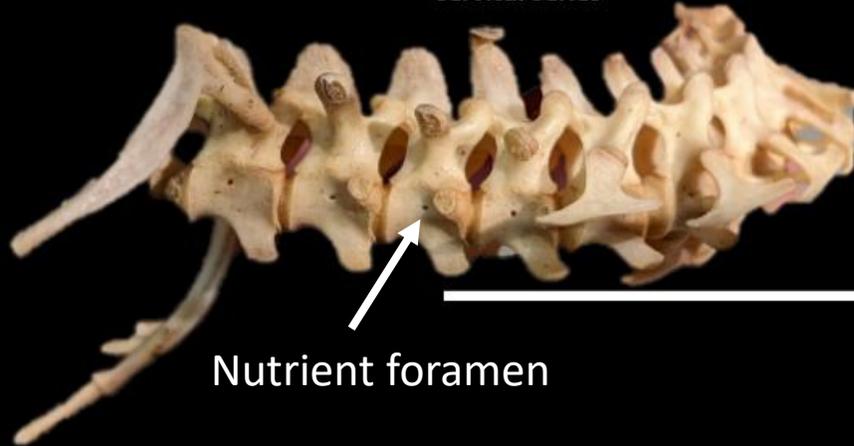
Dorsal Vertebrae



3 cm

LACM 159108 *Caiman crocodilus*

Cervical Series



Nutrient foramen

6 cm

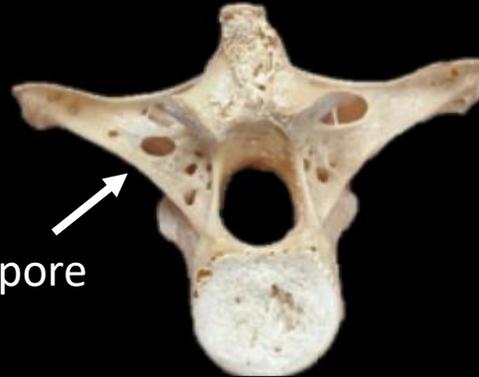
Dorsal Vertebrae



1.5 cm



NHMLAC *Fregata minor*



Pneumatopore



Pantodon buchholzi

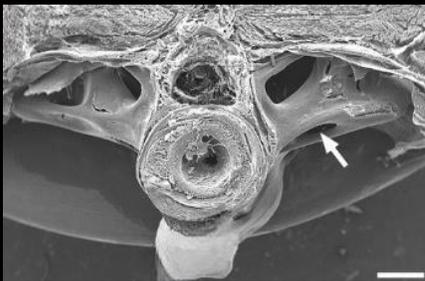


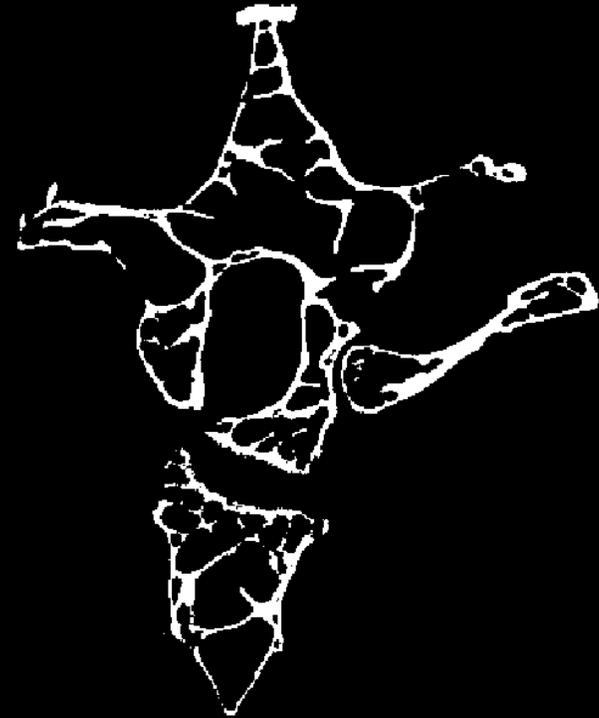
Figure 4: *Icardo et al., 2020*



Trabecular Architecture and Soft Tissue?



Varanus komodoensis

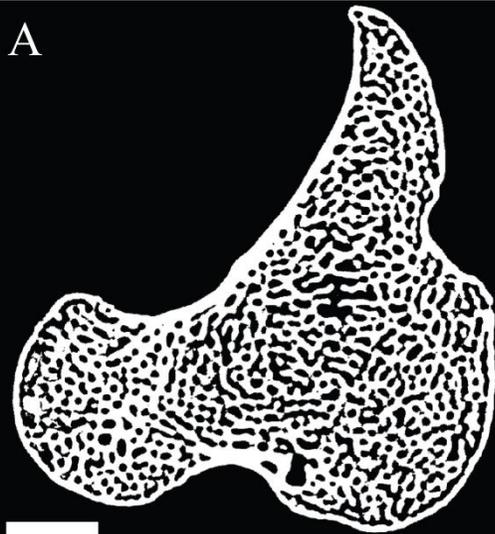


Psittacus erithacus

Trabecular Architecture and Soft Tissue?

Marrow-filled femur,
Casuarius casuarius

Mean Trabecular
Spacing= 0.638 mm

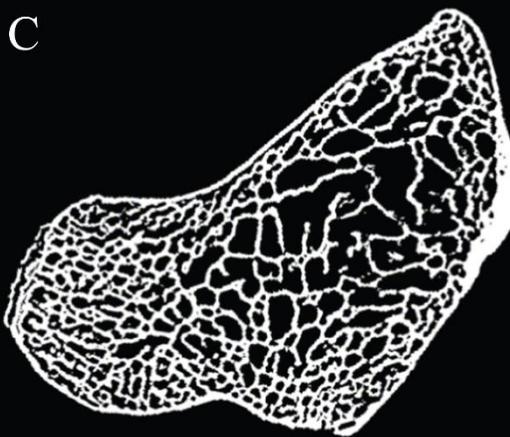


Pneumatized femur,
Dromaius novaehollandiae

Mean Trabecular
Spacing= 1.128 mm

Marrow-filled femur,
Gallus gallus

Mean Trabecular
Spacing= 0.320 mm

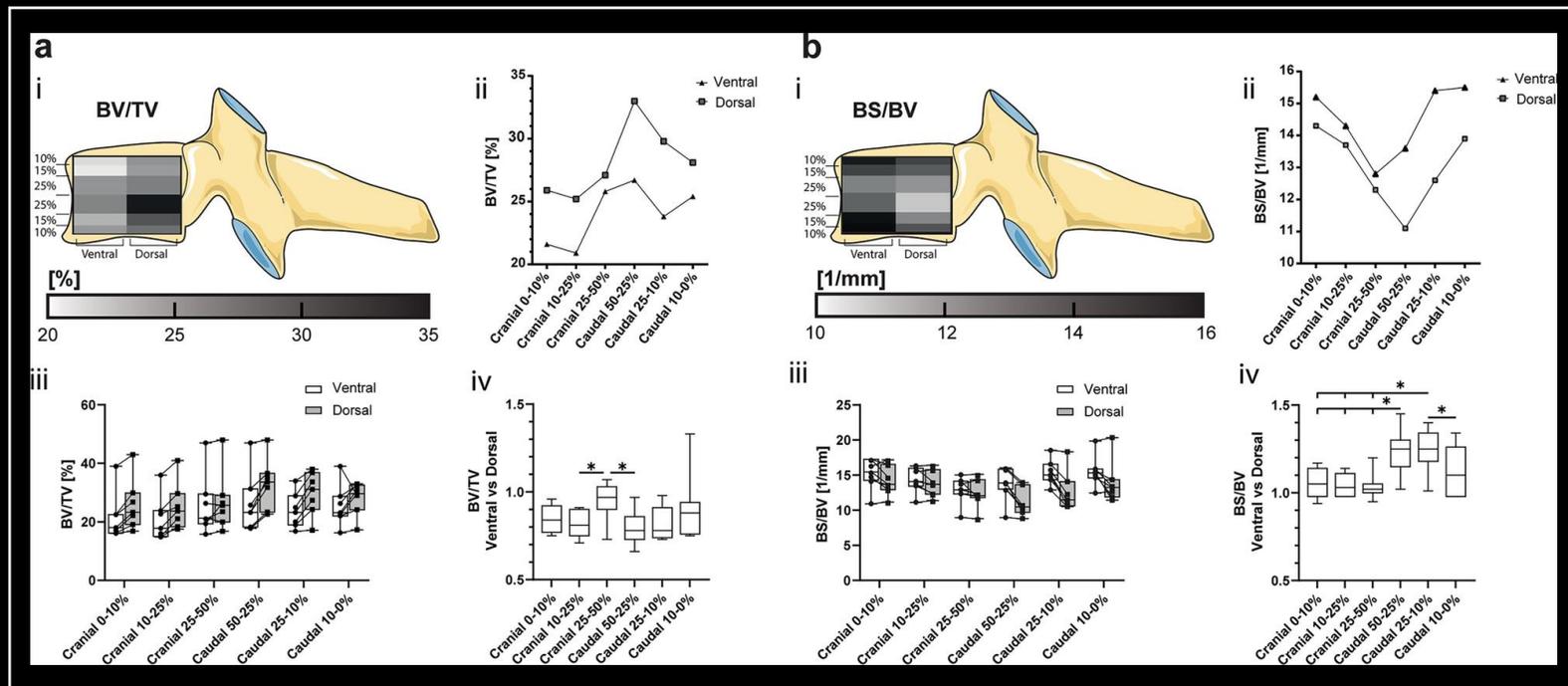
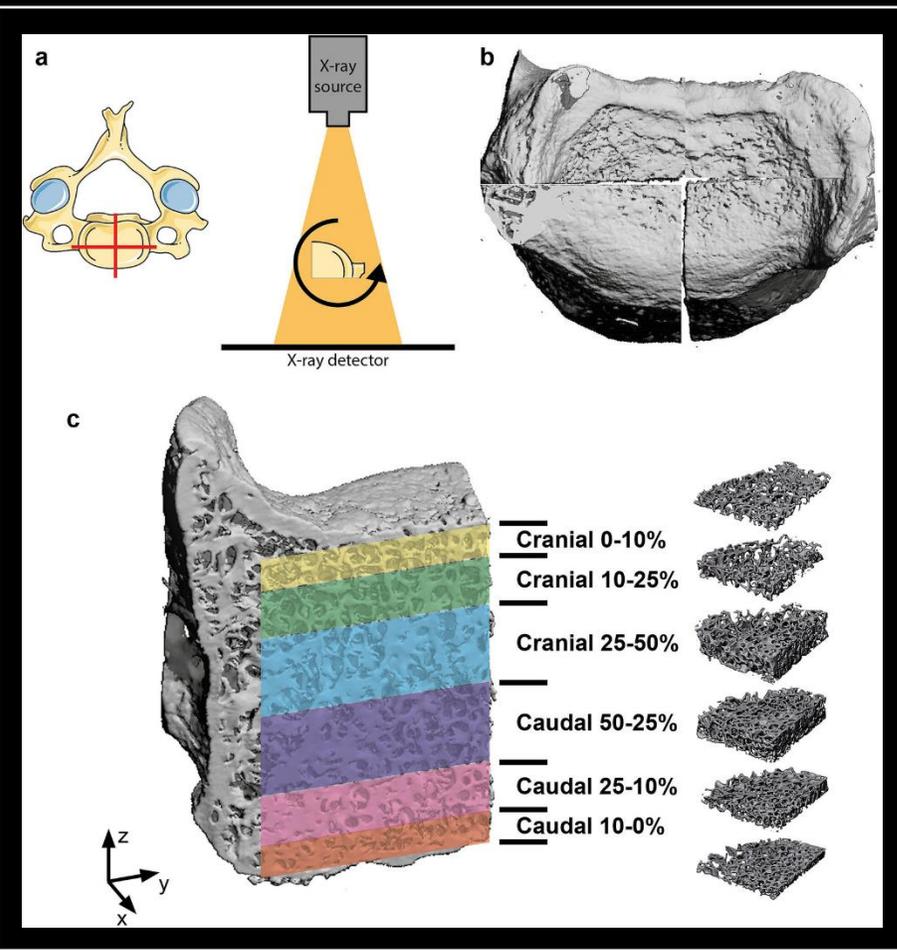


Pneumatized femur,
Alectura lathamii

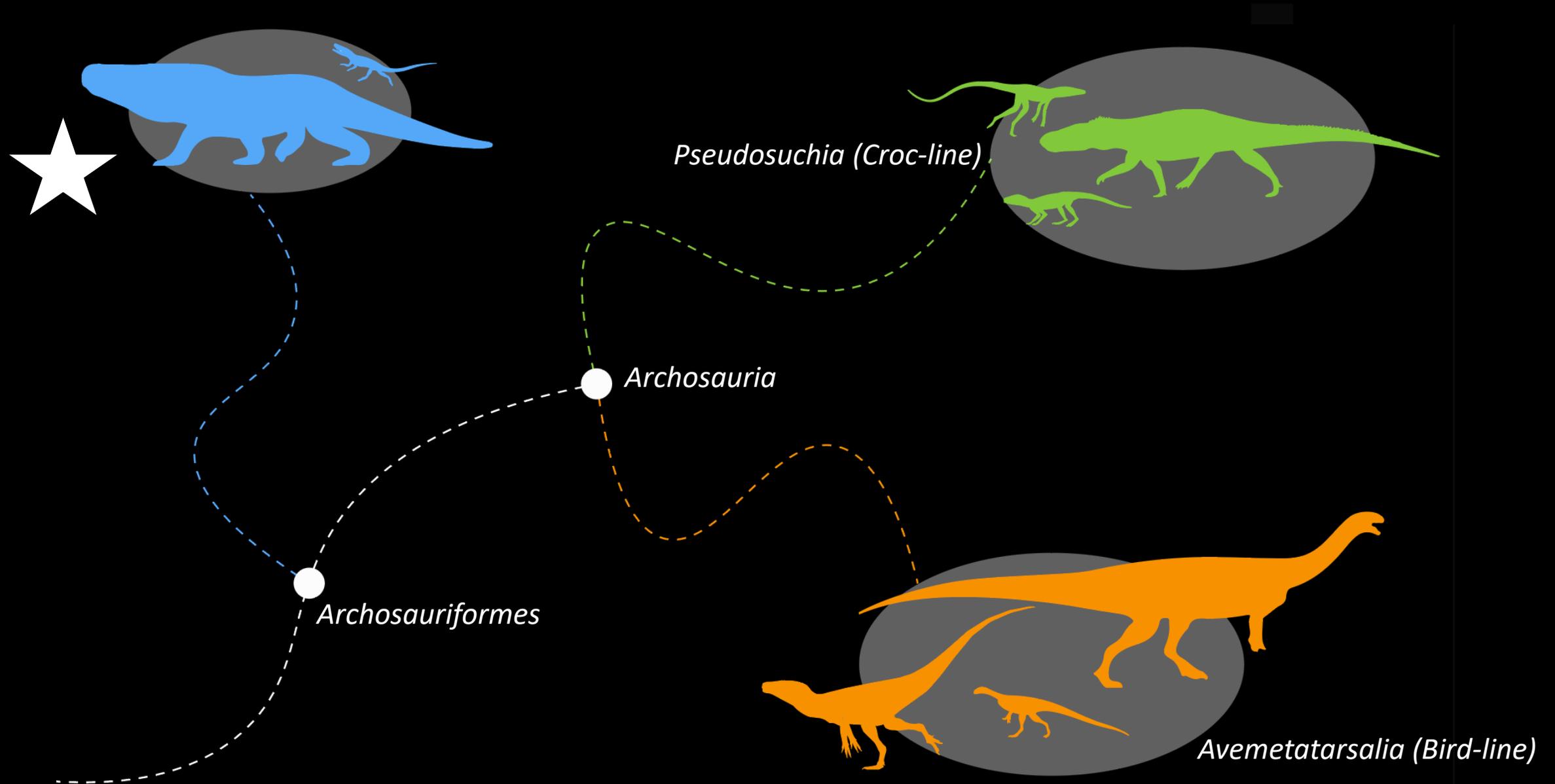
Mean Trabecular
Spacing= 0.999 mm

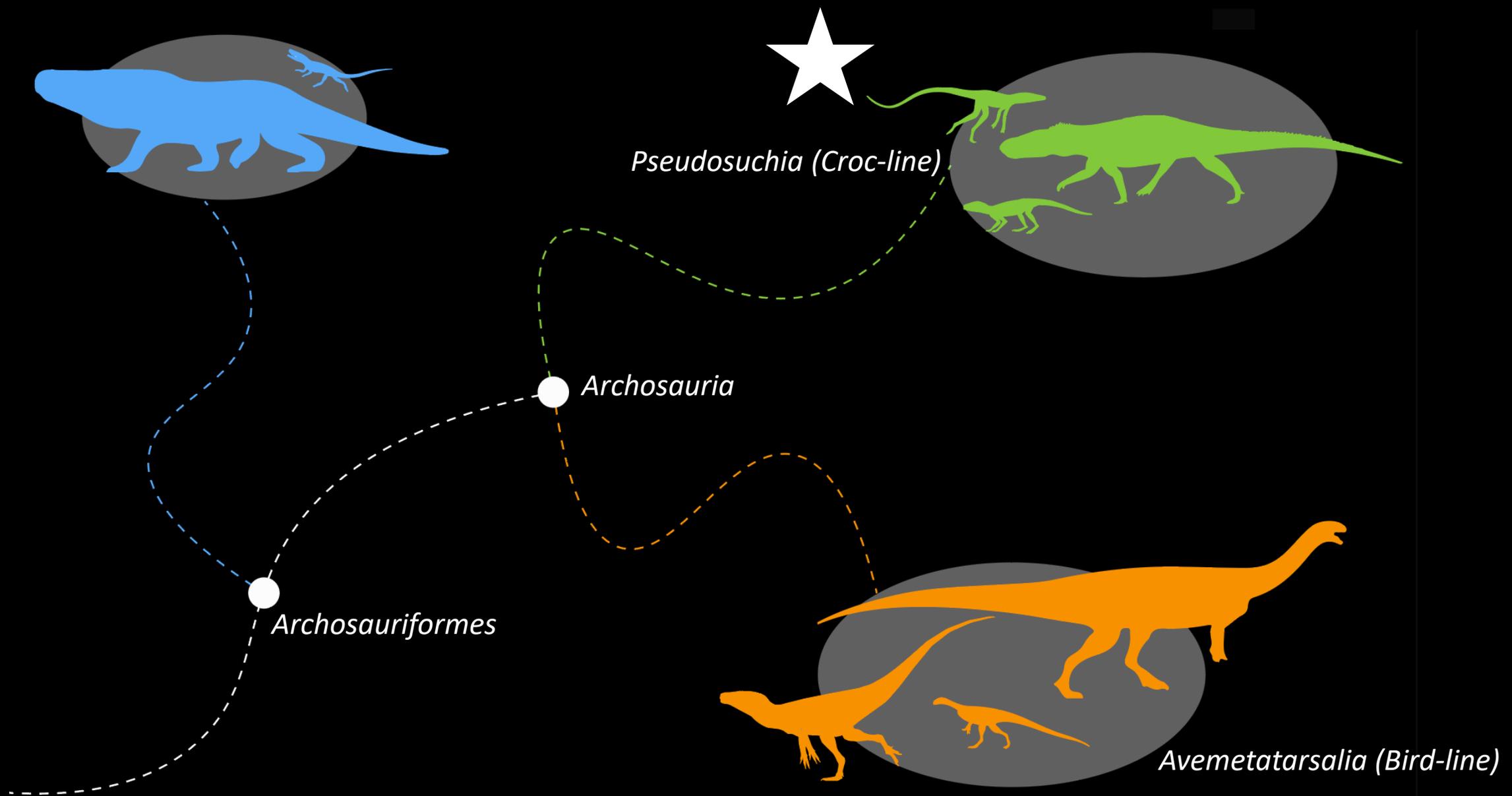
10 mm

VOI Cubes And Variation in Trabecular Thickness



What Can This Reveal About The Fossil Record?







Takeaways

1. μ CT data can be useful in validating external features in bone by revealing internal structure
2. When combined with reference material from extant organisms; μ CT can be a useful method for extracting as much biological data as possible from fossil material

Affiliated and Collaborating Organizations

Thank You

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NATURAL
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