USING CT DATA TO SCORE TAXA FOR PHYLOGENETIC ANALYSES

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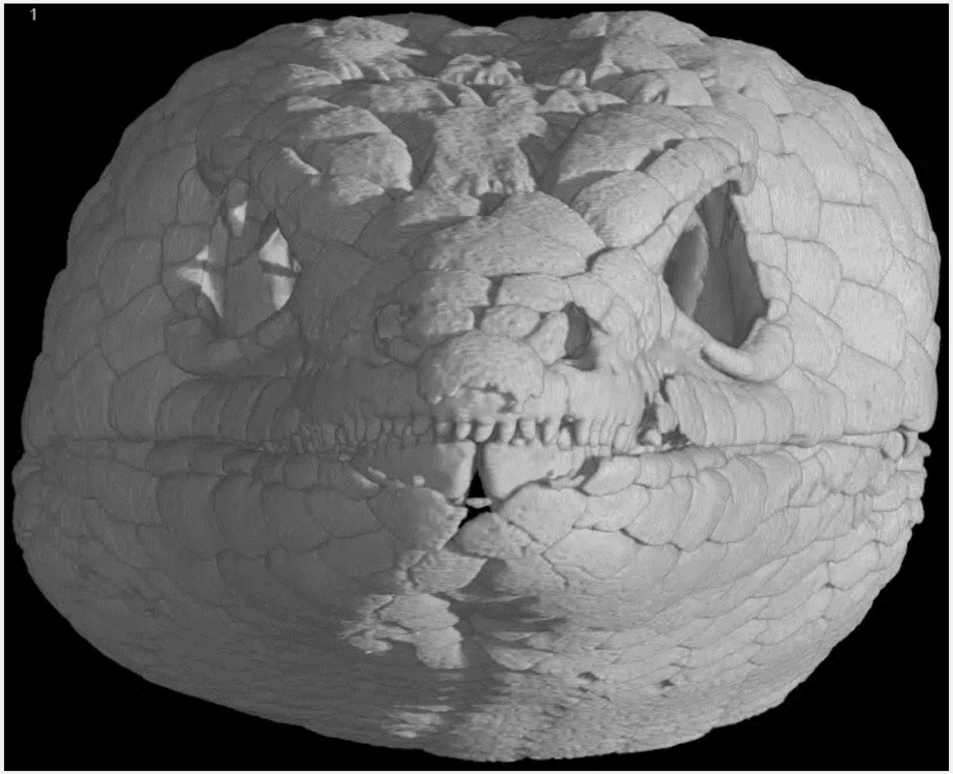
CT DATA

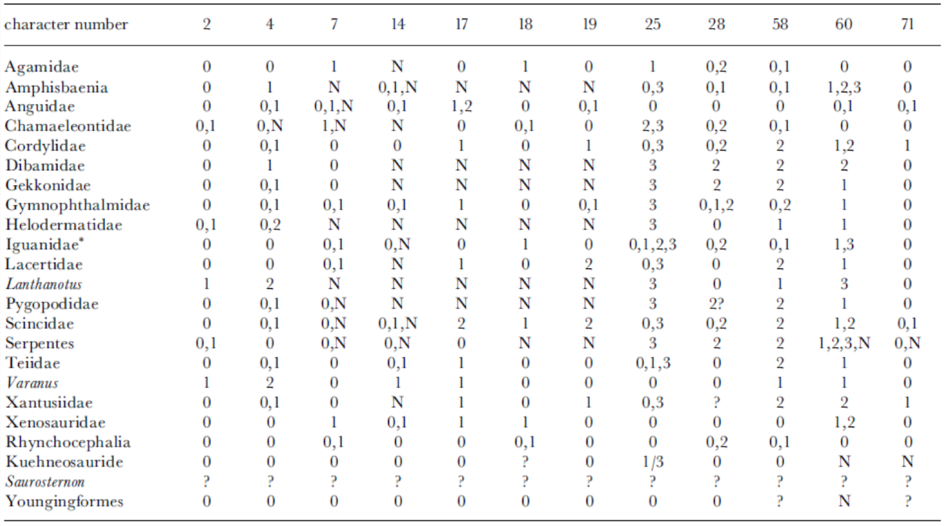
- Computed Tomography
  - Computer processed x-ray cross-section images (“slices”)
  - Can ultimately stitch these slices together to form a 3D model



Gauthier et al. 2012

PHYLOGENETIC ANALYSES

- While genetics is advancing rapidly, morphology remains the only way to incorporate fossils into phylogenetics
- Need to "score" taxa for a number of a morphological characters
  - Provides basis for reconstructing phylogenetic history

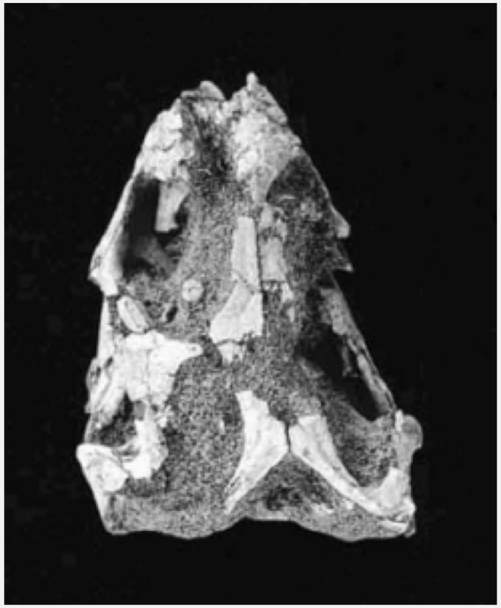


character number	2	4	7	14	17	18	19	25	28	58	60	71
Agamidae	0	0	1	N	0	1	0	1	0,2	0,1	0	0
Amphisbaenia	0	1	N	0,1,N	N	N	N	0,3	0,1	0,1	1,2,3	0
Anguidae	0	0,1	0,1,N	0,1	1,2	0	0,1	0	0	0	0,1	0,1
Chamaeleontidae	0,1	0,N	1,N	N	0	0,1	0	2,3	0,2	0,1	0	0
Cordylidae	0	0,1	0	0	1	0	1	0,3	0,2	2	1,2	1
Dibamidae	0	1	0	N	N	N	N	3	2	2	2	0
Gekkonidae	0	0,1	0	N	N	N	N	3	2	2	1	0
Gymnophthalmidae	0	0,1	0,1	0,1	1	0	0,1	3	0,1,2	0,2	1	0
Helodermatidae	0,1	0,2	N	N	N	N	N	3	0	1	1	0
Iguanidae*	0	0	0,1	0,N	0	1	0	0,1,2,3	0,2	0,1	1,3	0
Lacertidae	0	0	0,1	N	1	0	2	0,3	0	2	1	0
Lanthanotus	1	2	N	N	N	N	N	3	0	1	3	0
Pygopodidae	0	0,1	0,N	N	N	N	N	3	2?	2	1	0
Scincidae	0	0,1	0,N	0,1,N	2	1	2	0,3	0,2	2	1,2	0,1
Serpentes	0,1	0	0,N	0,N	0	N	N	3	2	2	1,2,3,N	0,N
Teiidae	0	0,1	0	0,1	1	0	0	0,1,3	0	2	1	0
Varanus	1	2	0	1	1	0	0	0	0	1	1	0
Xantusiidae	0	0,1	0	N	1	0	1	0,3	?	2	2	1
Xenosauridae	0	0	1	0,1	1	1	0	0	0	0	1,2	0
Rhynchocephalia	0	0	0,1	0	0	0,1	0	0	0,2	0,1	0	0
Kuehneosauride	0	0	0	0	0	?	0	1/3	0	0	N	N
Saurosternon	?	?	?	?	?	?	?	?	?	?	?	?
Youngingformes	0	0	0	0	0	0	0	0	0	?	N	?

Reynoso 1998

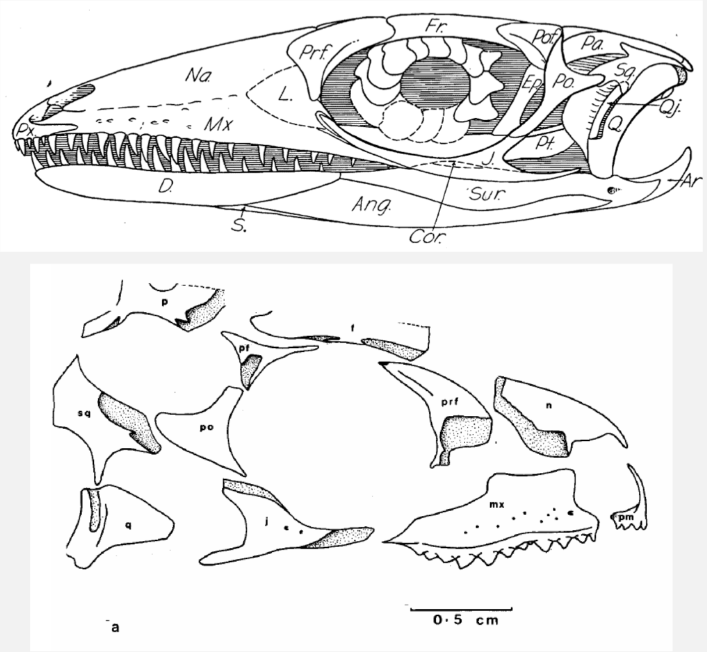
PHYLOGENETIC ANALYSES: BEFORE CT

Images



Morphology isn't 2-D!

Hand drawings



Accuracy?

Text descriptions

714 PALAEONTOLOGY, VOLUME 25

Description. Dermal bones of the skull roof. The premaxillae extend a short distance ventrally to form a rudimentary beak. They separate the external nares and meet medially in long narrow vertical processes that extend into slot facets between the nasals. Below the external naris a posterior extension of the premaxilla is slightly overlapped by the maxilla and this fairly weak contact may have been strengthened by ligaments. Four teeth are characteristically present (Pl. 70, fig. 1), but they remained discrete throughout life and, unlike *Clevosaurus* and *Sphenodon*, did not tend to become worn into a single chisel-like structure in more mature individuals. Posterior to the teeth is a short palatal shelf.

The maxillae (Pl. 69, figs. 1 and 3) extend the full depth of the external nares defining the lower anterior quadrant of each orbit. They strongly overlap both the nasals and the prefrontals at their upper limits, thereby bracing the snout. Approximately two-thirds of the ventral border of either orbit is formed by the maxilla, and the jugal contact slopes posteroventrally from this border. Mesially there is a large foramen (Pl. 69, fig. 3) which was continuous with a similar foramen in the palatine contact and this carried the maxillary nerve and artery. The lateral surfaces of the maxillae are perforated by a series of small foramina which carried the nerves and blood vessels that supplied the skin. Usually each maxillae bears twelve to fourteen acrodont teeth, rarely up to seventeen. Four basic tooth categories can be recognized: the anterior three or four teeth are approximately 1·0 mm high, conical, and with a slightly recurved apex. These are followed posteriorly by a variable number of smaller conical teeth, usually three but up to seven, which in rare instances exhibit a slight alternation in size. These teeth never exceed 0·6 mm. The succeeding four teeth increase in size from about 0·6 mm anteriorly to over 1·0 mm in the most posterior member of the series. They are obtusely conical with broad bases and each bears a small posterolingual flange. The flange is comparable with those of *Sphenodon* and *Clevosaurus*, but less well developed. Three obtusely conical teeth approximately 0·5 mm high occur posterior to the flanged series. All teeth bear a distinct radial ribbing that is most prominent on the lingual surfaces (Pl. 69, figs. 2 and 4).

Anteriorly the paired nasals (Pl. 70, fig. 10) narrow to slender processes that descend ventrally and embrace the premaxillae. At their posterior limits there are transverse sutures with the frontal. The nasals descend partly over the sides of the skull and broad depressions receive the anterodorsal edges of the maxillae, so that jointly the maxillae and nasals form the posterior boundary of the external nares. The nasals also bear facets for the prefrontals.

The prefrontals overlap the nasals and form the anterodorsal quadrant of each orbit. At their posterior limits they extend to a point nearly mid-way along the supraorbital margin where there is a distinct interlocking of prefrontal with frontal (text-fig. 2*b*). A medial flange of the prefrontal descends along the anterior border of the orbit to articulate in a complex socket on the dorsal surface of the palatine (Pl. 71, fig. 4).

No lacrimals have been recognized and there are no facets on the prefrontals which might suggest their presence.

The frontal is a single element (Pl. 70, fig. 5) with transverse sutures separating it anteriorly from the nasals and posteriorly from the parietals. It forms the supraorbital margin for a short distance between the prefrontals and postfrontals and has rigid contacts with these elements (text-fig. 2*b*).

The parietals are fused, unlike the primitive situation, and form a broad and flat skull roof which is perforated by a well-developed parietal foramen. Anteriorly there are facets to receive the postfrontals and frontal (Pl. 70, fig. 7), and posteriorly lateral processes meet the squamosals.

Essentially triradiate bones, both postfrontals possess a long slender anterior process that slots into a narrow groove situated on the posterolateral margin of the frontal, and a shorter posterior process that articulates with the anterolateral edge of the parietal (Pl. 70, fig. 11). The third process is ventrolaterally directed and bears a depression to receive the postorbital; combined, these two elements jointly form the posterior border of the orbit. The postfrontals also enter into the anterior margins of the upper temporal fossae.

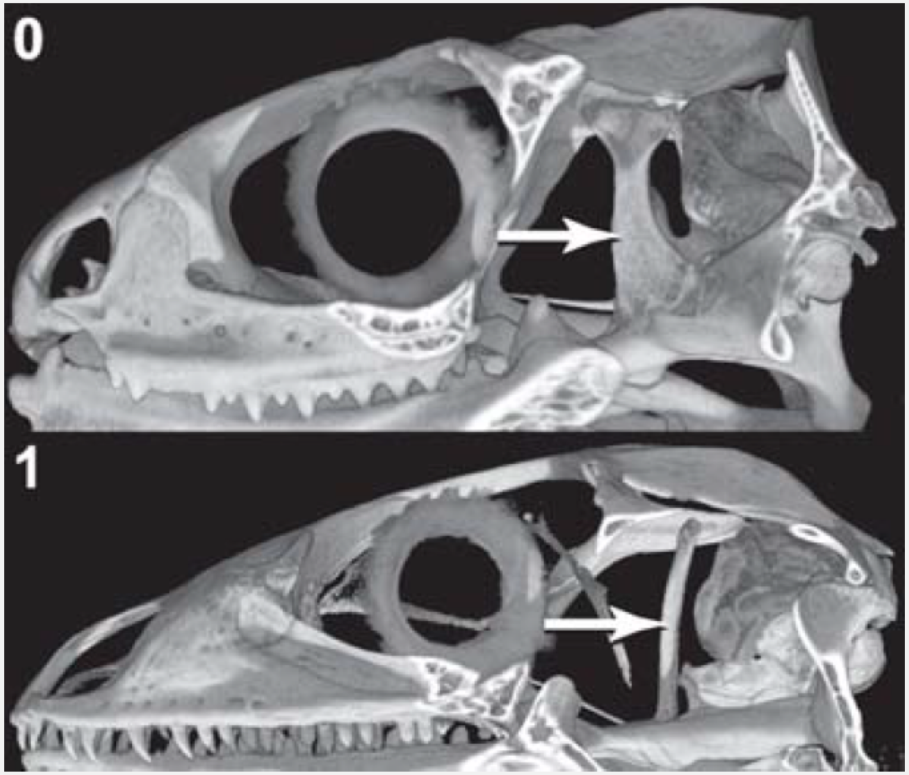
The postorbitals (Pl. 70, fig. 3) are approximately triangular bones that strongly overlap the squamosals posteriorly, and descend ventrally to meet and slightly overlap the jugals. A large area of contact between the postorbital and postfrontal is responsible for a rigid postorbital bar. There is no contact between the postorbital and the parietal.

No way to double check!

Sues et al. 1994, Camp 1945, Fraser 1982

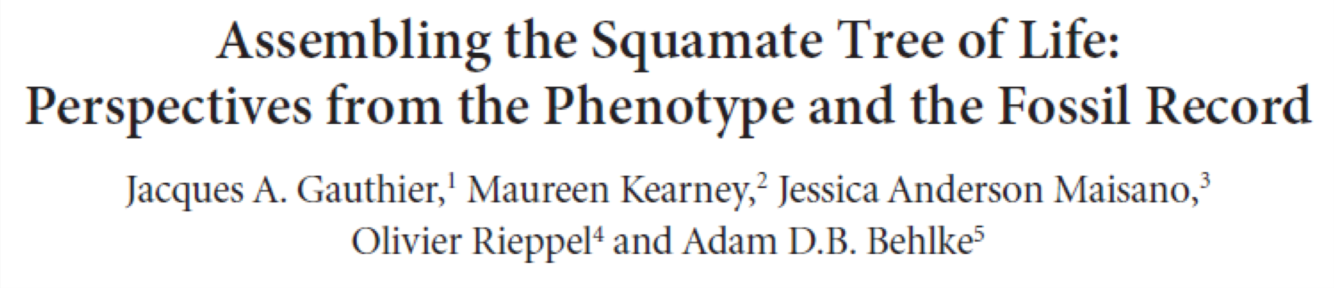
PHYLOGENETIC ANALYSES: AFTER CT

- Accurate anatomical representation
- 3-Dimensional
- Digital
- Internal structure
  - Sub-dermal
  - Bone structure
- Non-destructive
- Ready for measurement



Gauthier et al. 2012

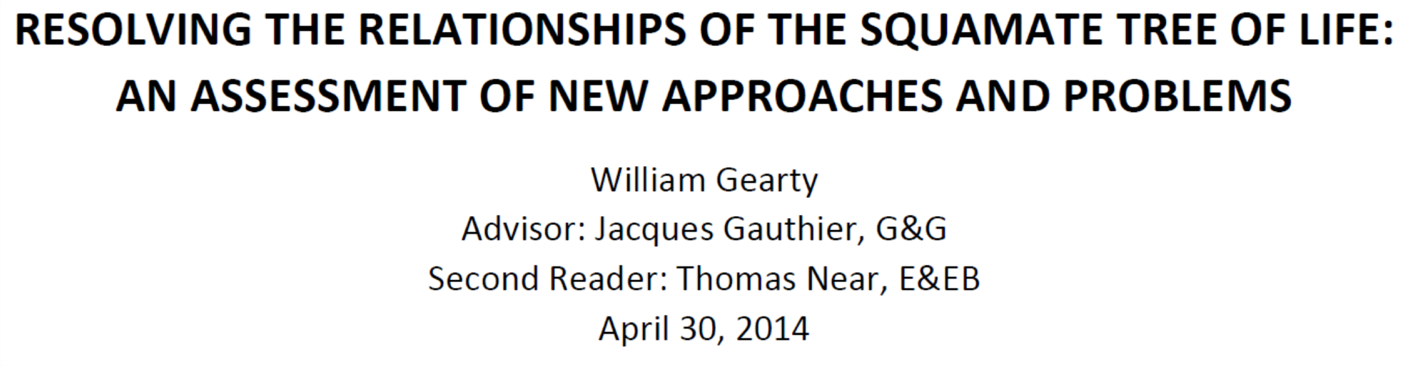
CASE #1: SQUAMATE TREE OF LIFE



Assembling the Squamate Tree of Life: Perspectives from the Phenotype and the Fossil Record

Jacques A. Gauthier,[1] Maureen Kearney,[2] Jessica Anderson Maisano,[3]
Olivier Rieppel[4] and Adam D.B. Behlke[5]

(Bulletin of the Peabody Museum of Natural History, 2012)

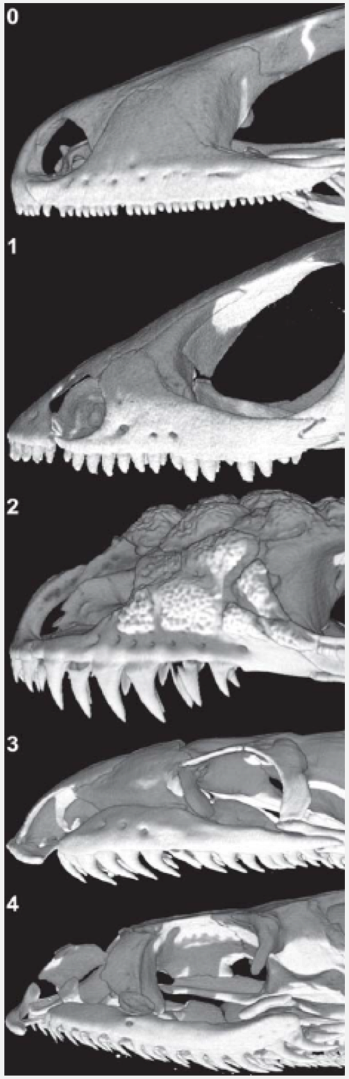


RESOLVING THE RELATIONSHIPS OF THE SQUAMATE TREE OF LIFE: AN ASSESSMENT OF NEW APPROACHES AND PROBLEMS

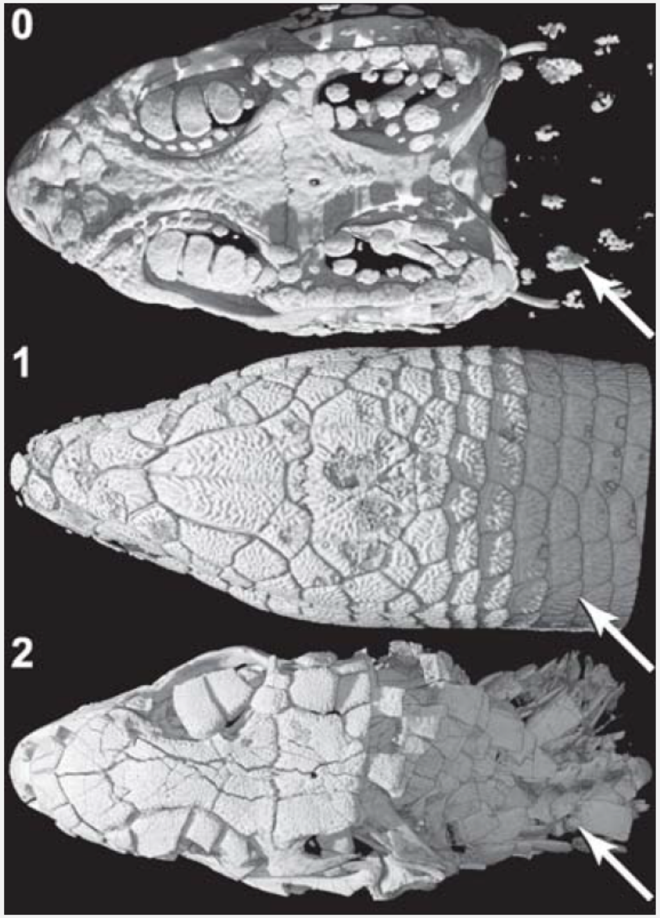
William Gearty
Advisor: Jacques Gauthier, G&G
Second Reader: Thomas Near, E&EB
April 30, 2014

(Will’s Undergrad Thesis)

CASE #1:
SQUAMATE TREE OF LIFE

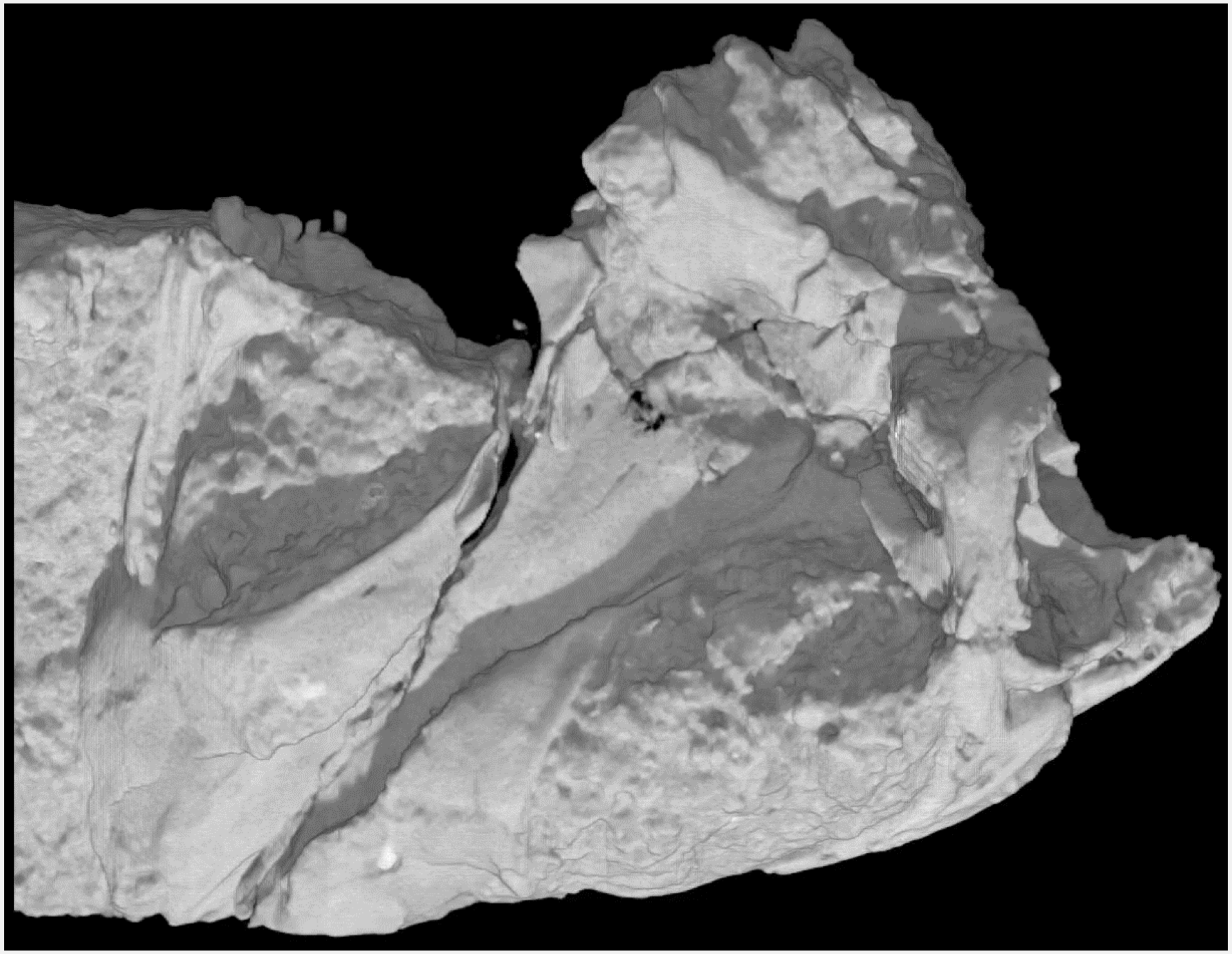


- ~200 species
  - 140 extant, 60 extinct
  - Most skulls scored using CT scans
    - All scans on digimorph.org
- 600+ morphological characters
  - Skull + Appendicular skeleton
- Standardization of character states
  - Allows for easy addition of future taxa

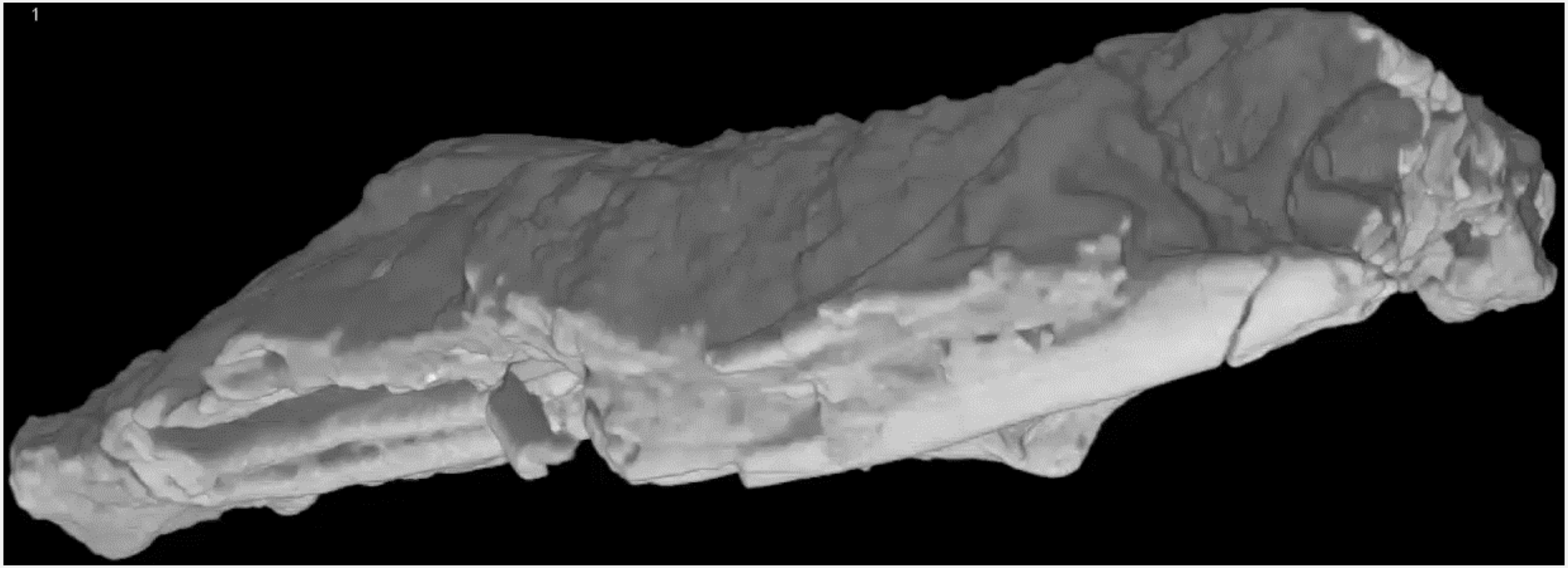


Gauthier et al. 2012

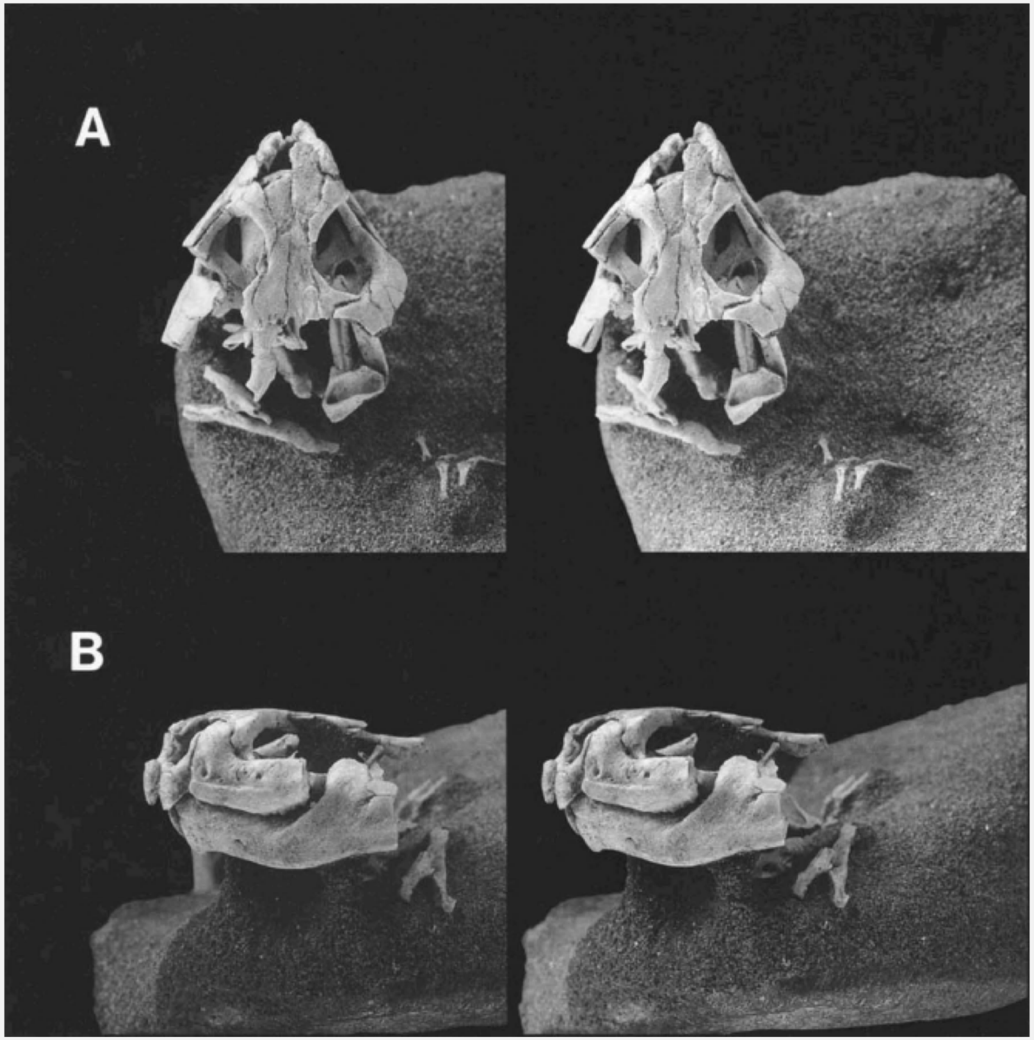
CASE #1:
SQUAMATE TREE OF LIFE



CASE #1:
SQUAMATE TREE OF LIFE

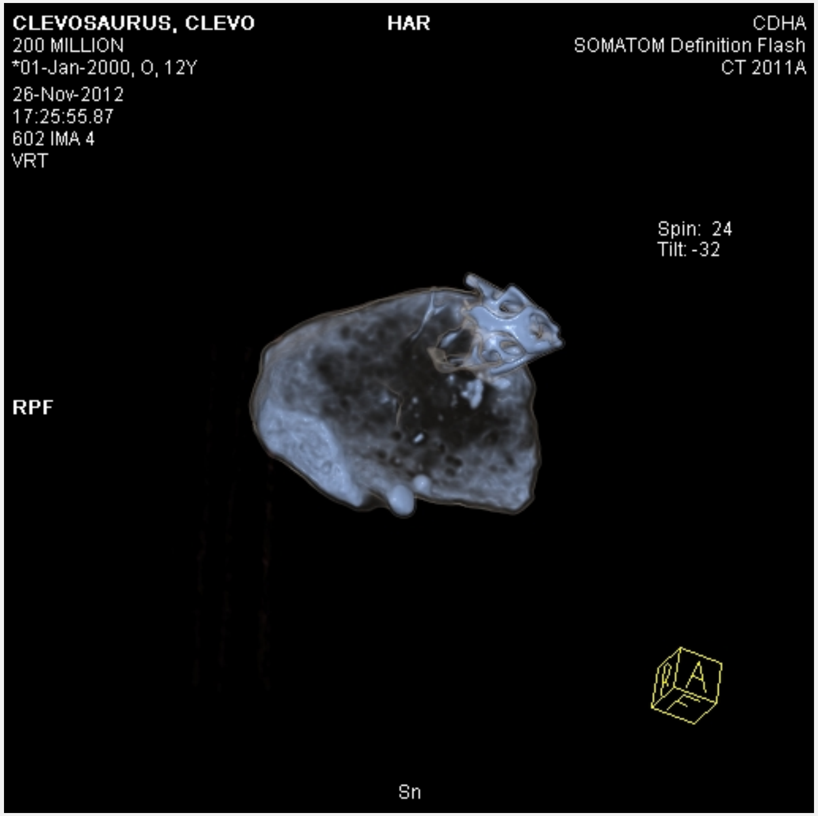


CASE #1:
SQUAMATE TREE OF LIFE



Sues et al. 1994

CASE #1:
SQUAMATE TREE OF LIFE

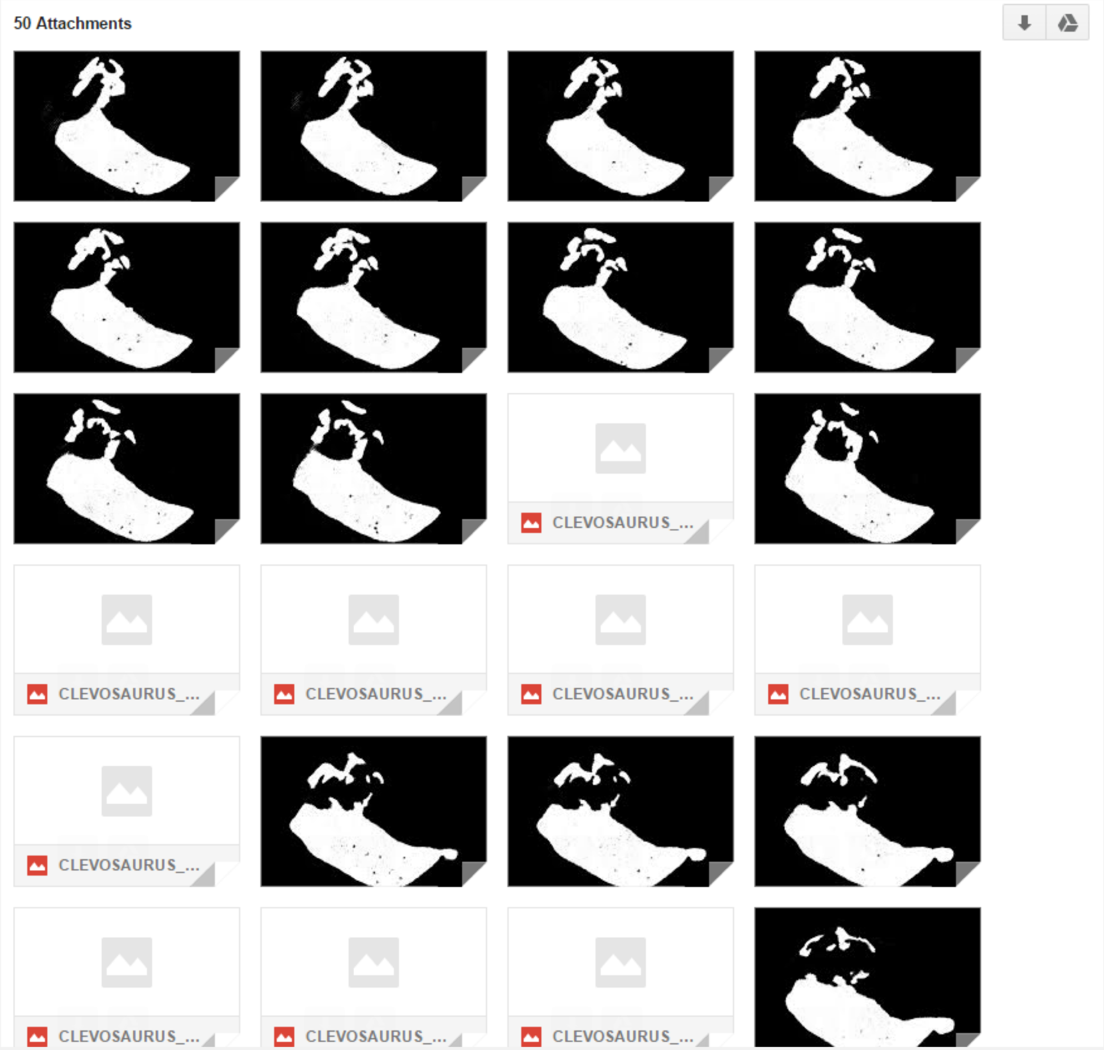


Courtesy of Nova Scotia Museum

CASE #1:
SQUAMATE TREE OF LIFE

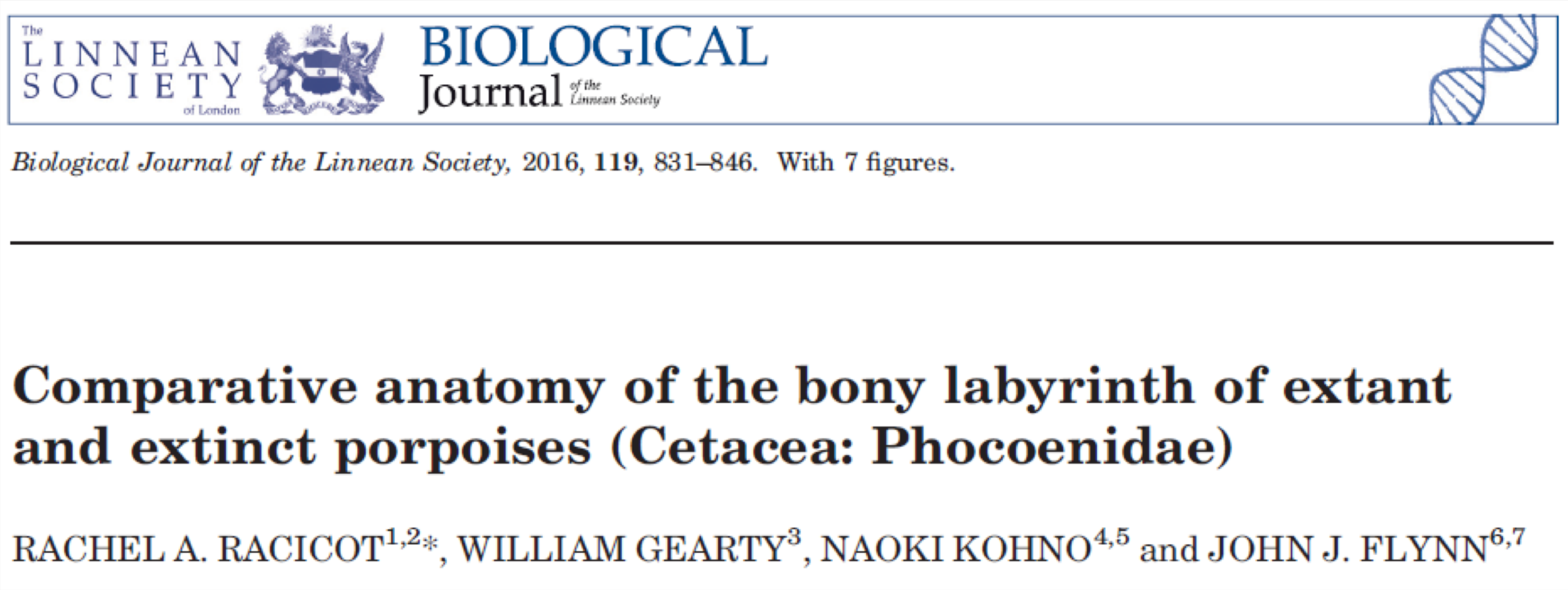
An aside:

- Don't send slices as individual email attachments!
- (This is one of a number of similar emails)



50 Attachments

CASE #2:
PORPOISE EARS



The LINNEAN SOCIETY of London
BIOLOGICAL Journal of the Linnean Society

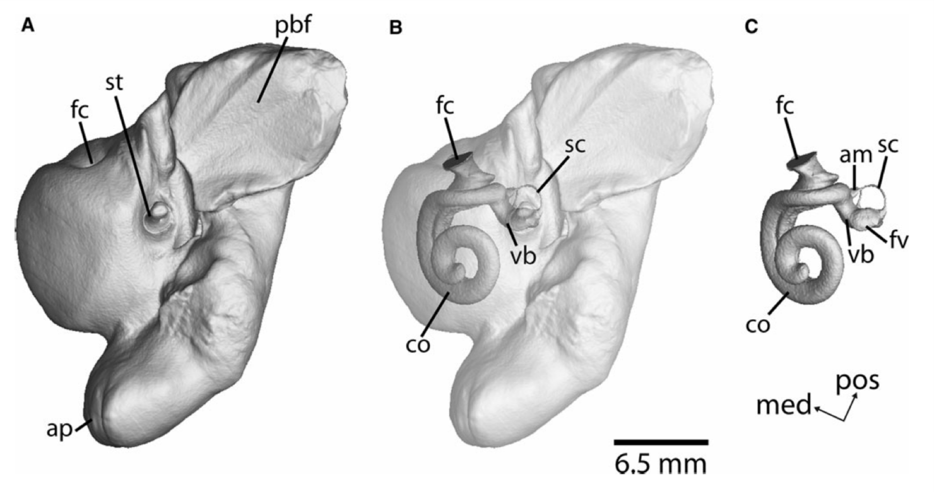
Biological Journal of the Linnean Society, 2016, **119**, 831–846. With 7 figures.

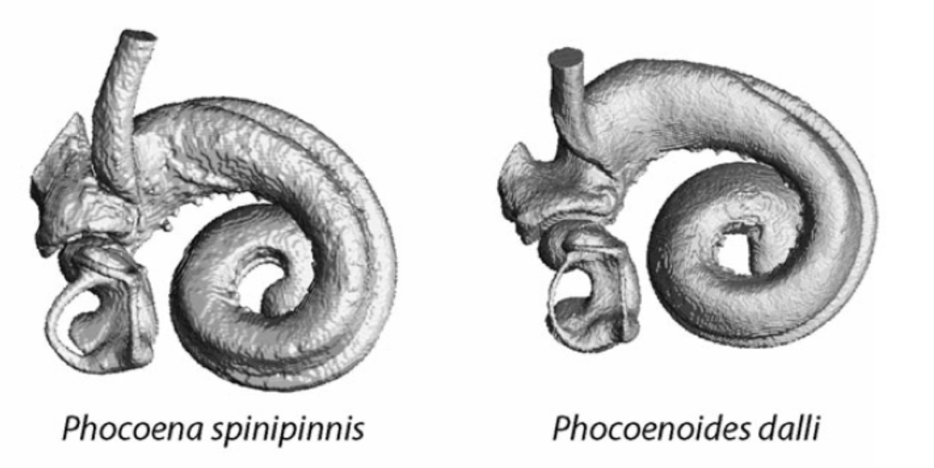
Comparative anatomy of the bony labyrinth of extant and extinct porpoises (Cetacea: Phocoenidae)

RACHEL A. RACICOT[1,2]*, WILLIAM GEARTY[3], NAOKI KOHNO[4,5] and JOHN J. FLYNN[6,7]

CASE #2:
PORPOISE INNER EARS

- Bony labyrinths of16 specimens
  - 6 extant species
  - 9 extinct species
  - Will be on morphosource.org
- Numerous quantitative measurements
  - Lengths
  - Ratios
  - Angles
  - Volumes

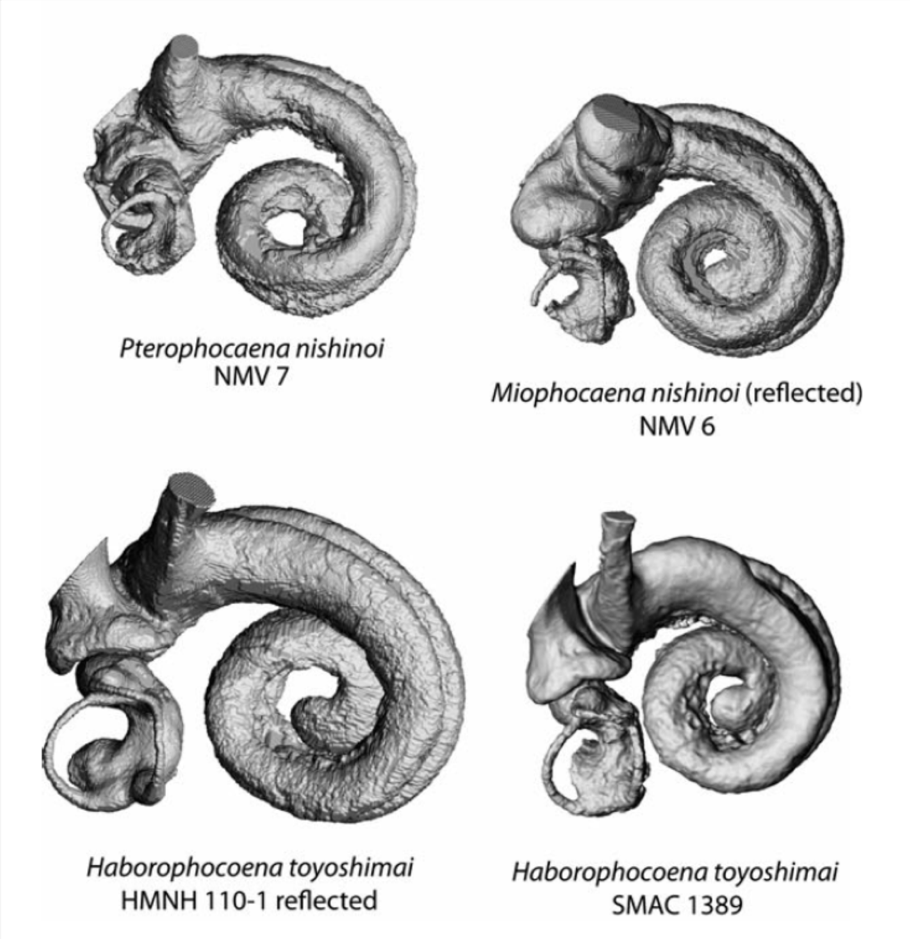



Phocoena spinipinnis

Phocoenoides dalli

Racicot et al. 2016

CASE #2:
PORPOISE INNER EARS



Fossil Porpoises

- Internal structures excellently preserved, even in fossils
- Get out what you put in
  - Not magic

Racicot et al. 2016

CONCLUSIONS

- CT data provides a new, [usually] better way to look at zoological and paleontological specimens
- Often can be critical for investigating internal anatomy without destructive approaches
  - Contrast can be an issue in older/altered fossils
- Ultimately, CT scans provide super accessible, exceptionally accurate representations of collections material
  - Important for research that requires specimens from numerous institutions/museums
- Museums: Keep imaging your data! (CT, surface, photos, etc.)
- Researchers: Use specimen image data! You have no excuses!
  - If you get new data, share it!

ACKNOWLEDGMENTS

YALE UNIVERSITY
GEOLOGY AND GEOPHYSICS

iDigBio
Integrated Digitized Biocollections

Stanford
SCHOOL OF EARTH, ENERGY
& ENVIRONMENTAL SCIENCES | Geological Sciences