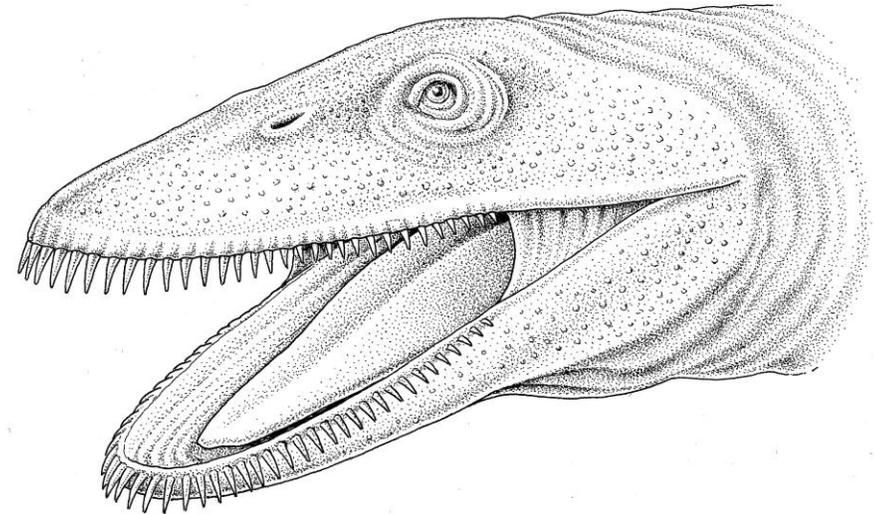
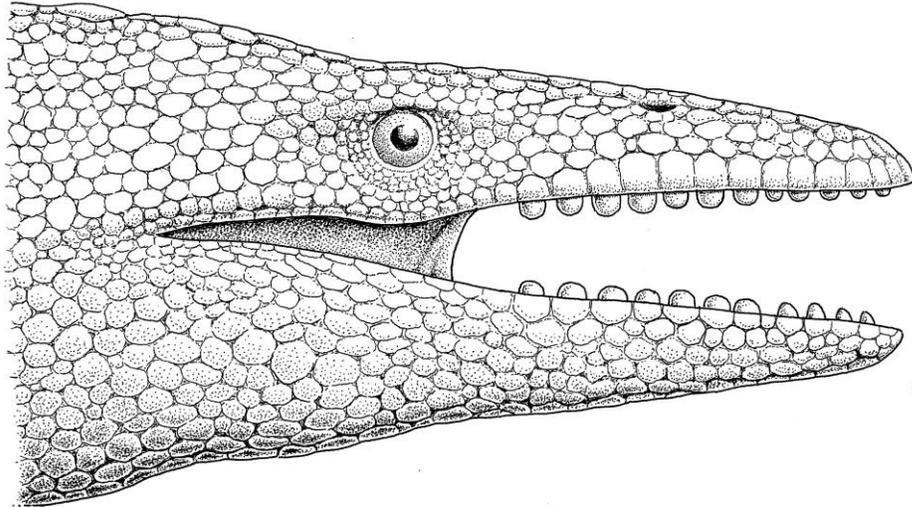


EWOLUCJA KONWERGENTNA KRĘGOWCÓW



Konwergencja pokarmowa w morzach



Dr Daniel Tyborowski

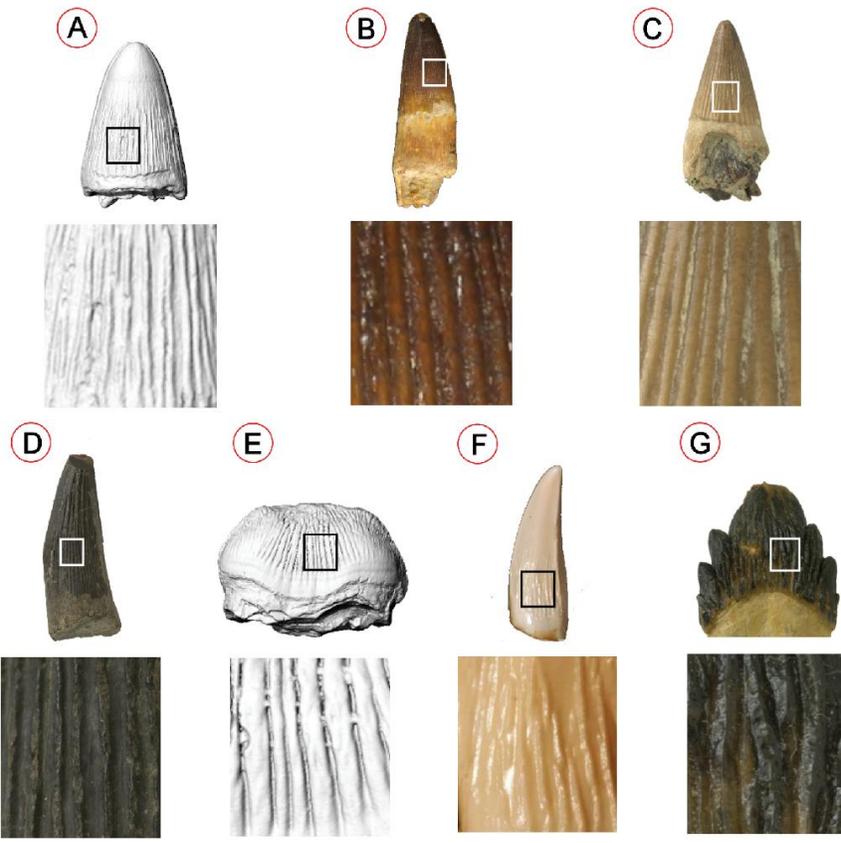
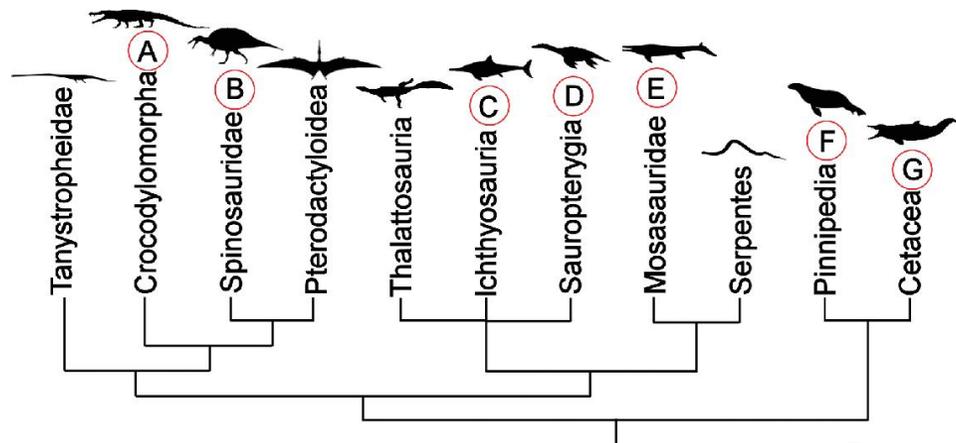
Katedra Geologii Historycznej, Regionalnej i Paleontologii

Wydział Geologii UW

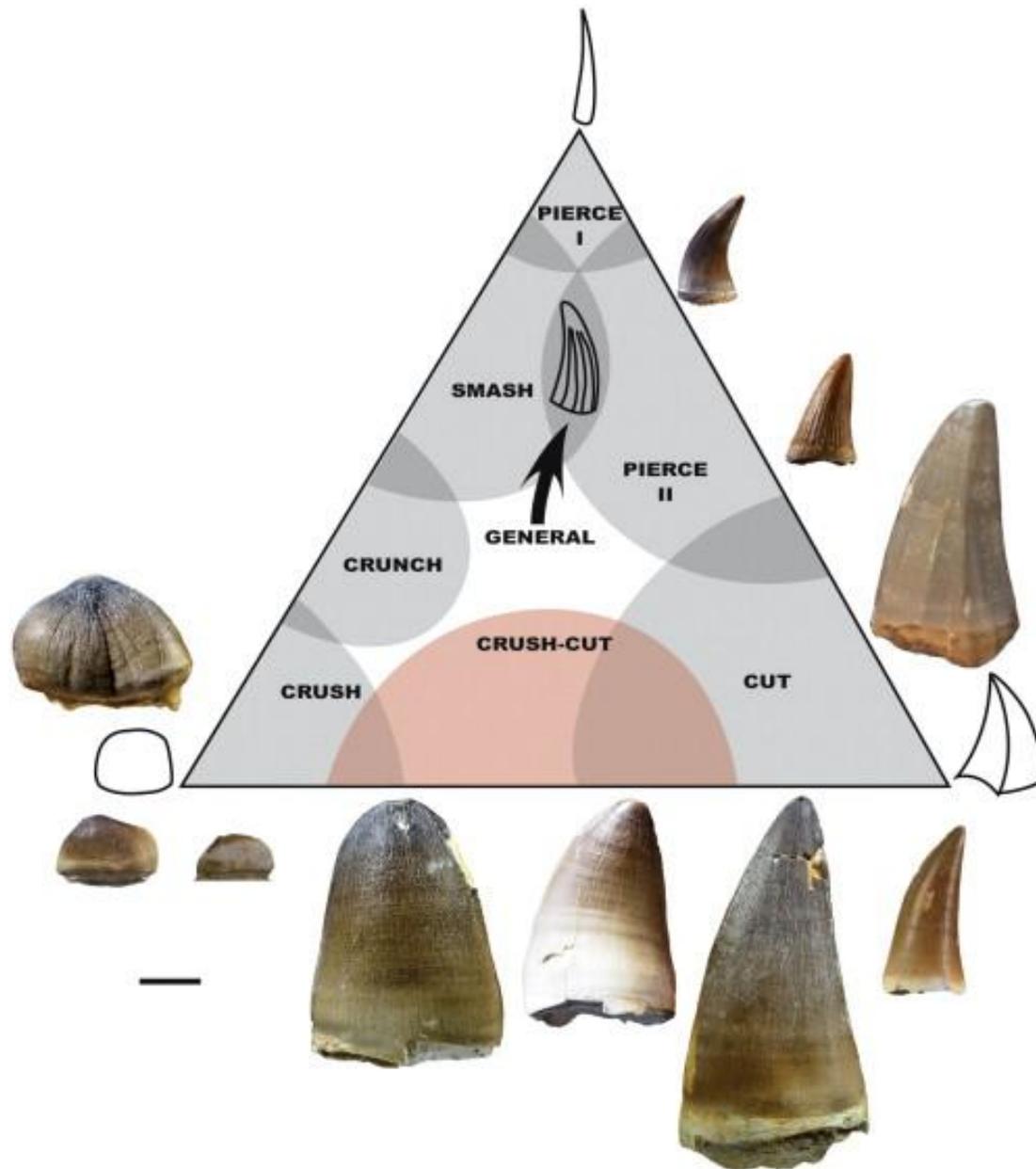
d.tyborowski@uw.edu.pl



UNIWERSYTET
WARSZAWSKI

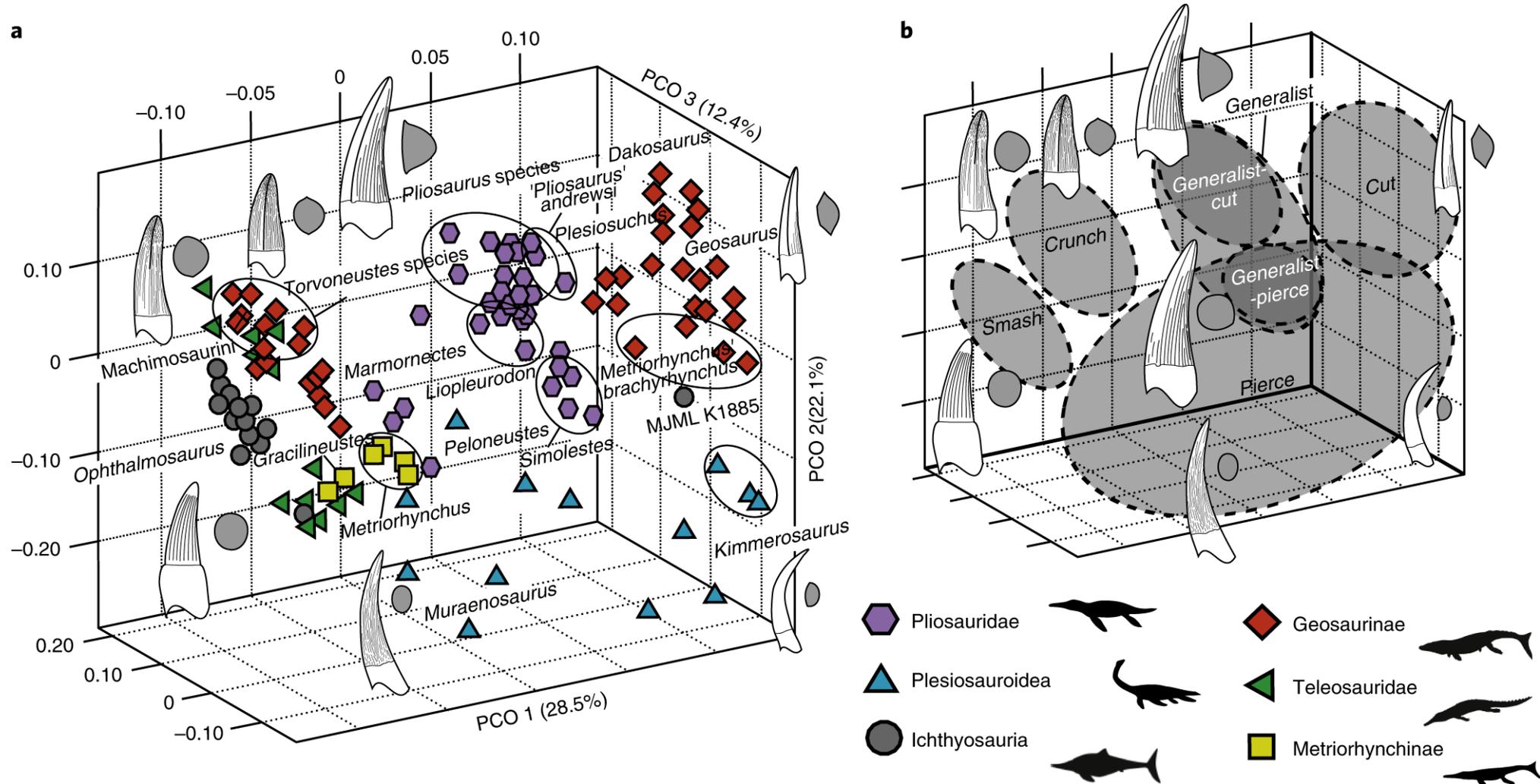


McCurry et al., 2019

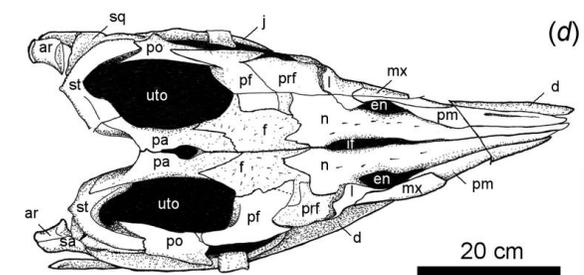
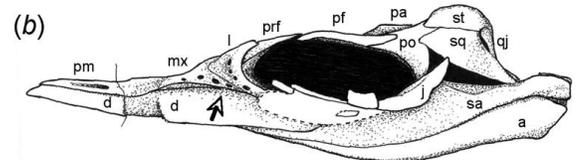


Bardet et al., 2015

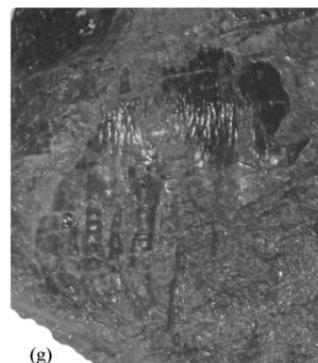
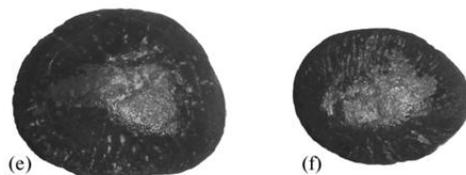
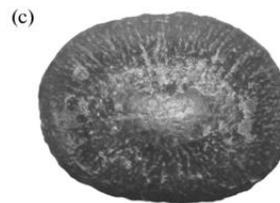
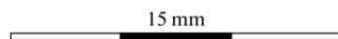
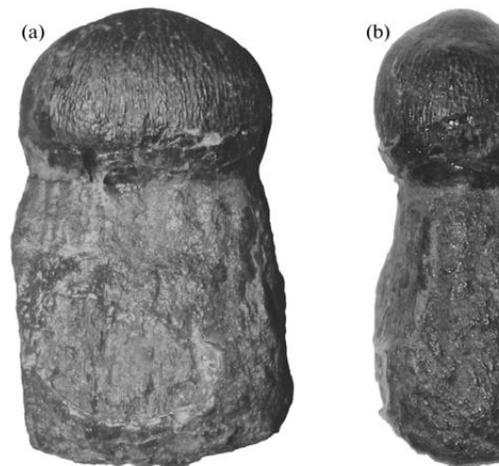
Gildie pokarmowe jurajskich gadów morskich



Mezozoiczna Rewolucja Morska



Filtrujący *Guanlingsaurus*
Jiang et al., 2013

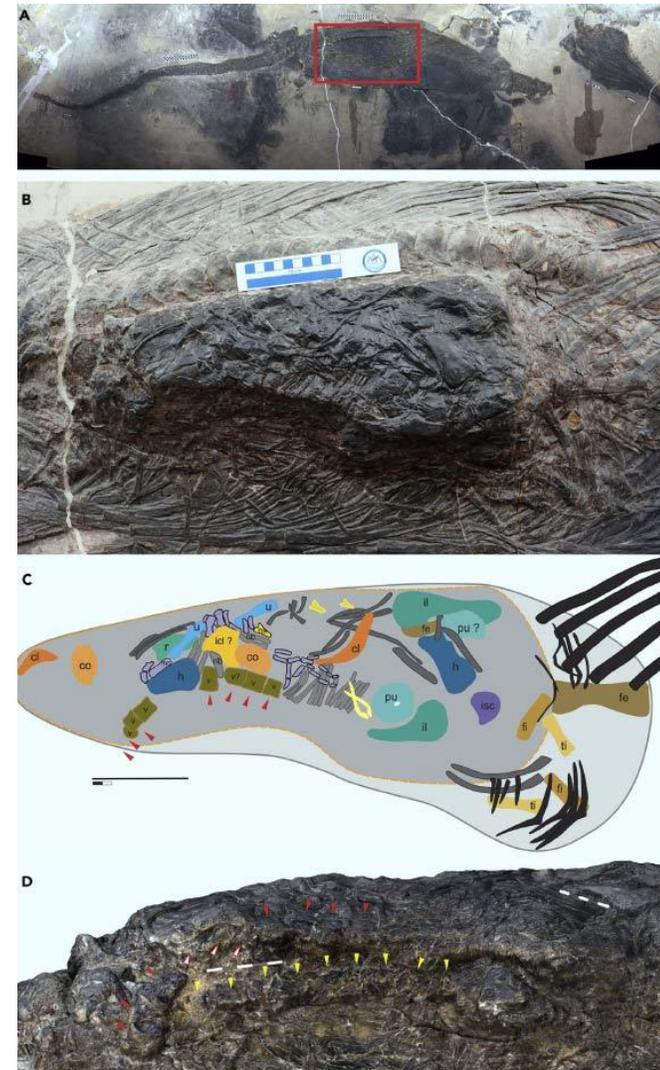
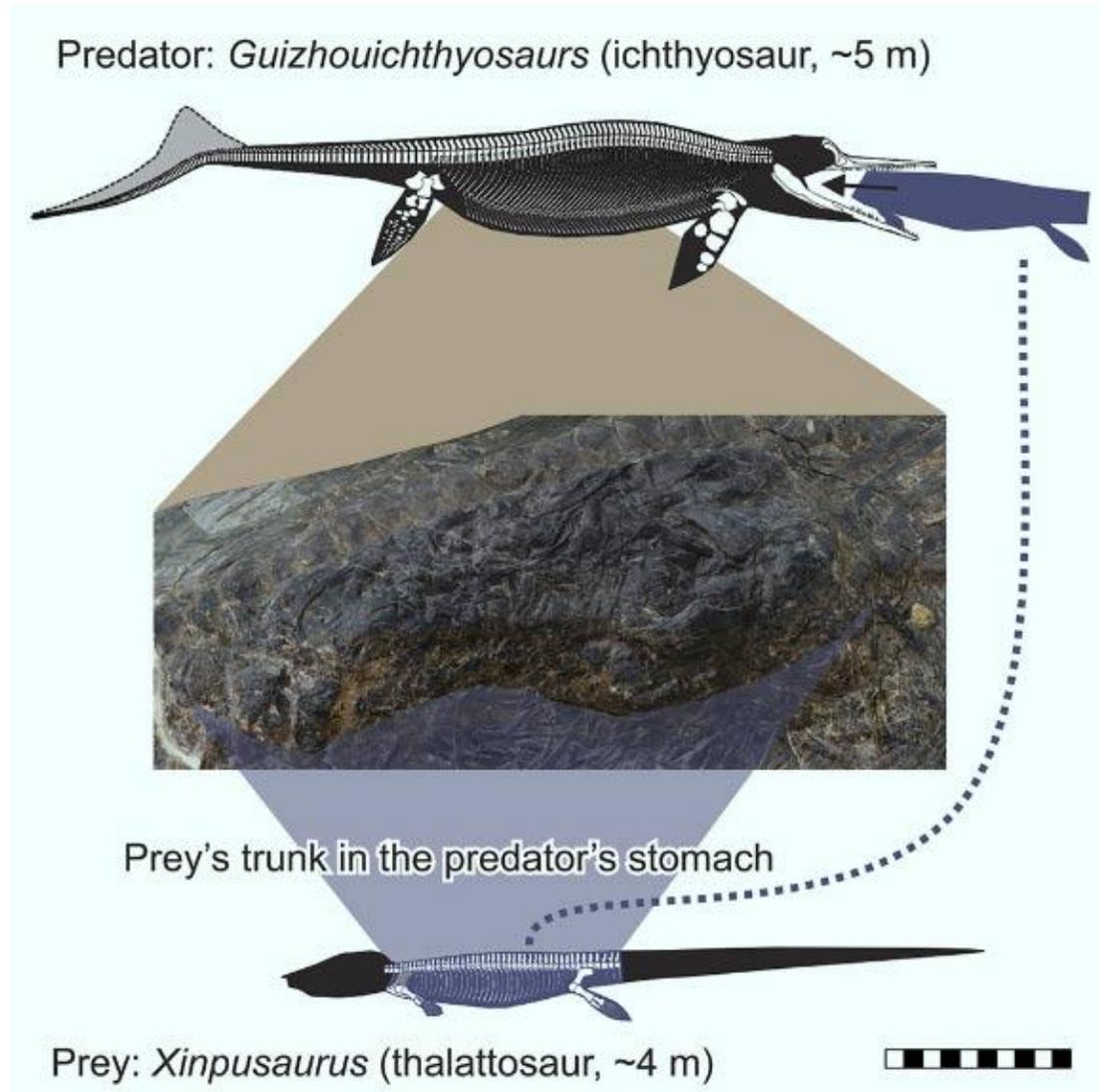


Zęby *Tholodus*
Arkhangelsky et al., 2016



Potężny *Temnodontosaurus*
Pardo-Pérez et al., 2018

Makrodrapieżnictwo wśród triasowych ichtiozaurów



Oraz kredowych – *Kyhytysuka sachicarum*

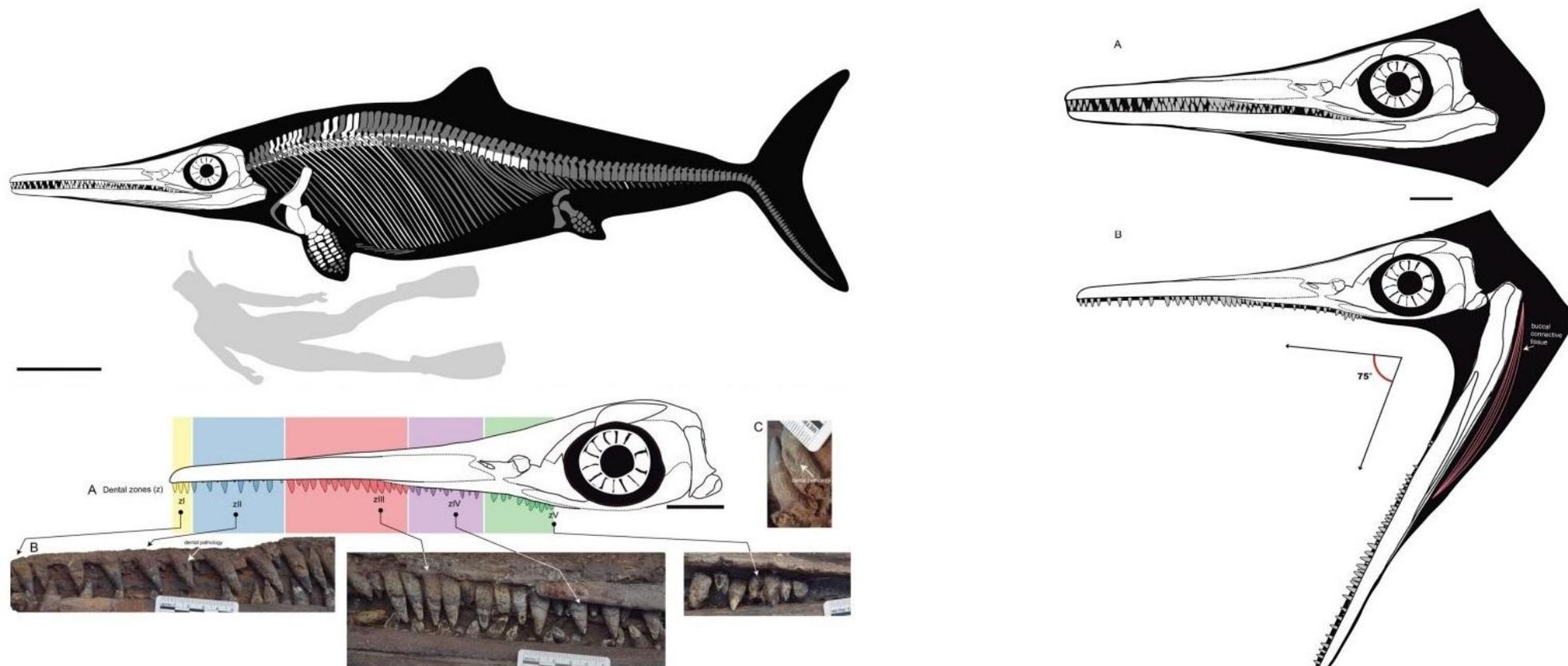
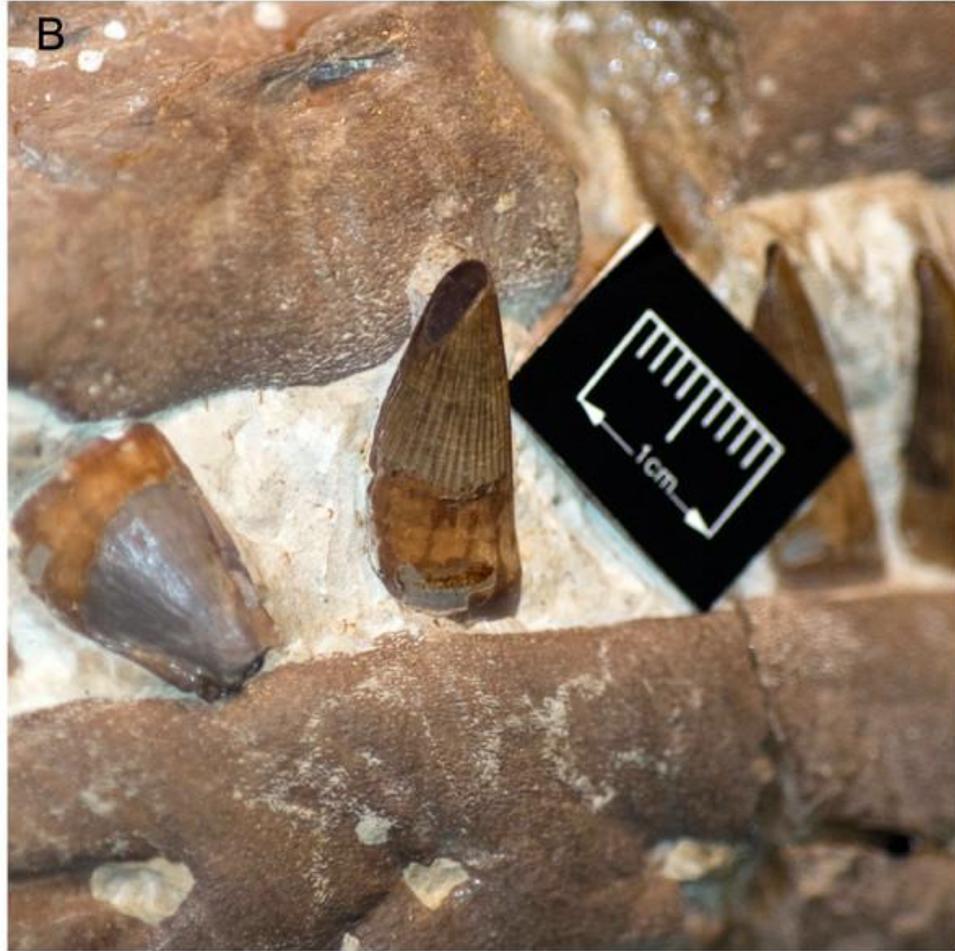
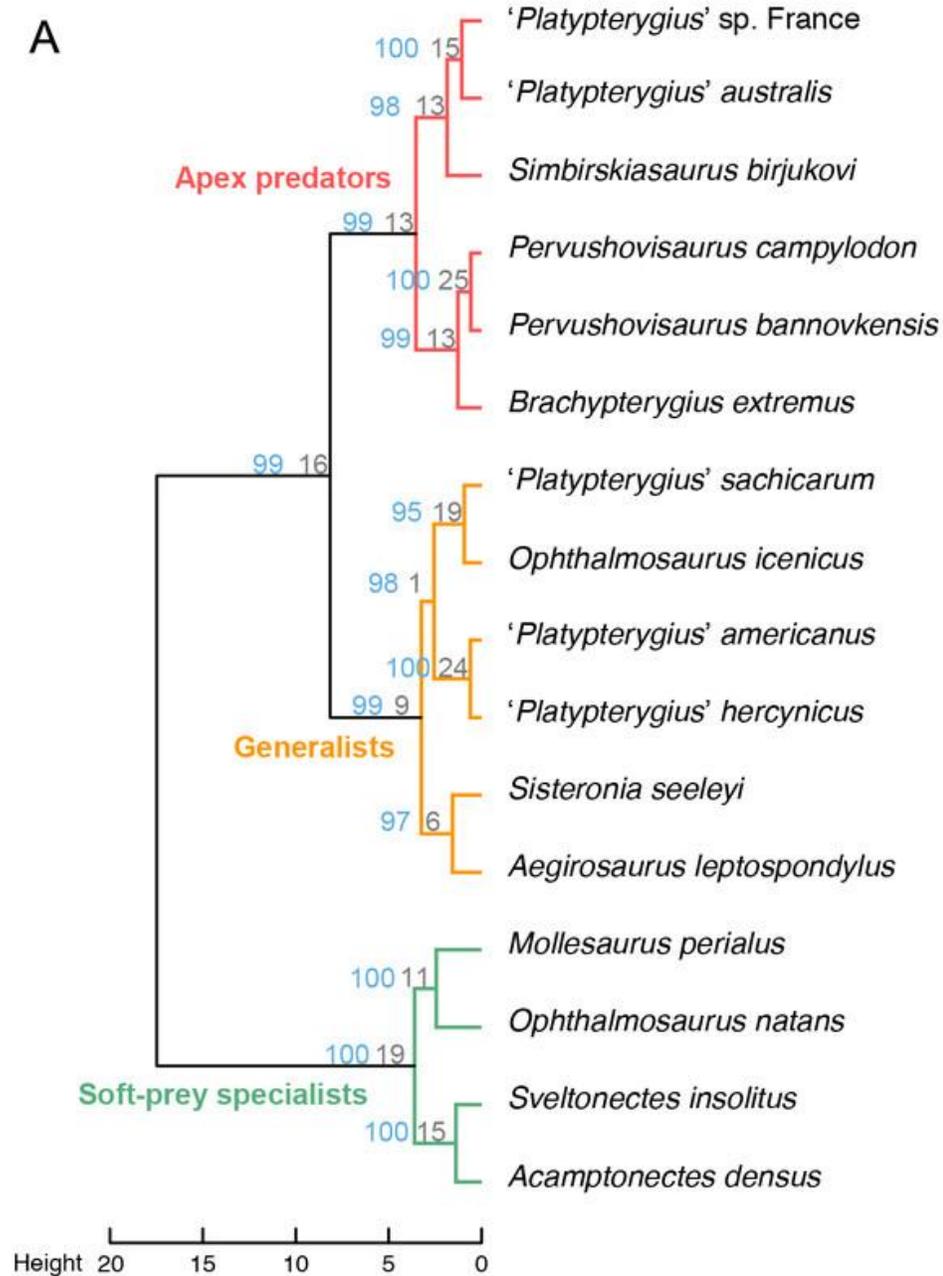


Figure 10. Reconstruction of the skull of *Kyhytysuka sachicarum* comb. nov., DON-19761. **A**, showing morphological differentiation across the teeth, and **B**, gape interpretation. Scale bar = 10 cm.

A



Cluster dendrogram
 Distance: euclidean
 Cluster method: ward.D
 Confidence metrics (%):
 Approximate unbiased *P*-value
 Standard bootstrap

Delfiny oceaniczne krótkoszczykie

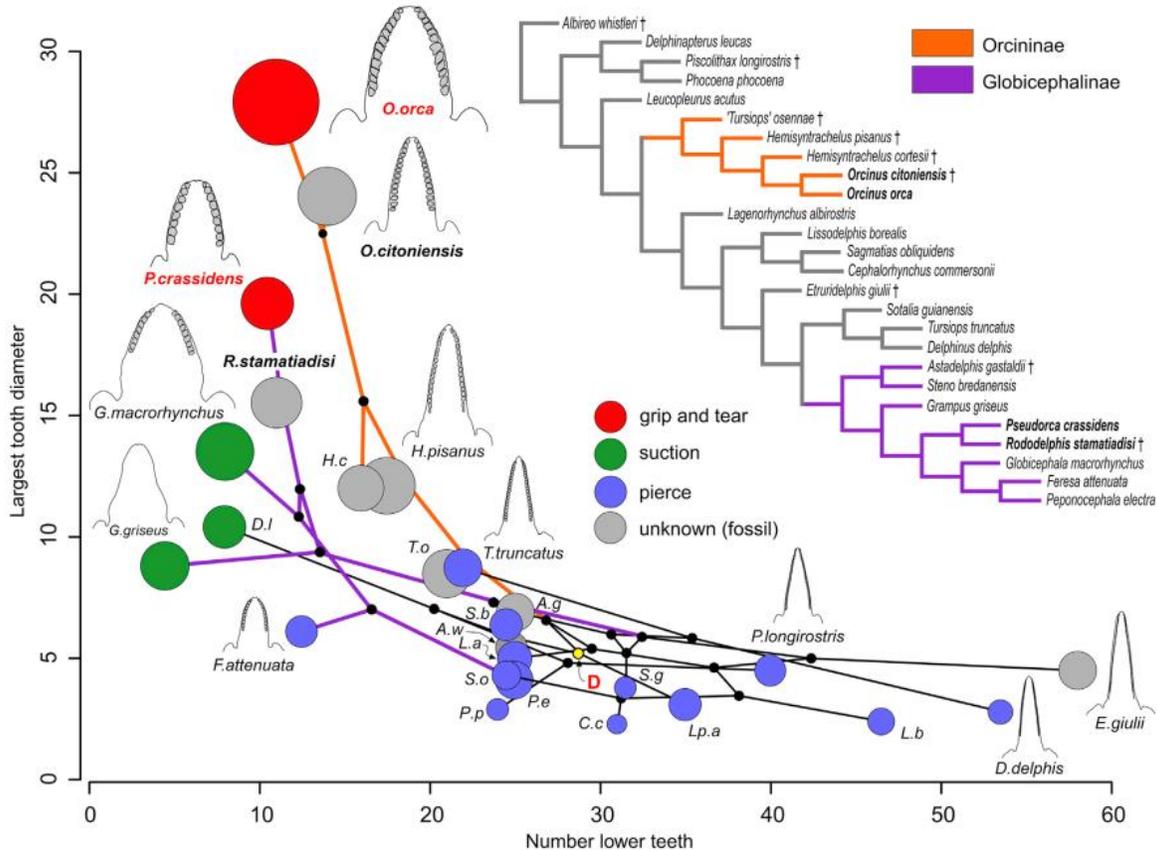
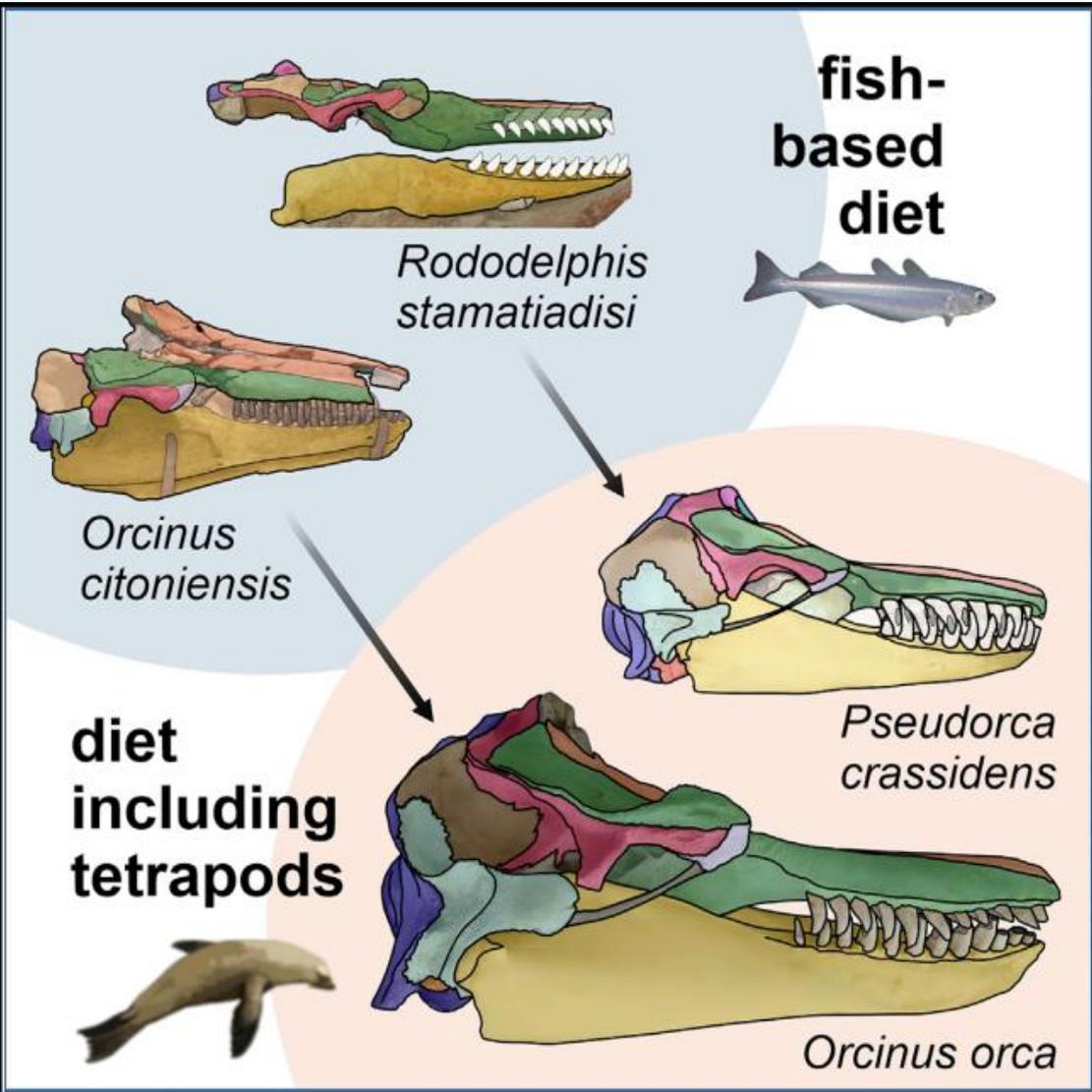


Delfinowiec białonosy
Lagenorhynchus albirostris

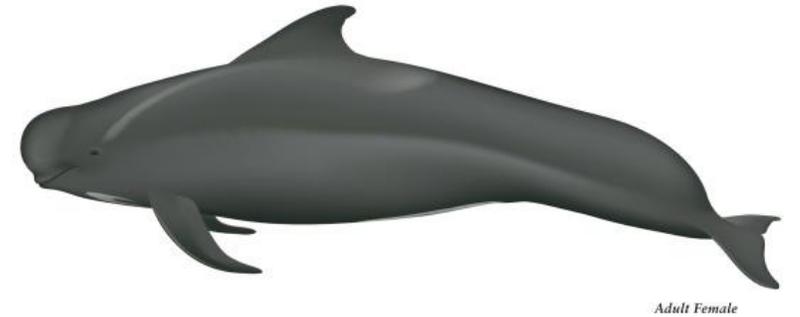


Orki oceaniczne *Orcinus orca*

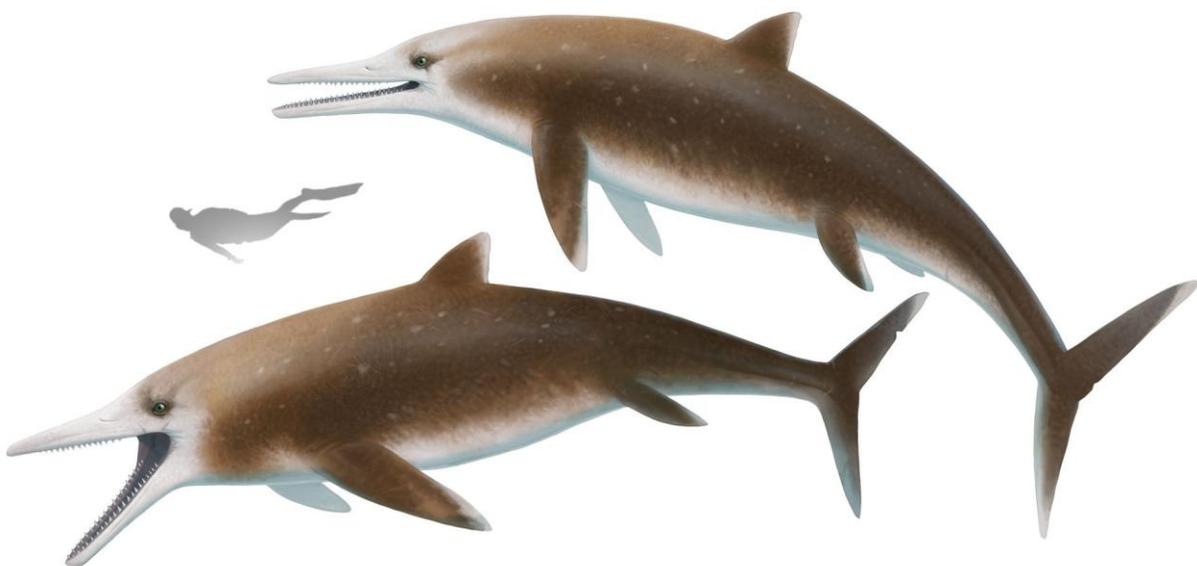
Ekomorfi orki



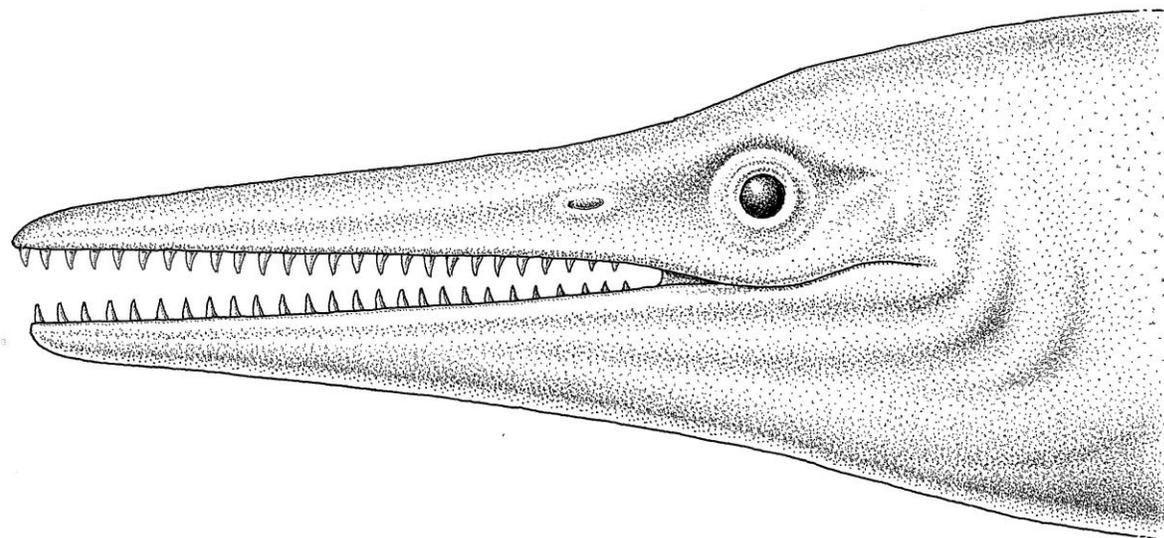
Współczesne grindwale



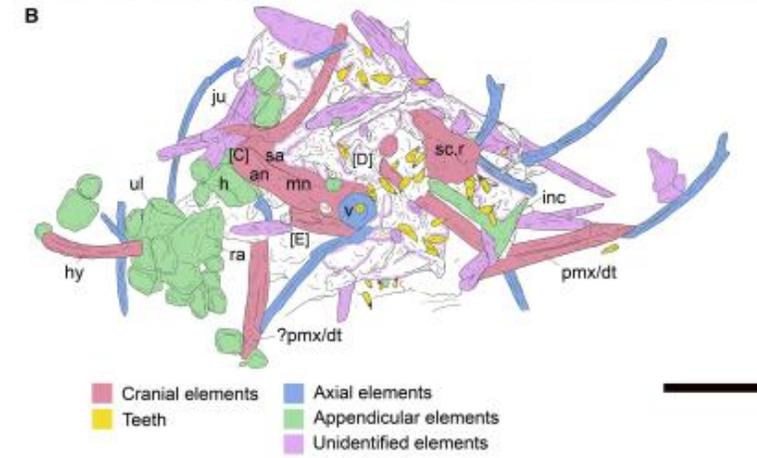
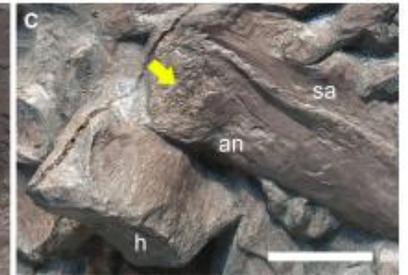
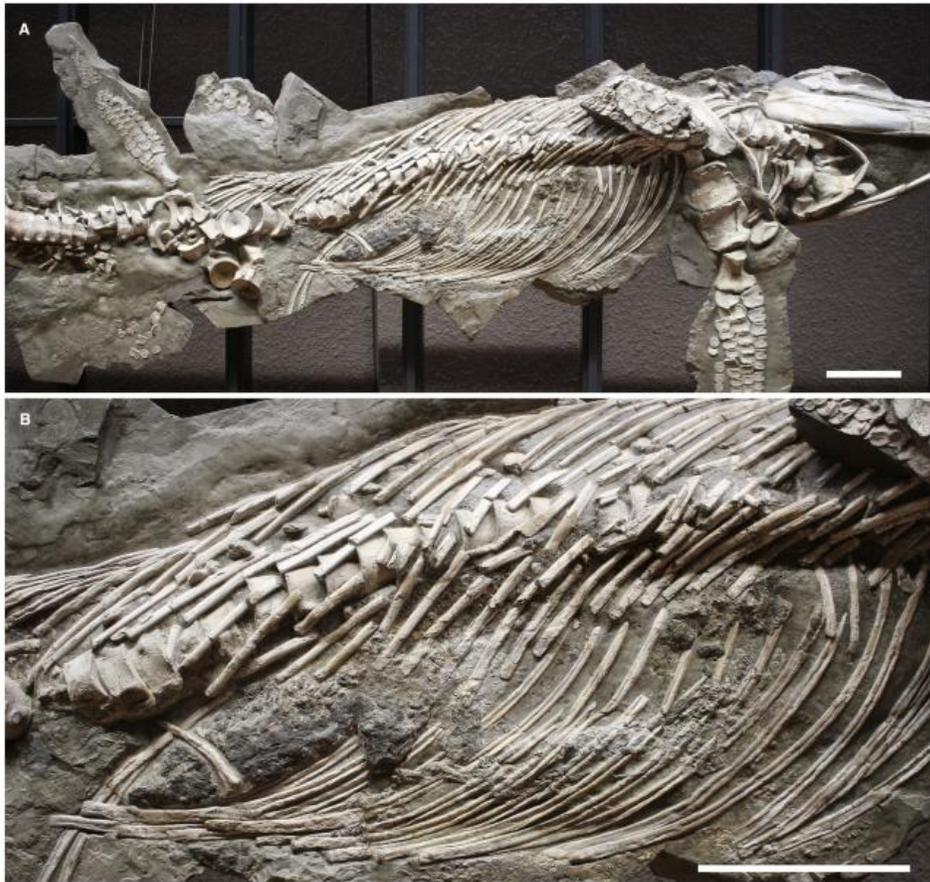
Temnodontosaurus – jurajska orka



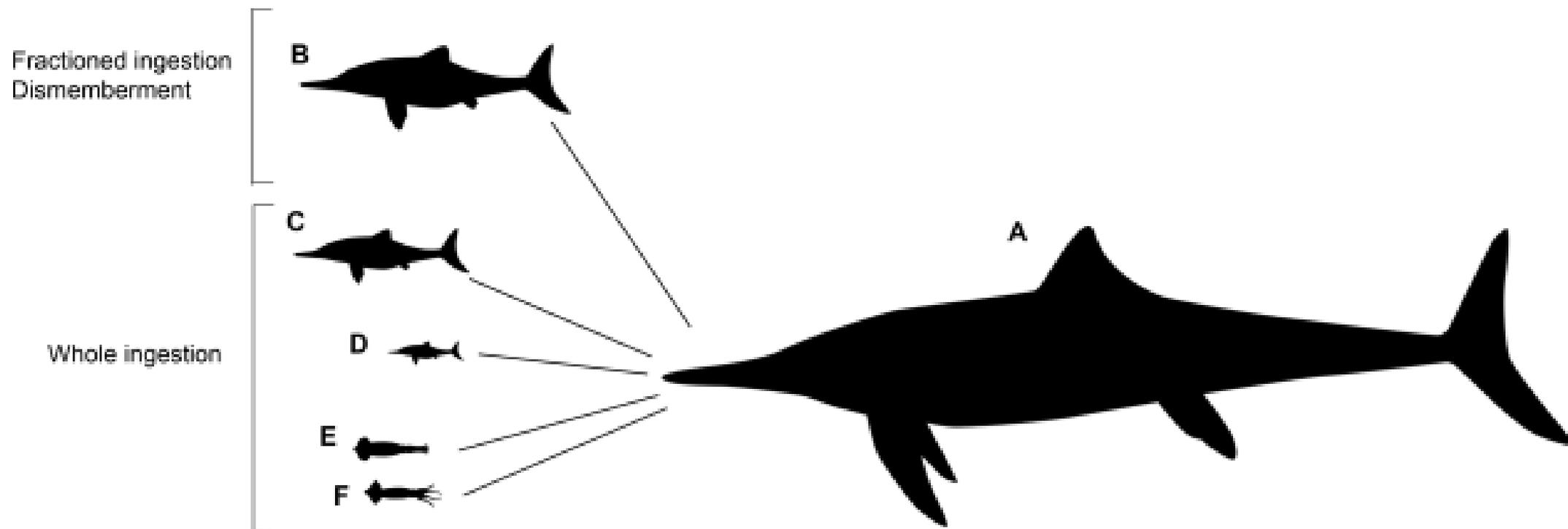
duskyvel.deviantart.com

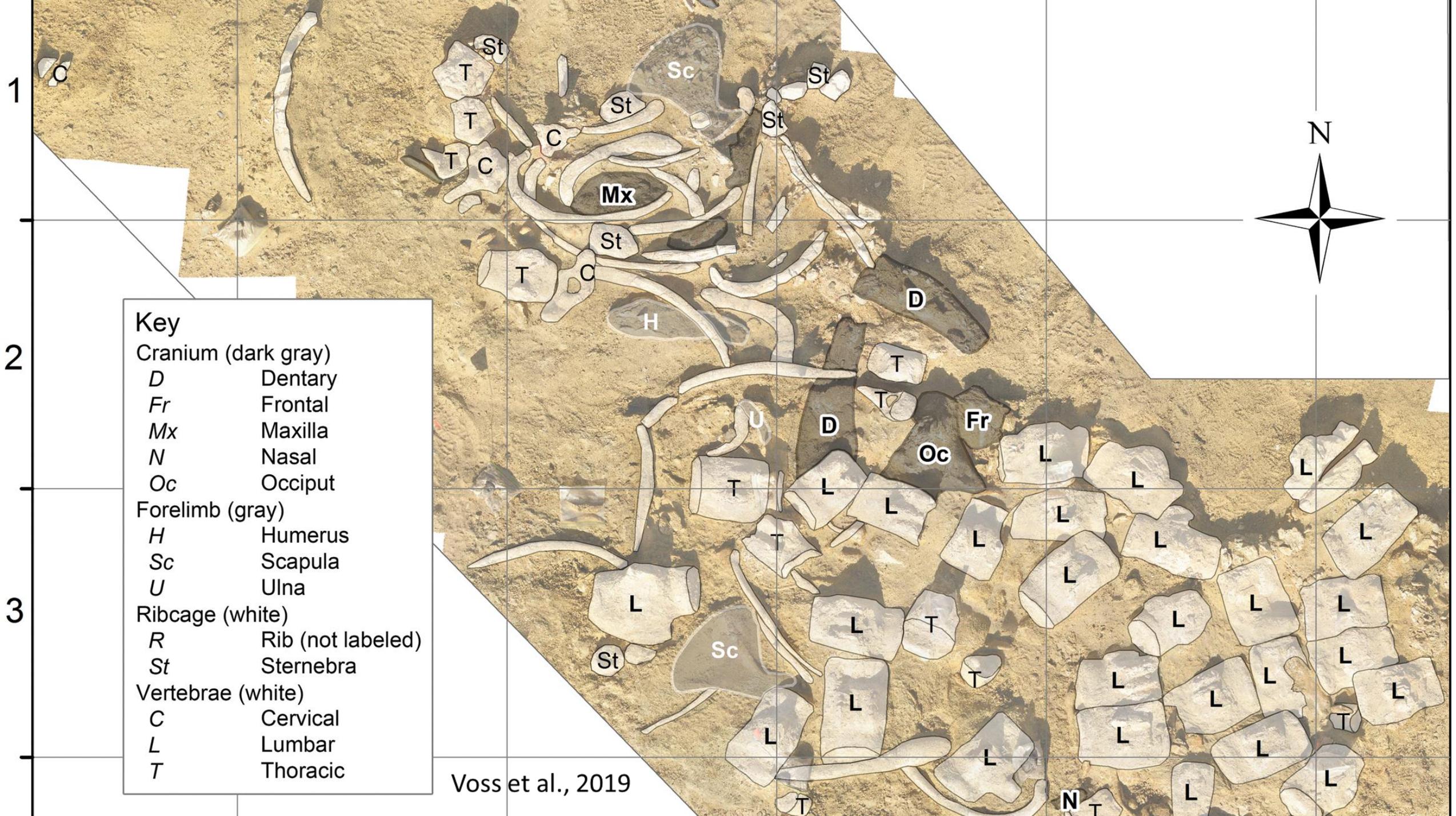


Treści żołądkowe sprzed 180 milionów lat



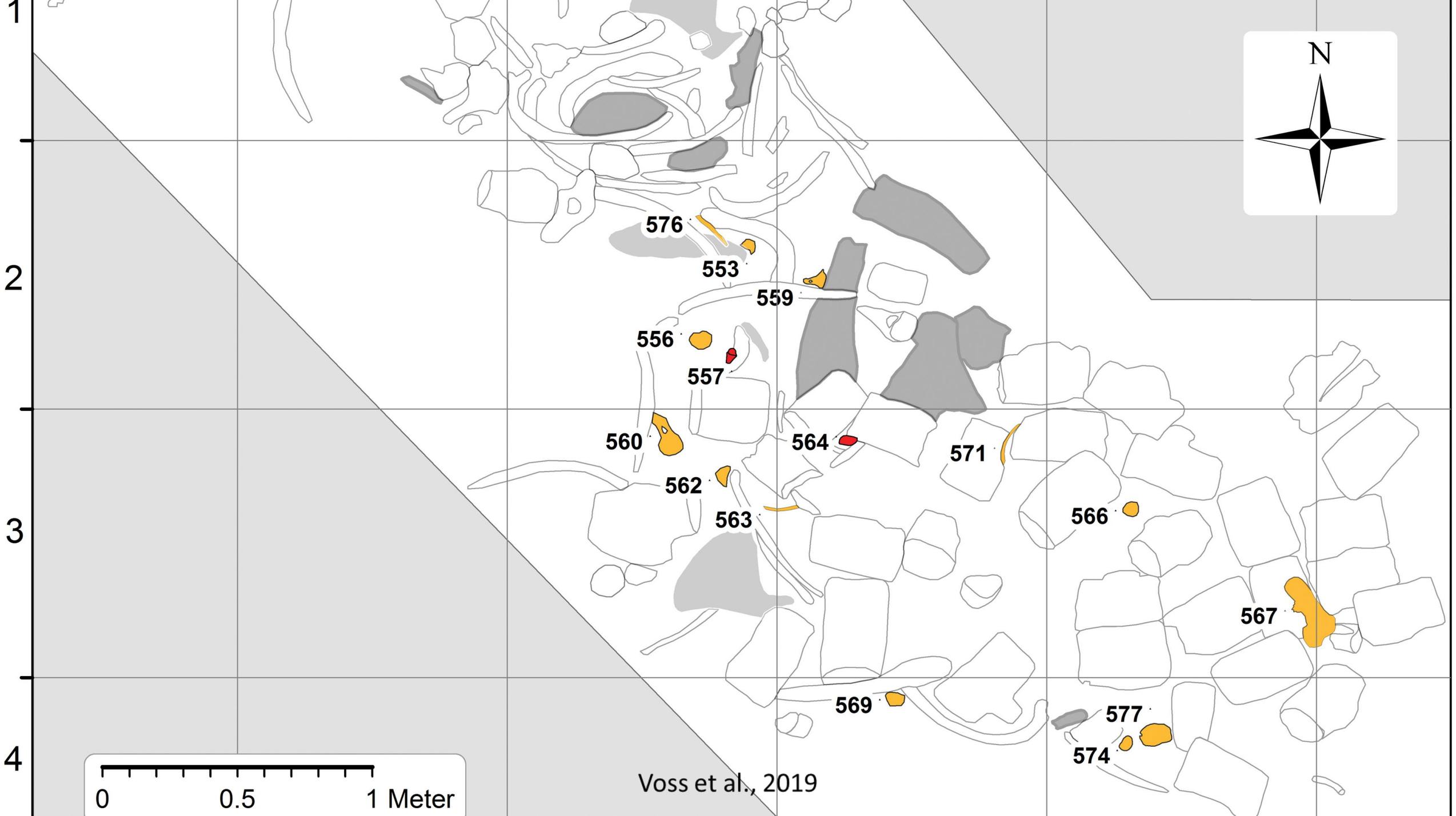
Temnodontozaury zjadały wszystkich!





Key	
Cranium (dark gray)	
<i>D</i>	Dentary
<i>Fr</i>	Frontal
<i>Mx</i>	Maxilla
<i>N</i>	Nasal
<i>Oc</i>	Occiput
Forelimb (gray)	
<i>H</i>	Humerus
<i>Sc</i>	Scapula
<i>U</i>	Ulna
Ribcage (white)	
<i>R</i>	Rib (not labeled)
<i>St</i>	Sternebra
Vertebrae (white)	
<i>C</i>	Cervical
<i>L</i>	Lumbar
<i>T</i>	Thoracic

Voss et al., 2019



576

553

559

556

557

560

564

571

562

563

566

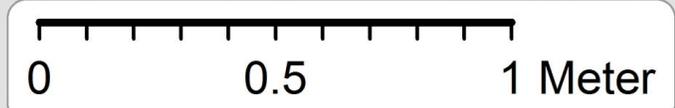
567

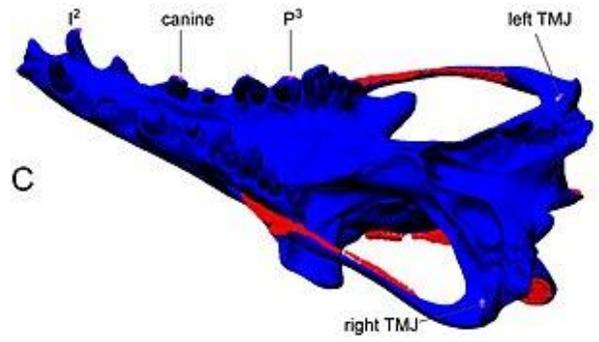
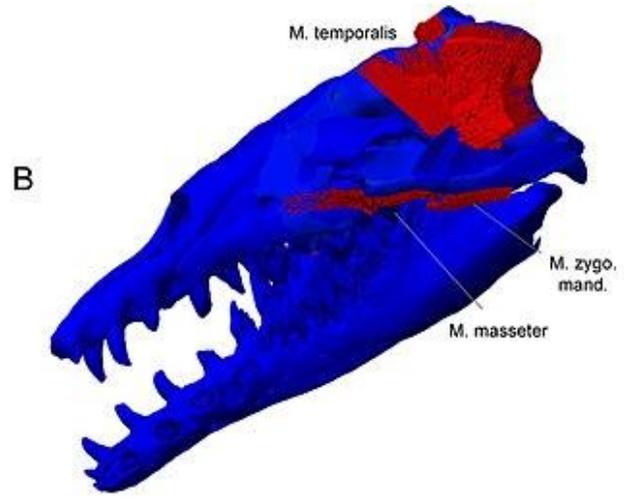
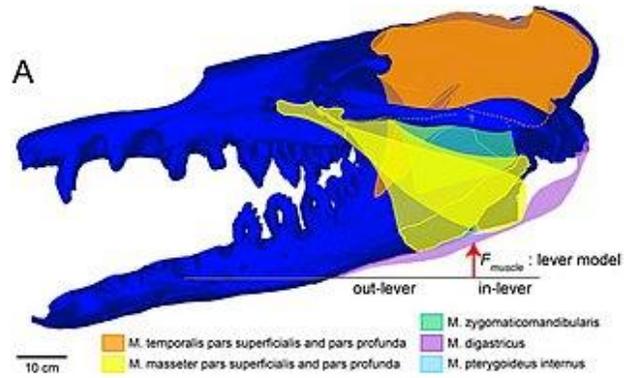
569

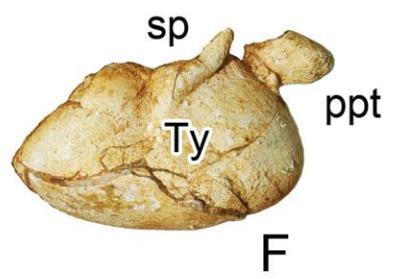
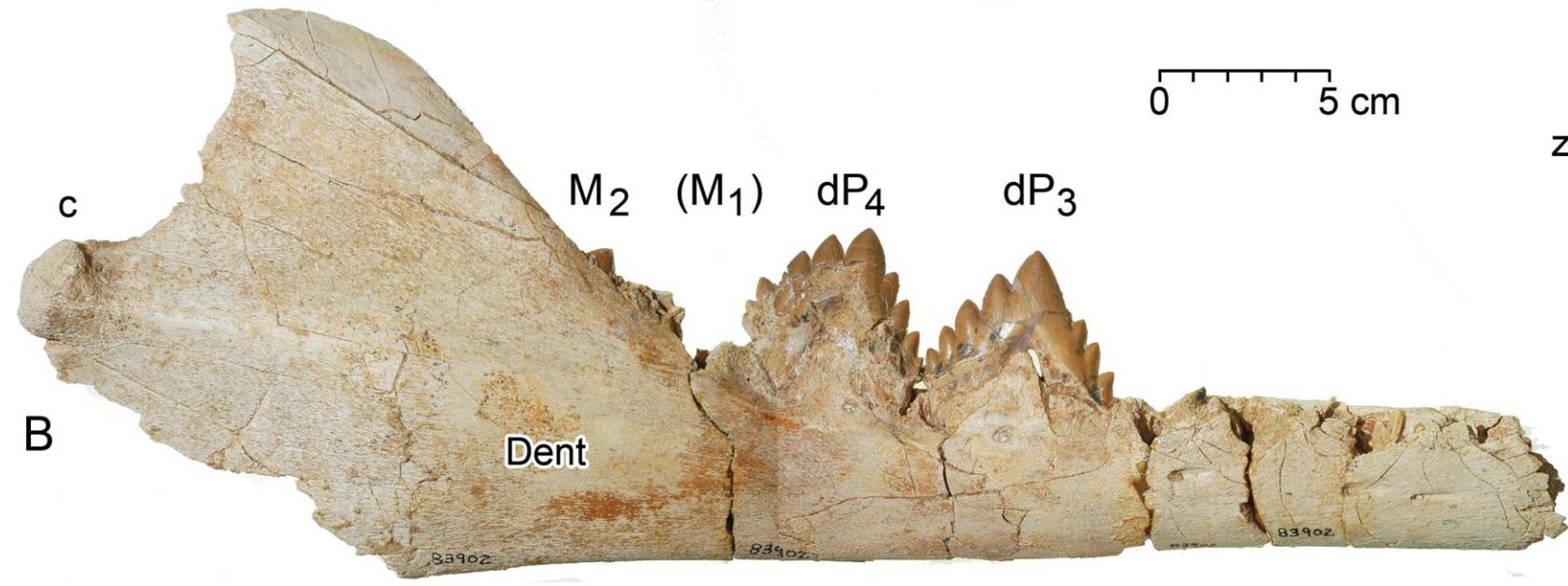
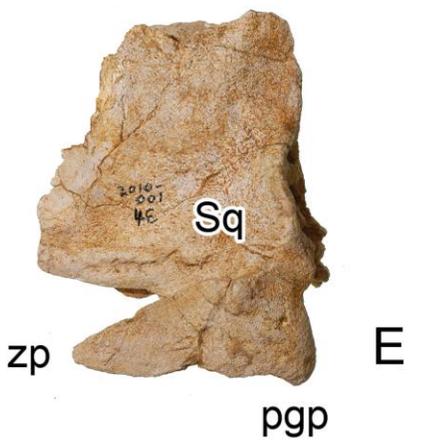
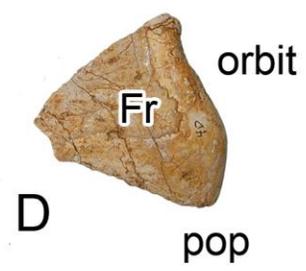
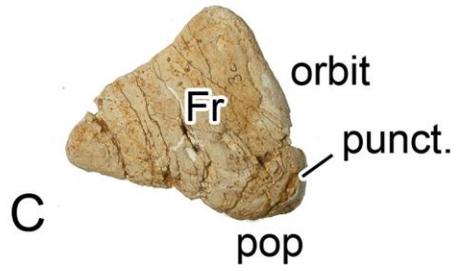
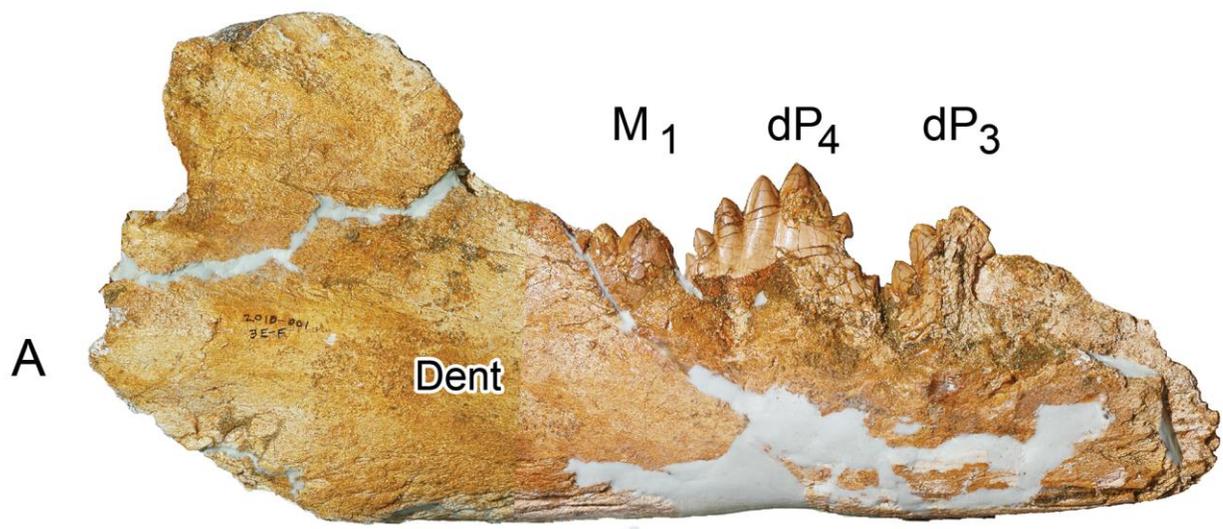
577

574

Voss et al., 2019



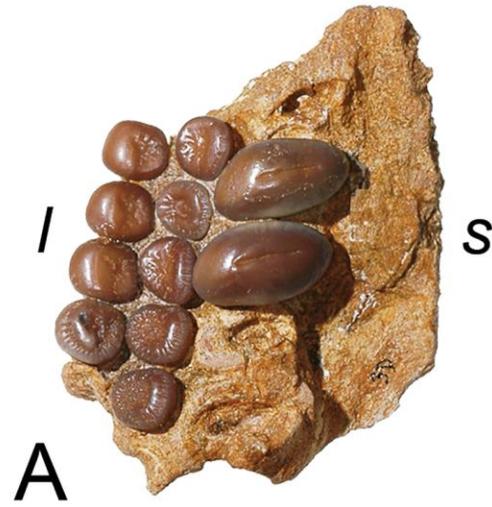




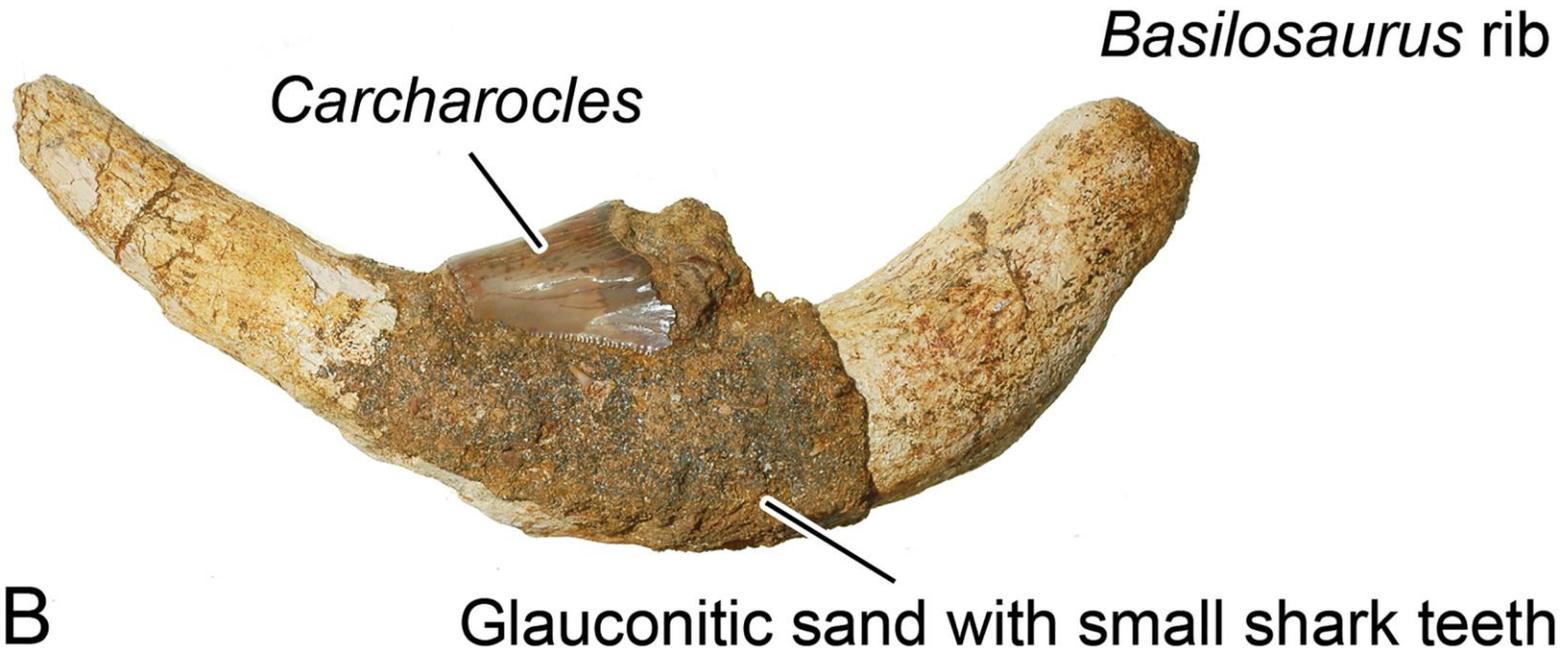
Voss et al., 2019



https://c1.staticflickr.com/7/6032/6329877372_fd59ff7861_b.jpg



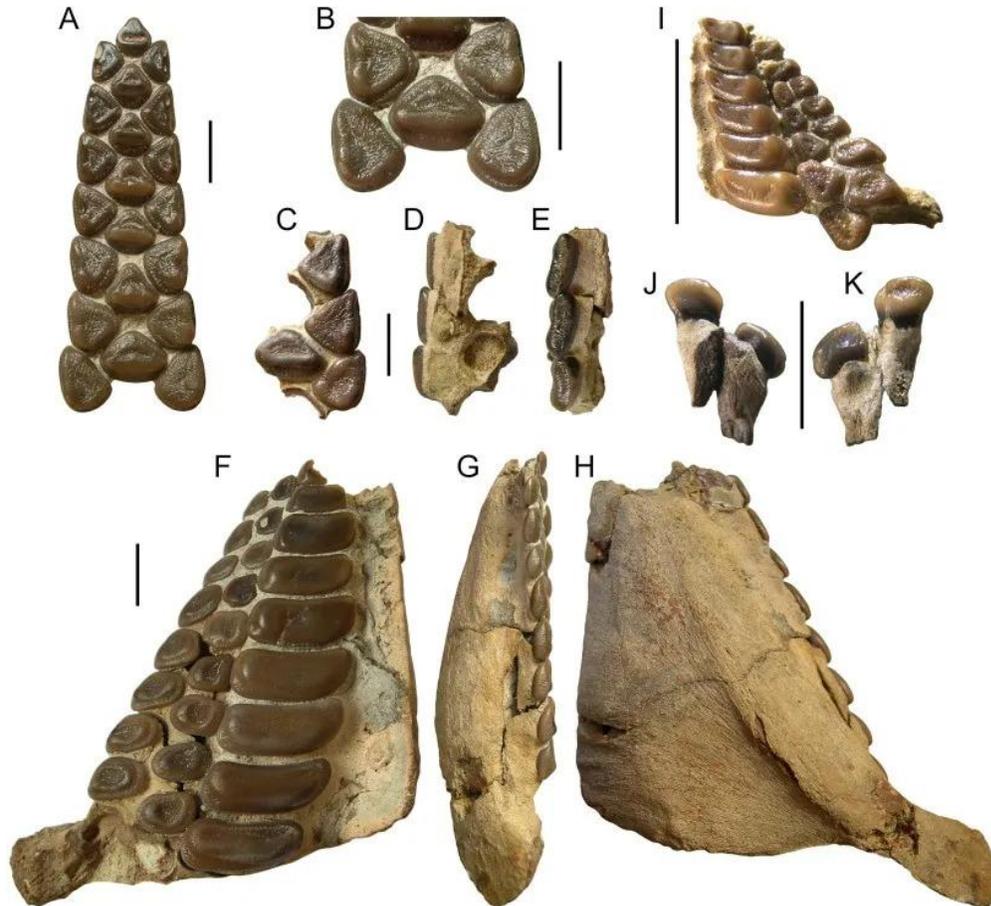
A



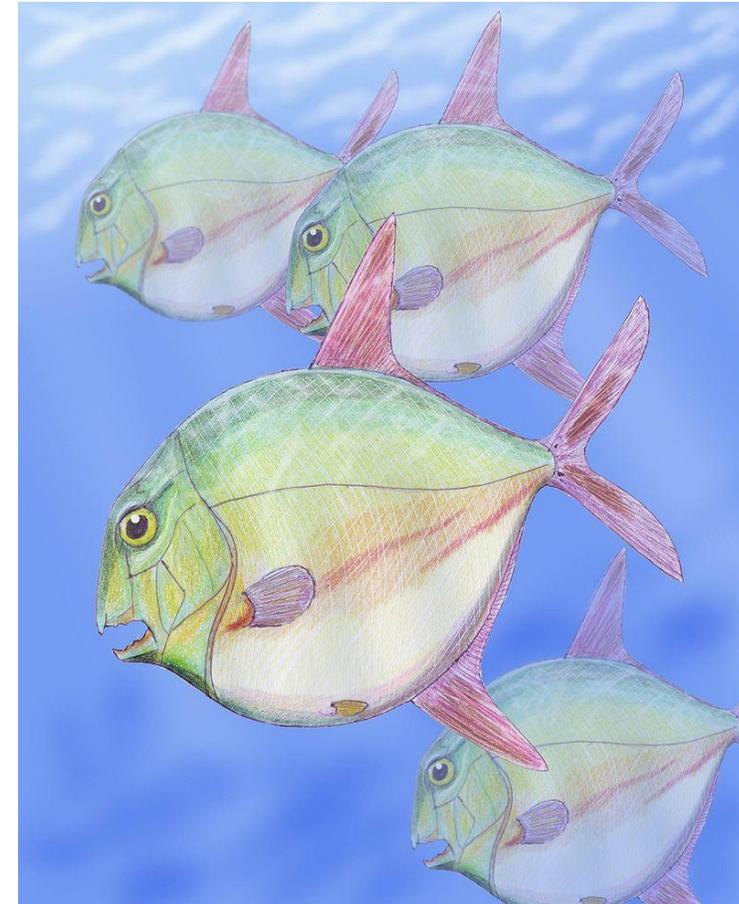
B

Glaucanitic sand with small shark teeth

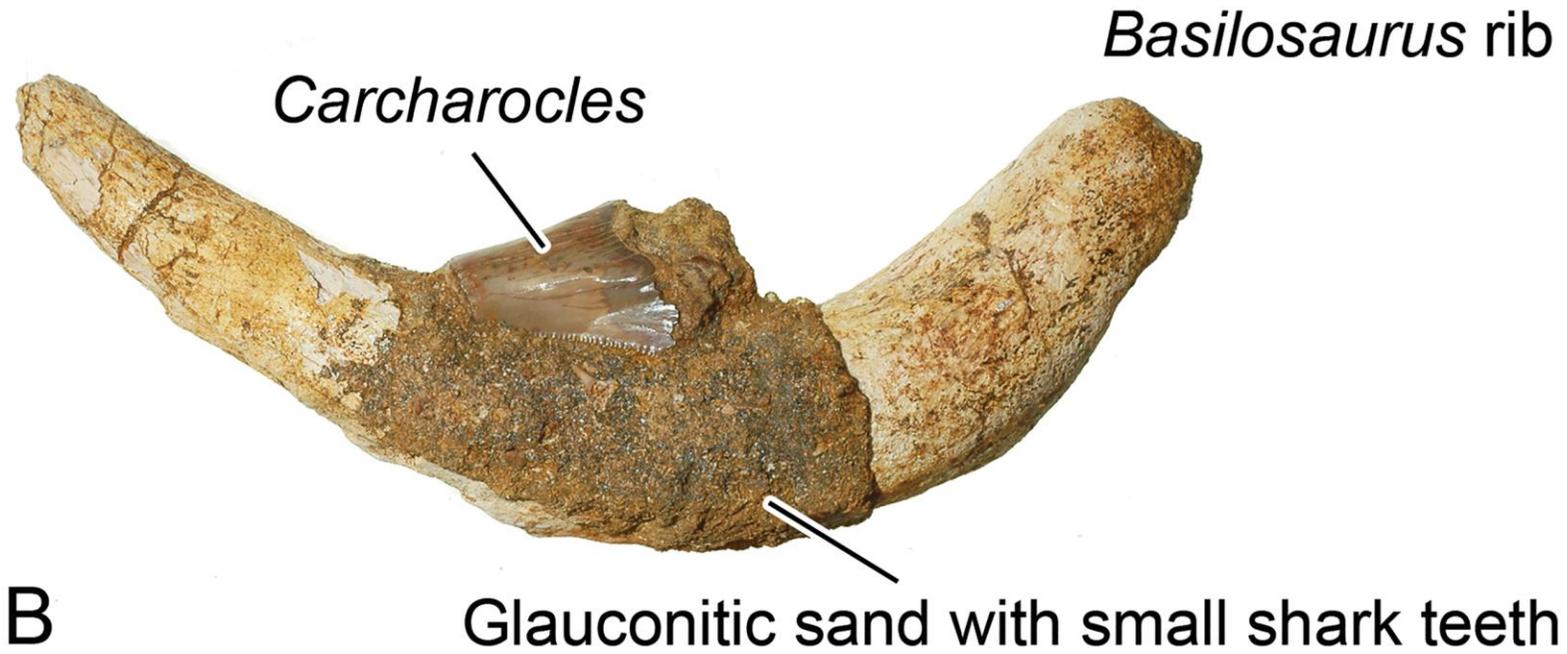
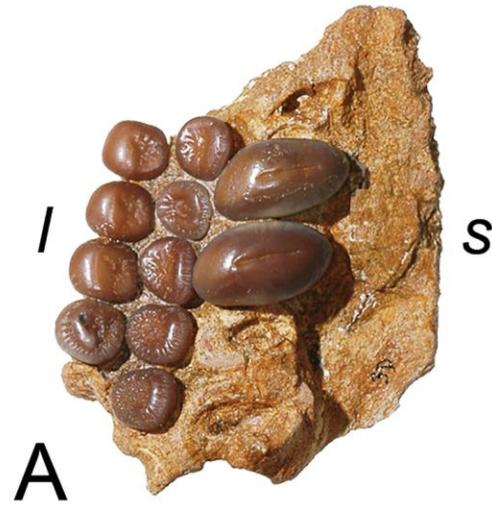
Pyknodonty – ryby o stalowych szczękach!



Vullo et al., 2018



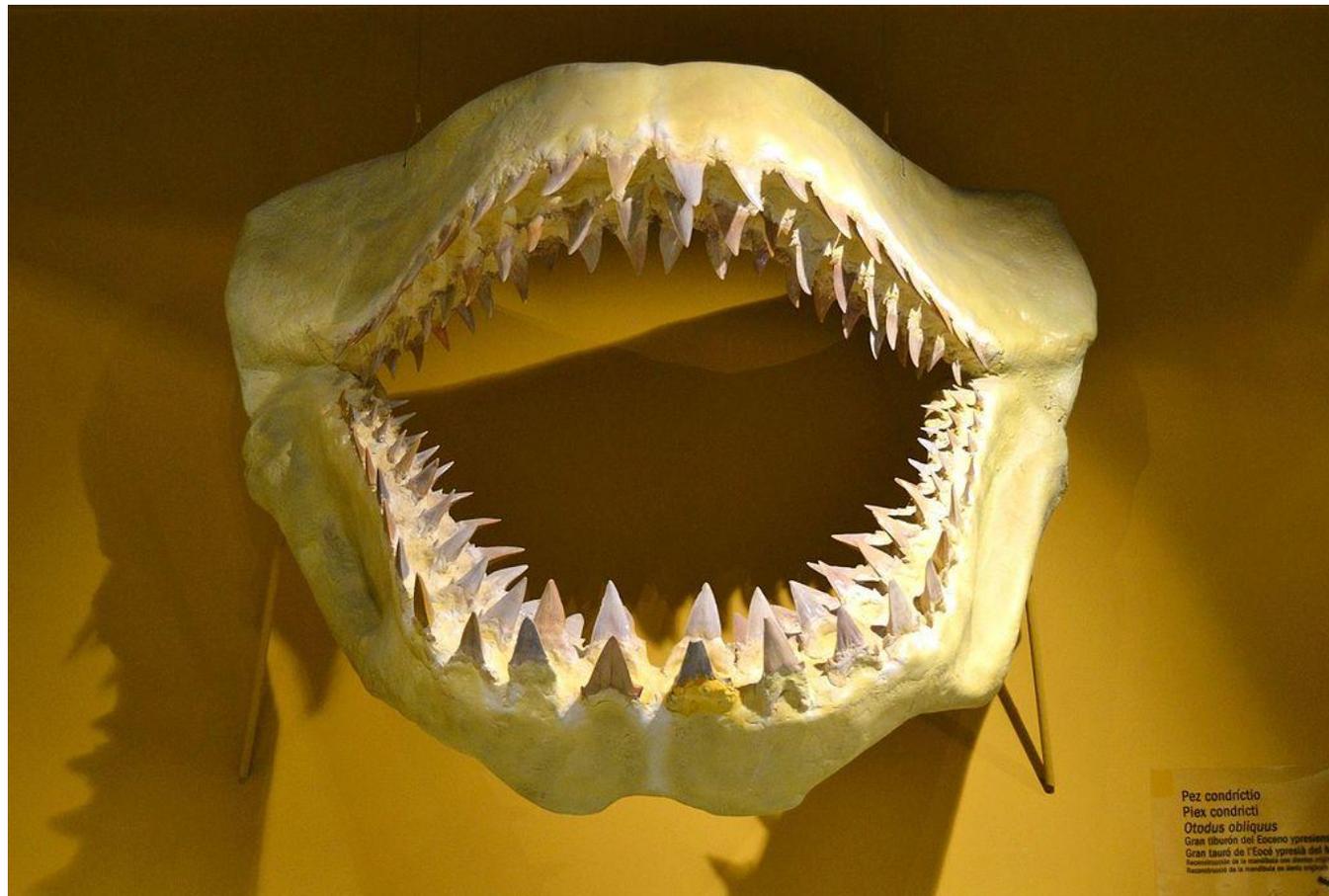
Rekonstrukcja: Dmitry Bogdanov



Rekiny wielkozębne wczesnego kenozoiku



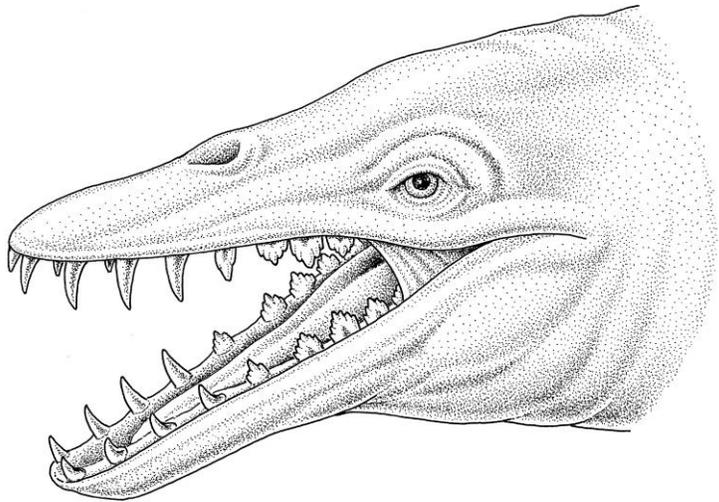
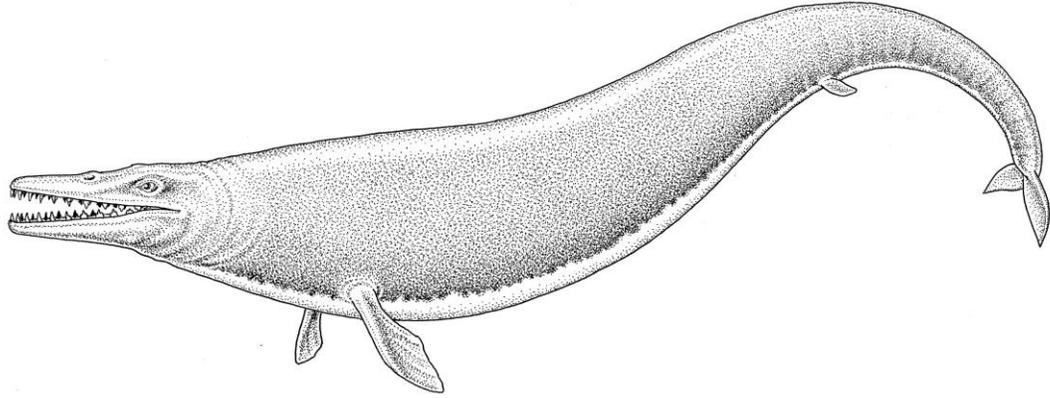
Carcharocles sokolovi



Otodus obliquus

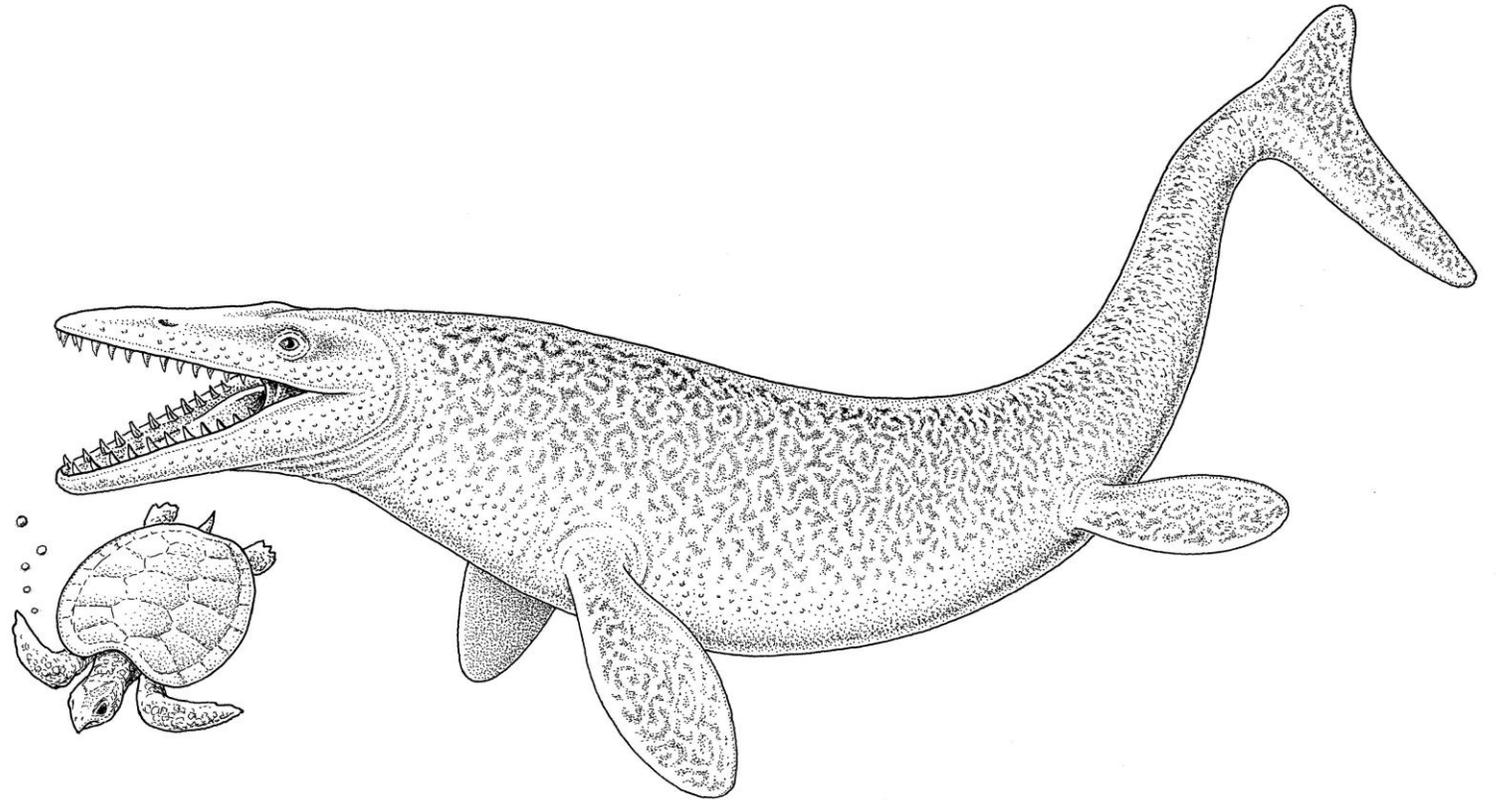
Pez condrietto
Plex condrietti
Otodus obliquus
Gran tiburón del Eoceno ypreoceno
Gran tiburón de Eocén ypreocén del Mar
Internacional de la Universidad de Zaragoza
Reconstrucción de la mandíbula en forma original

Basilosaurus zjadał wszystkich!



Szkielet bazylozaura w Nantes History Museum we Francji

Mozazaury – morskie warany



<http://www.eartharchives.org/articles/mosasaurus-last-of-the-great-marine-reptiles/>

Ryc. Bogusław Waksmundzki



Rekonstrukcja: Marcin Ambrozik

Aparat gębowy przystosowany do połykania dużych ofiar



https://commons.wikimedia.org/wiki/File:Mosasaur_skull.JPG

Mosasaurus baugeri

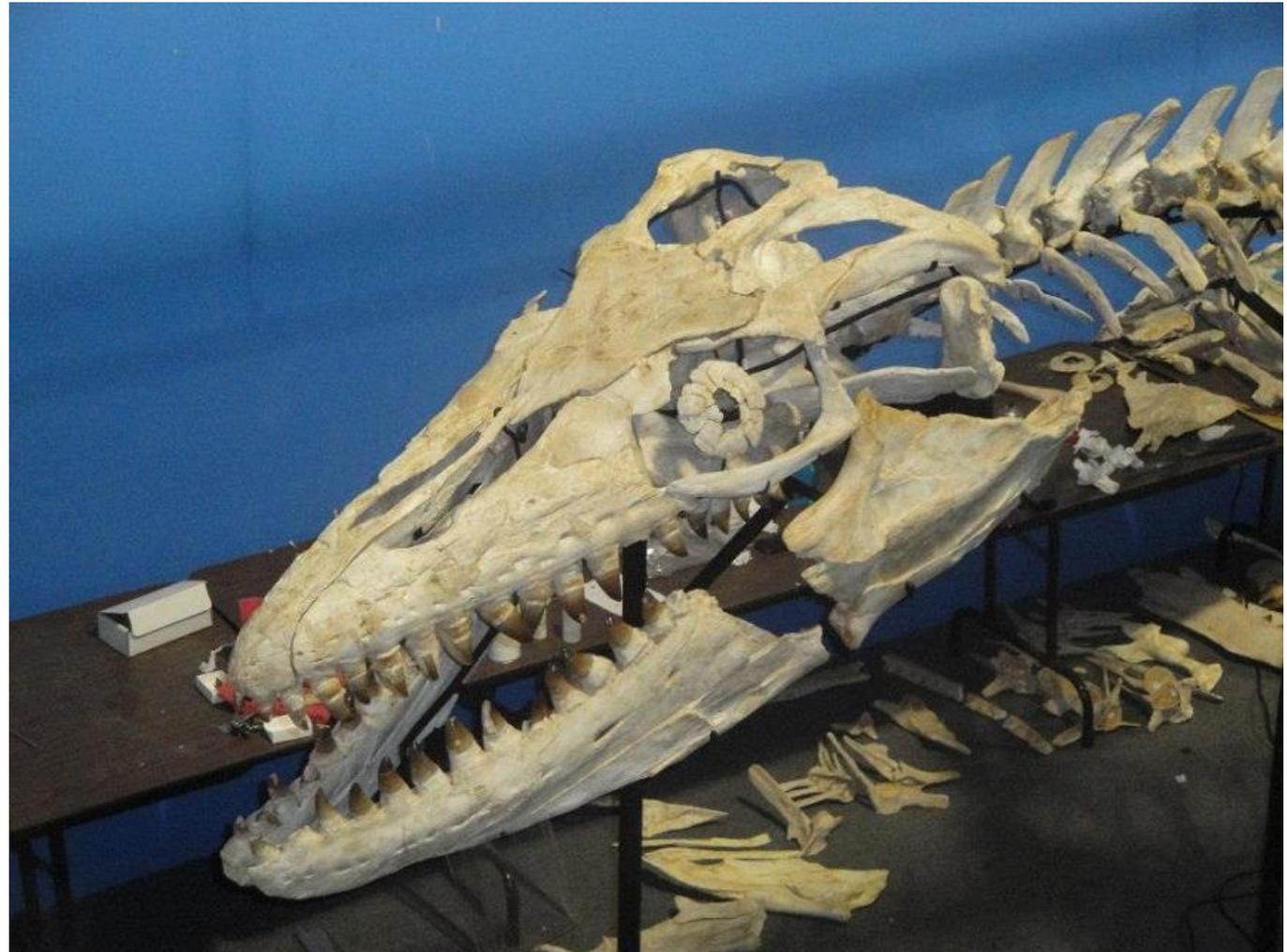


<http://www.thefossilforum.com/index.php?topic/35999-moroccan-mosasaur/>

Prognathodon – mozazaur o potężnych szczękach

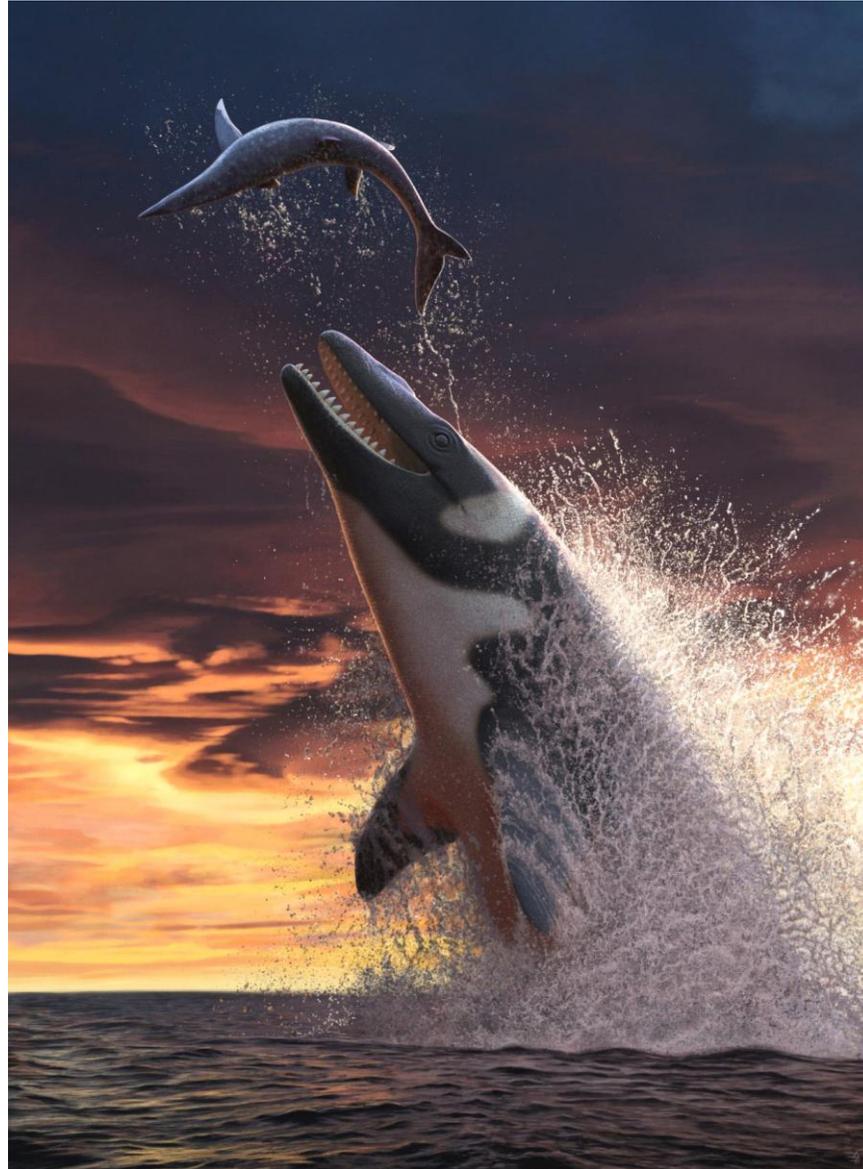


Rekonstrukcja Dmitry Bogdanov



<http://www.thefossilforum.com/index.php?/topic/35999-moroccan-mosasaurs/>

Thalassotitan atrox





<http://www.thefossilforum.com/index.php?/topic/35999-moroccan-mosasaur/>



Delfiny oceaniczne długoszczękie



Steno długonosy *Steno bredanensis*



Delphinus delphis delphis

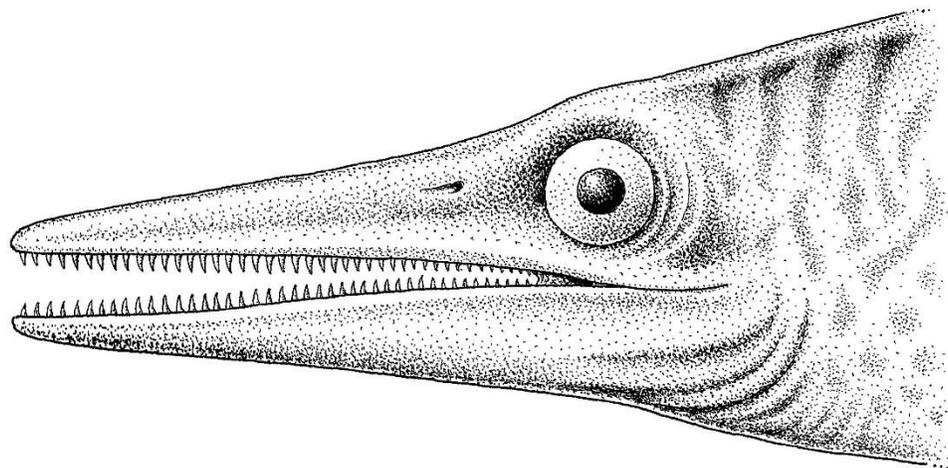


Delphinus delphis bairdii

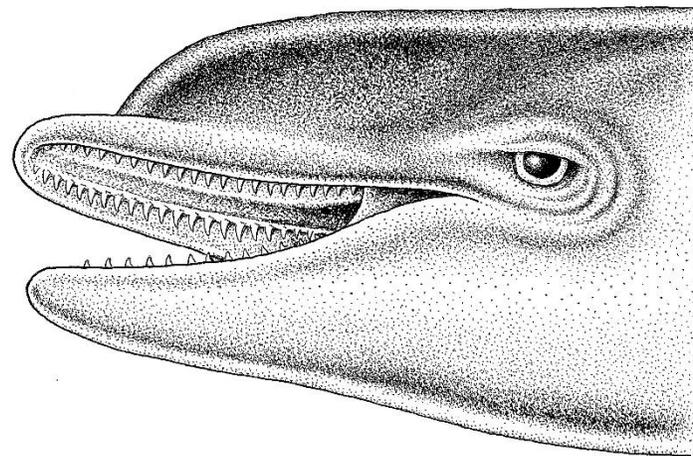


Delphinus delphis tropicalis

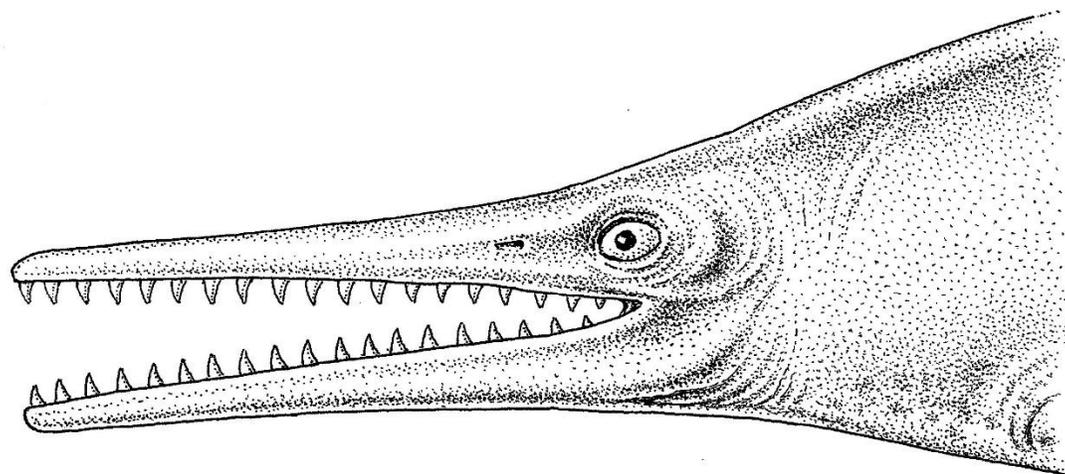
Delfin zwyczajny *Delphinus delphis*



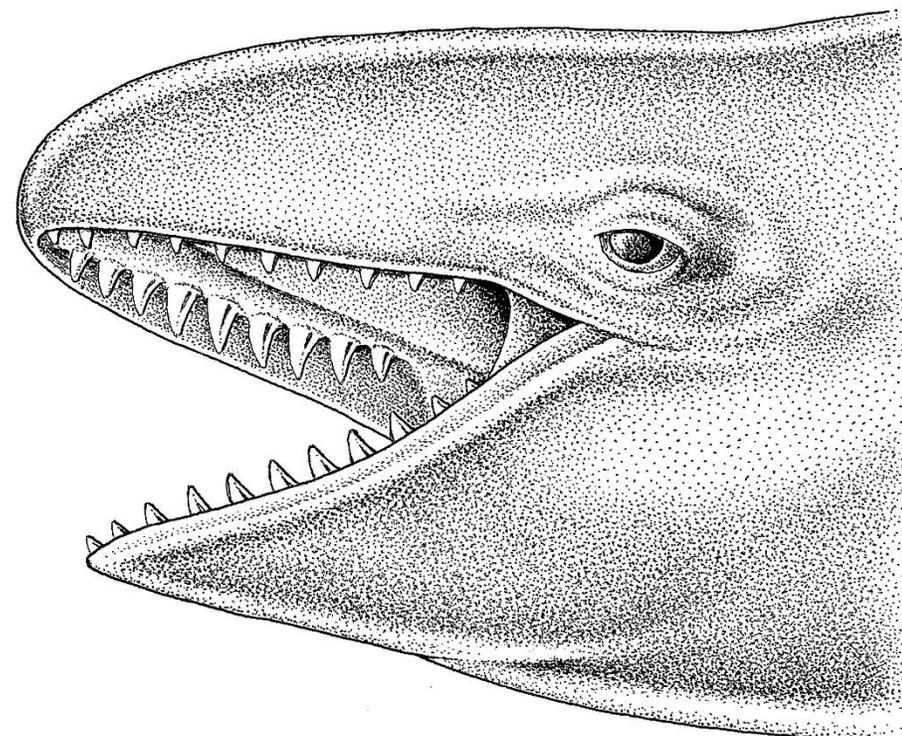
Ichtiozaur *Ophthalmosaurus natans*



Delfin butlonosy *Tursiops truncatus*



Ichtiozaur *Platypterygius hercynicus*

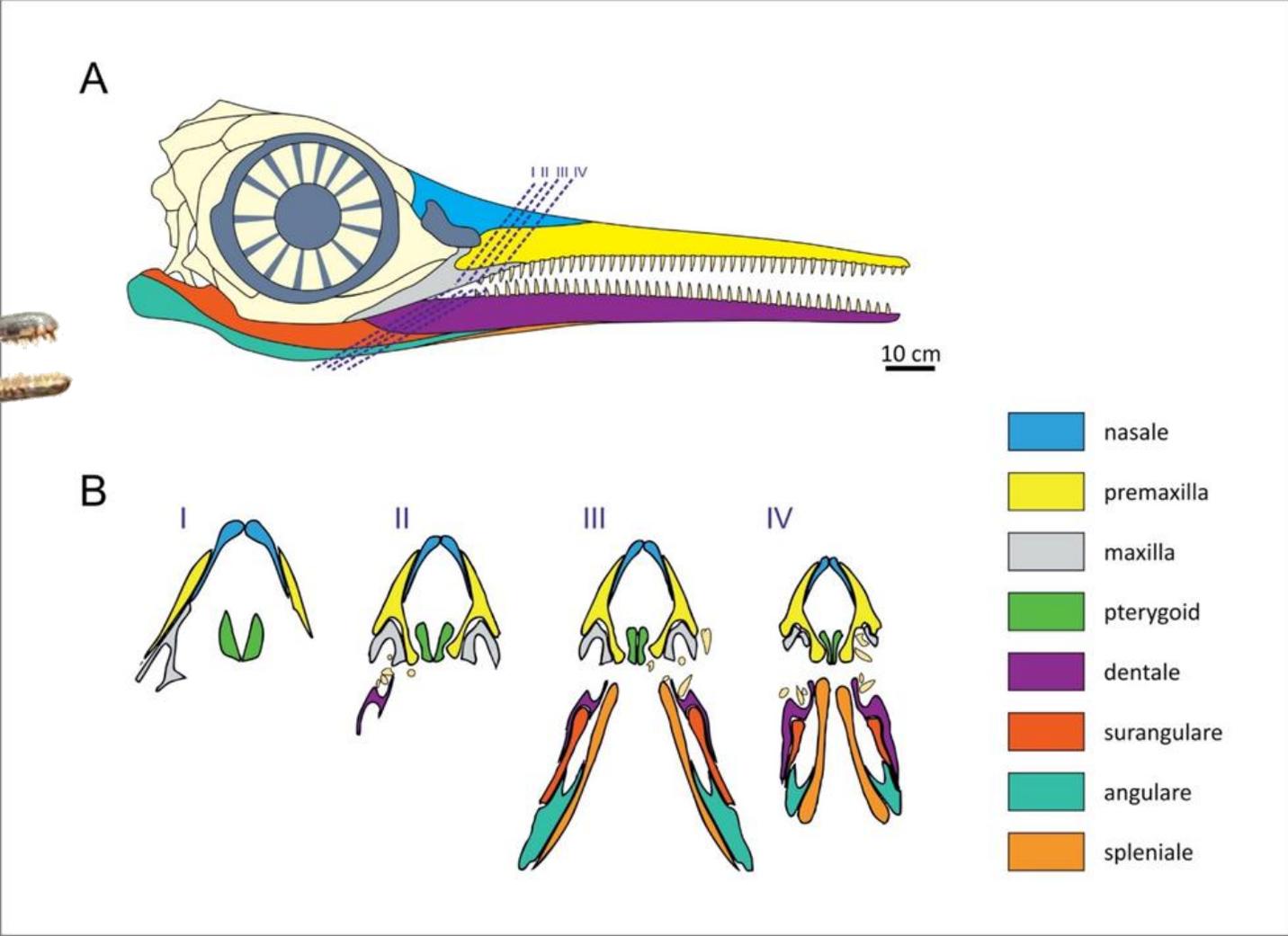


Szablogrbiet waleniożerny *Pseudorca crassidens*

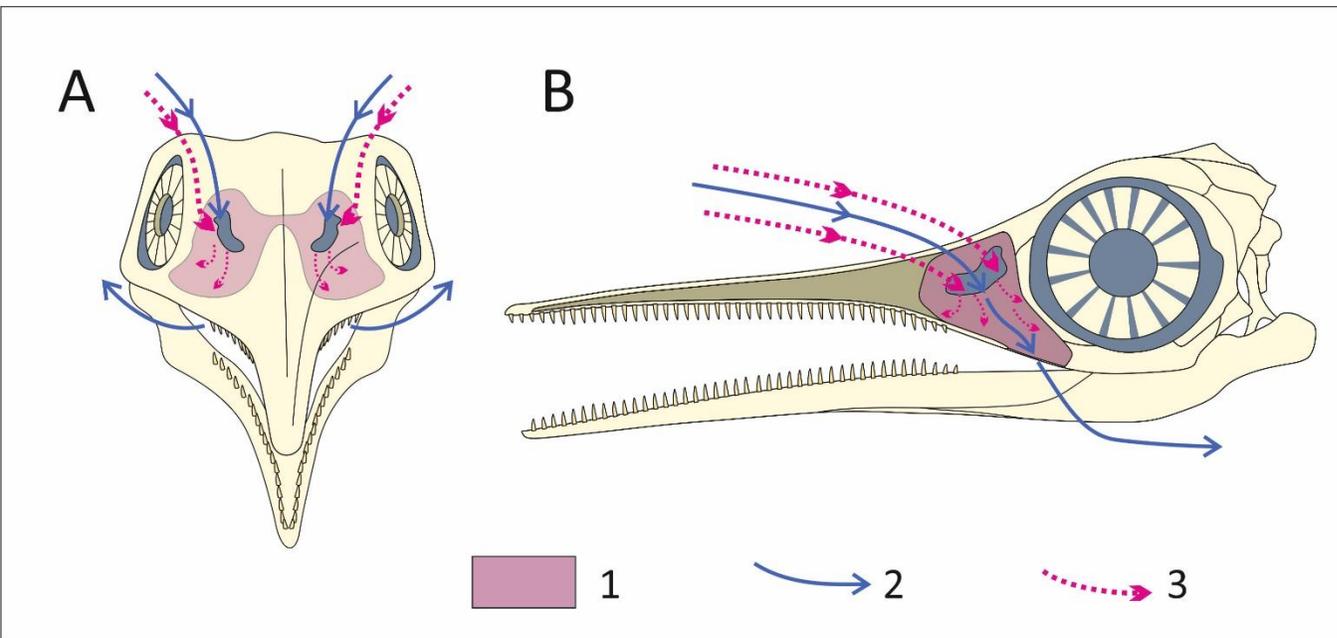
Oftalmozauridy – prawdziwe „rybojaszczury”



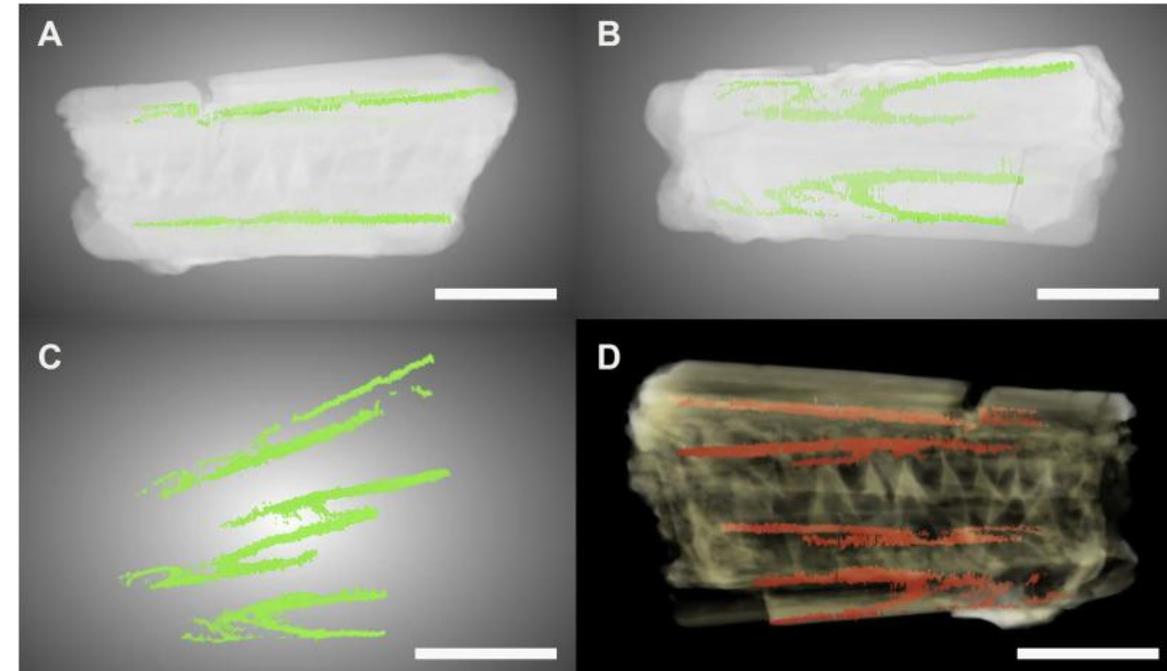
Ichthyosaur *Cryptoptygius*
(*Undorosaurus?*) *kielanae*



Drapieżniki o rozbudowanych zmysłach

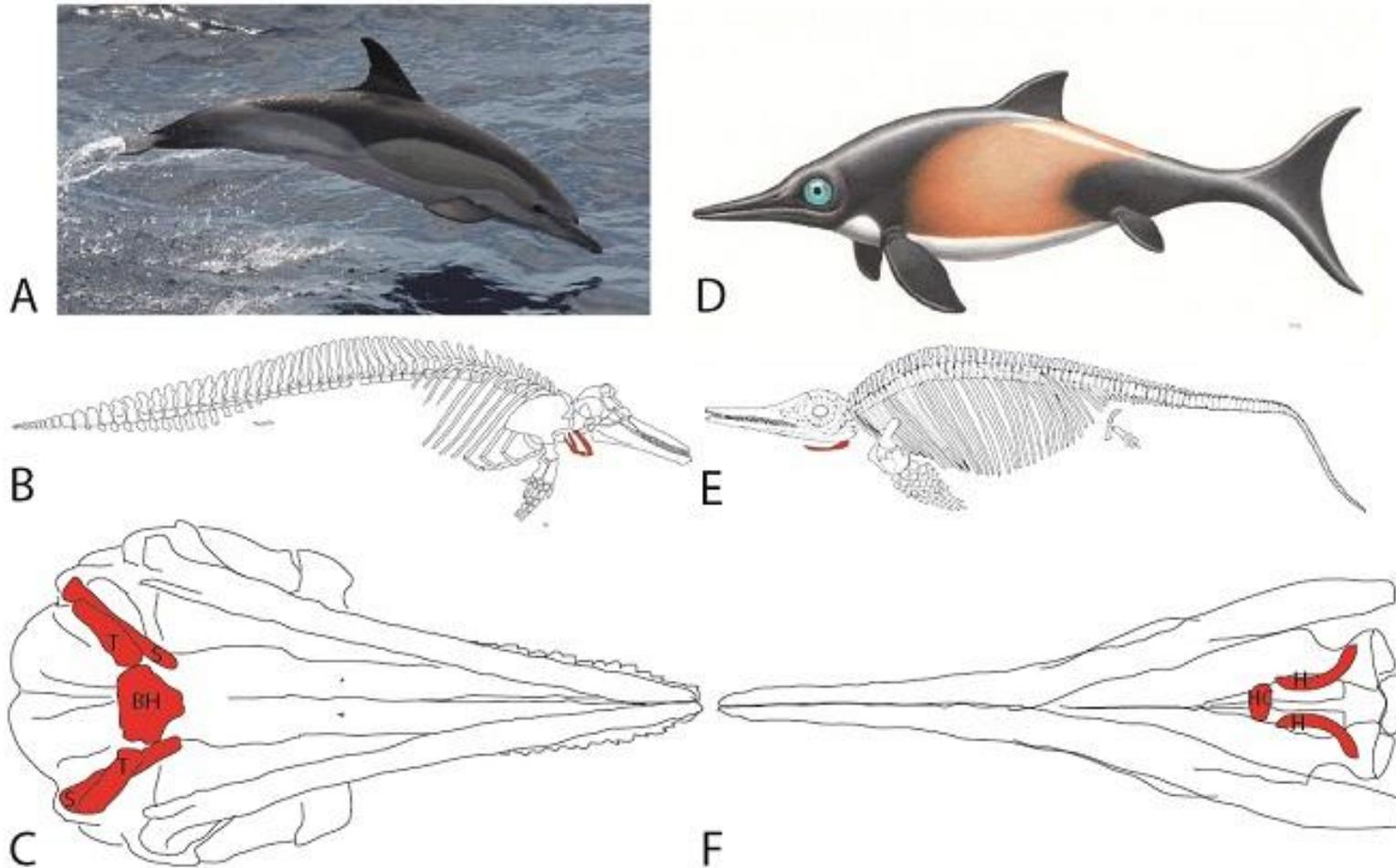


Rekonstrukcja systemu węchowego oftalmozaurida z Morawicy; Tyborowski et al., 2020



Kanały systemu neuronaczyniowego w szczękach ichtiozaura z Włoch (Serafini et al., 2022)

Różne sposoby odżywiania

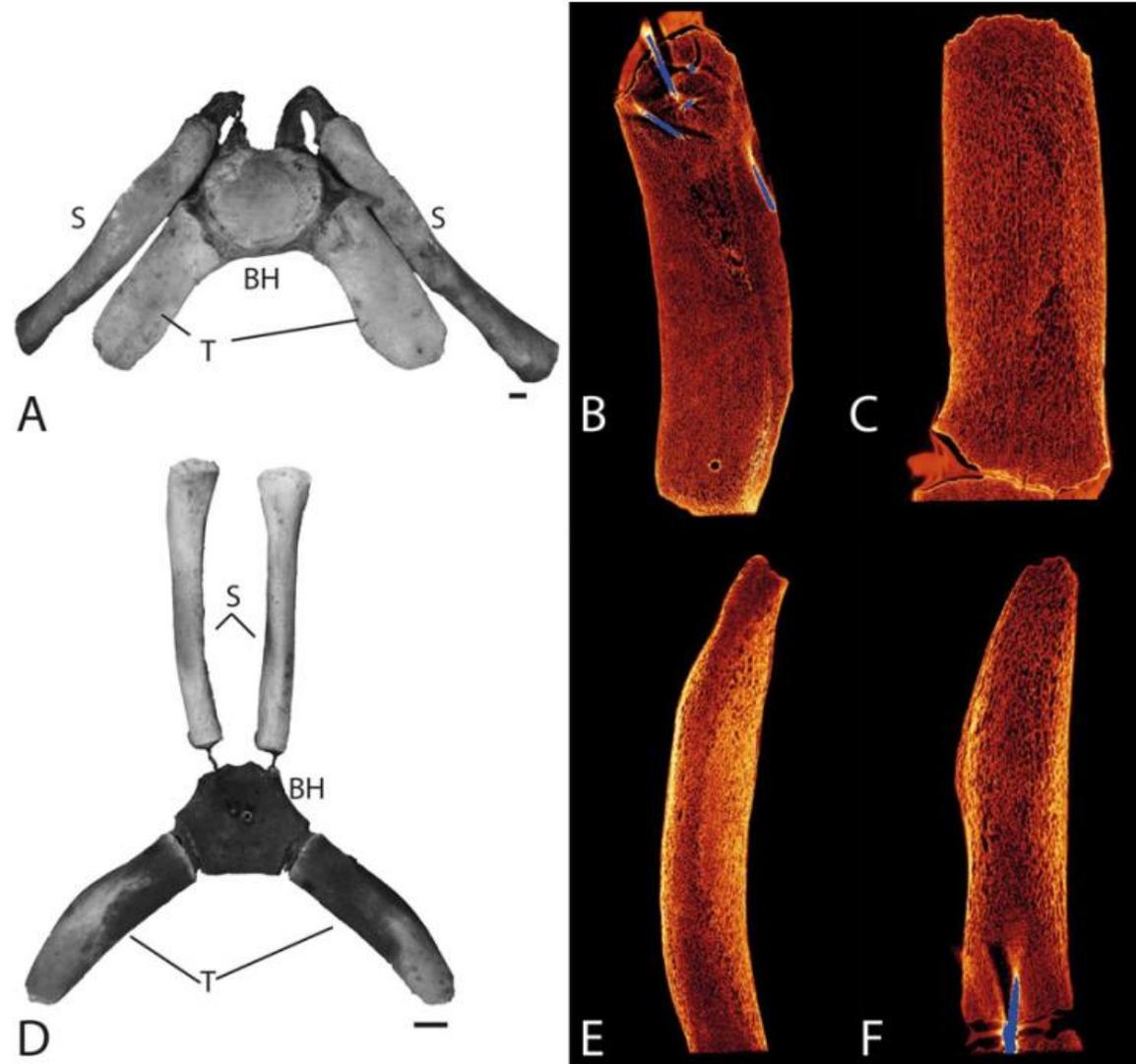


Delsett et al., 2023

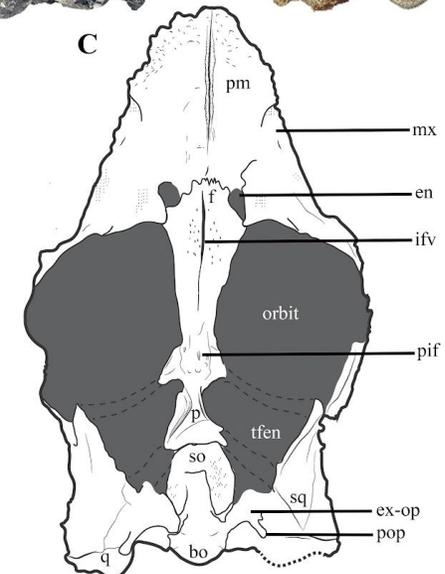
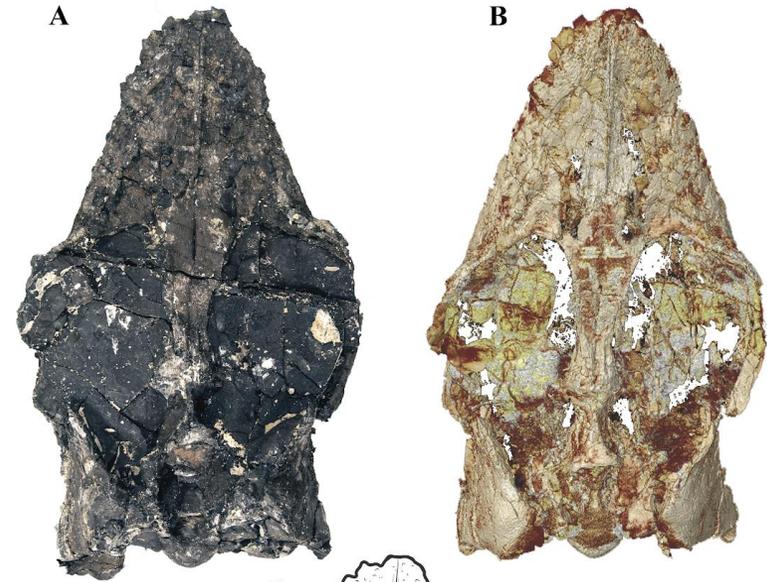
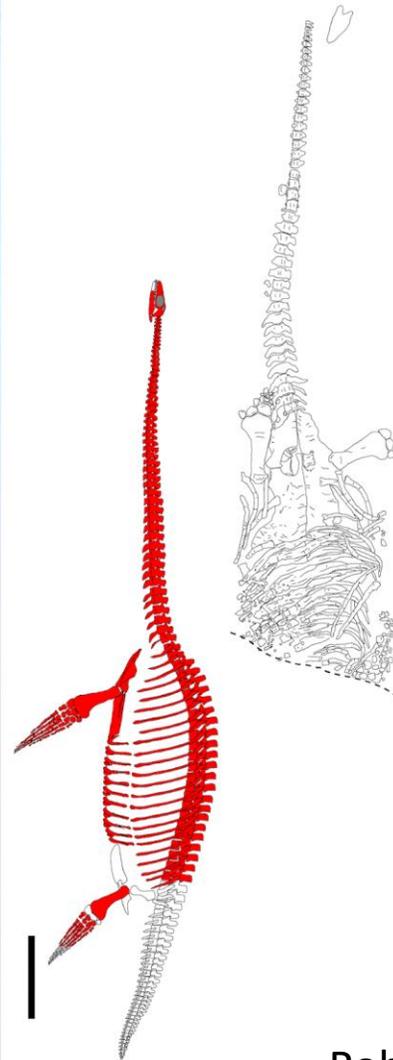
Różnice mikrostrukturalne



Różnice mikrostrukturalne

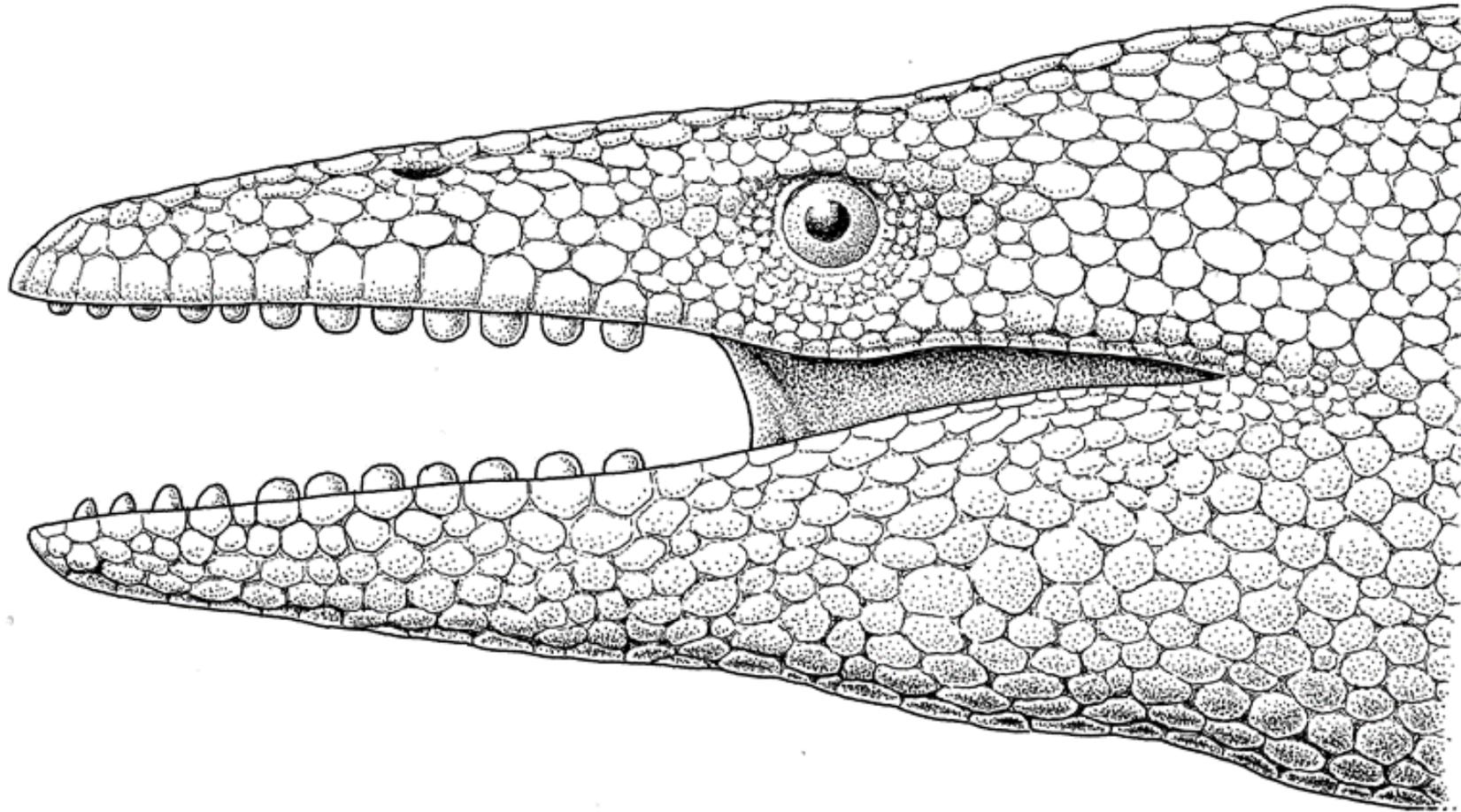


Ophthalmothule – plezjozaur o wielkich oczach

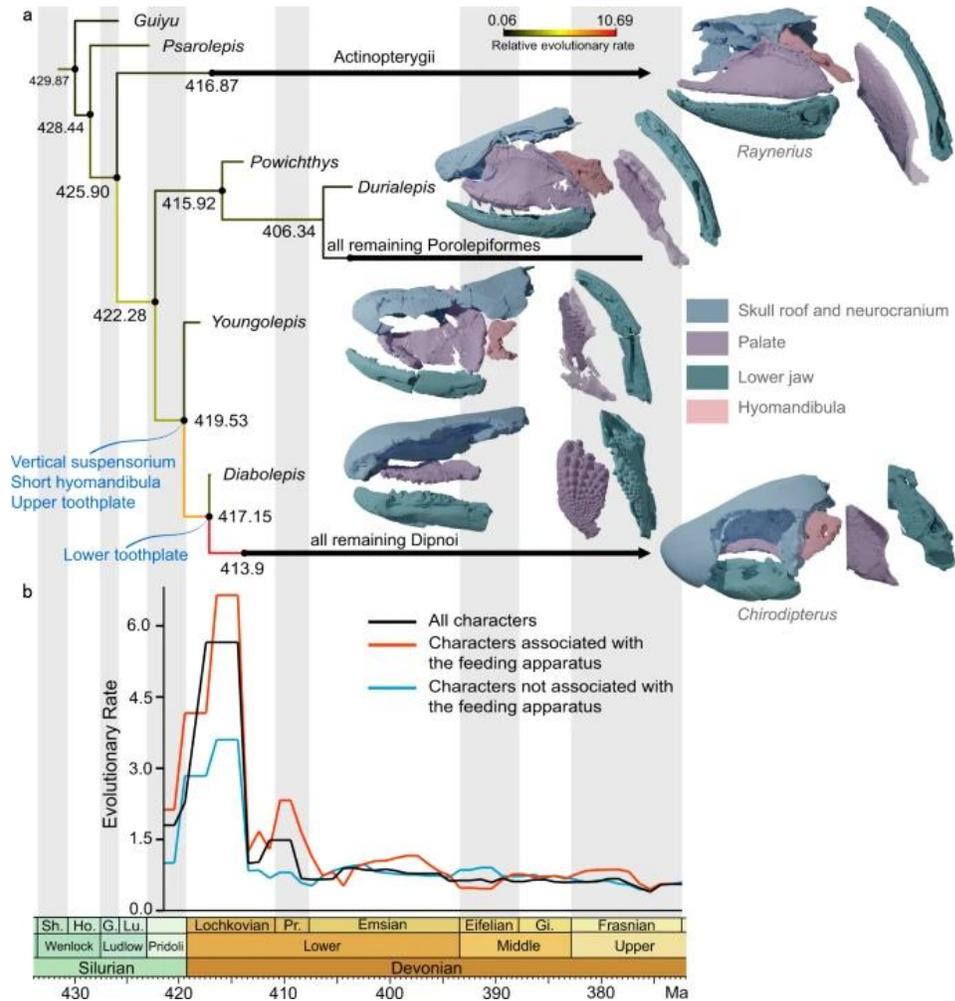


Roberts et al., 2020

Durofagia – odżywanie się twardą zdobyczą



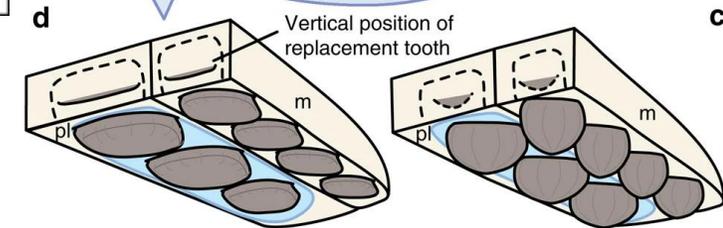
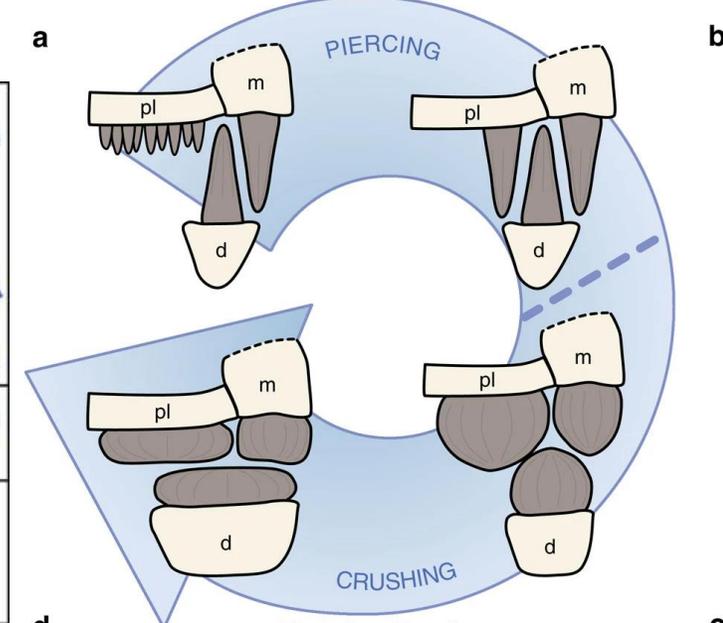
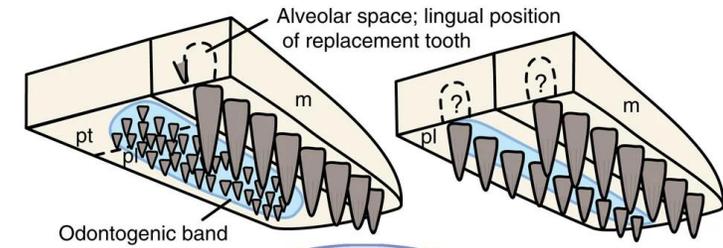
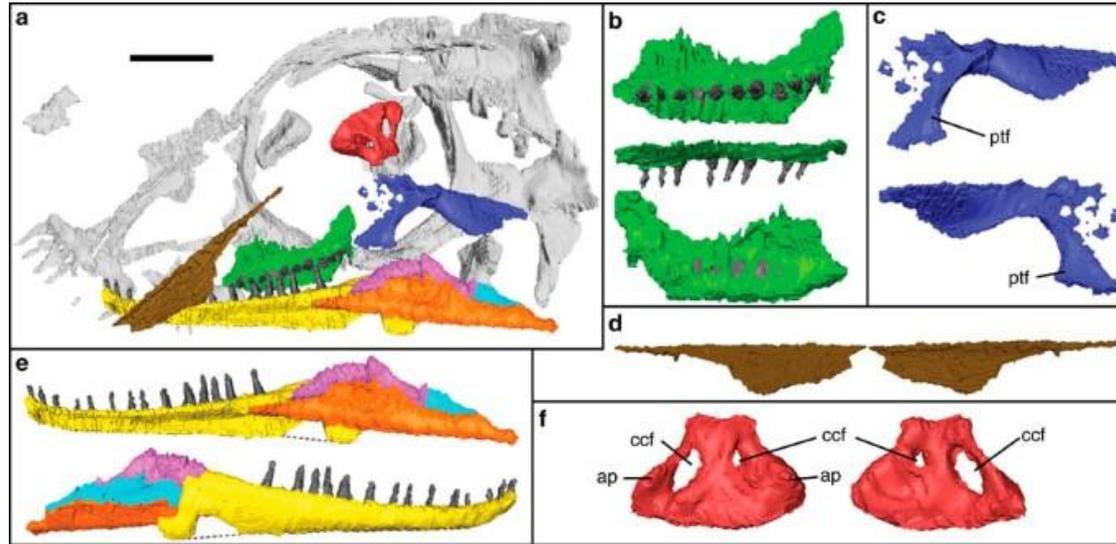
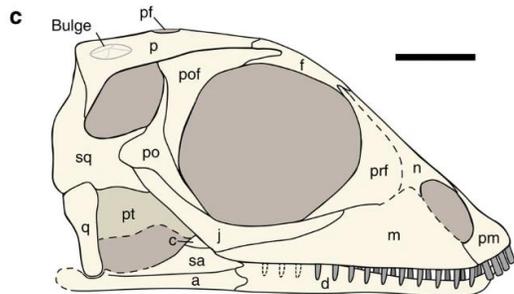
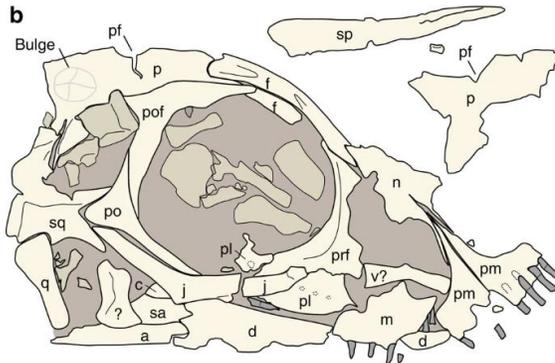
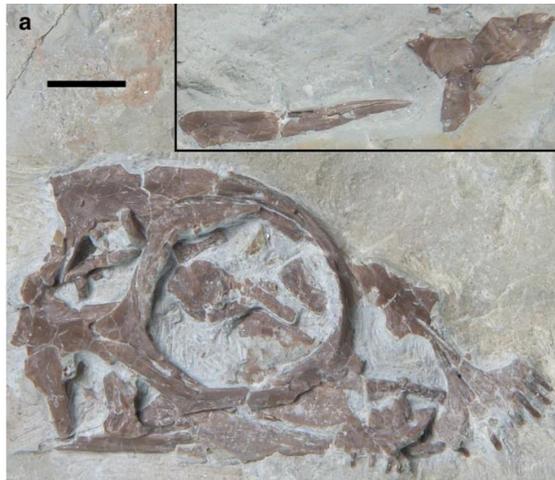
Durofagia u ryb dwudysznych



Cui et al., 2022



Ewolucja durofagii



Neenan et al., 2013

Plakodonty (Placodontia) – durofagiczne gady morskie



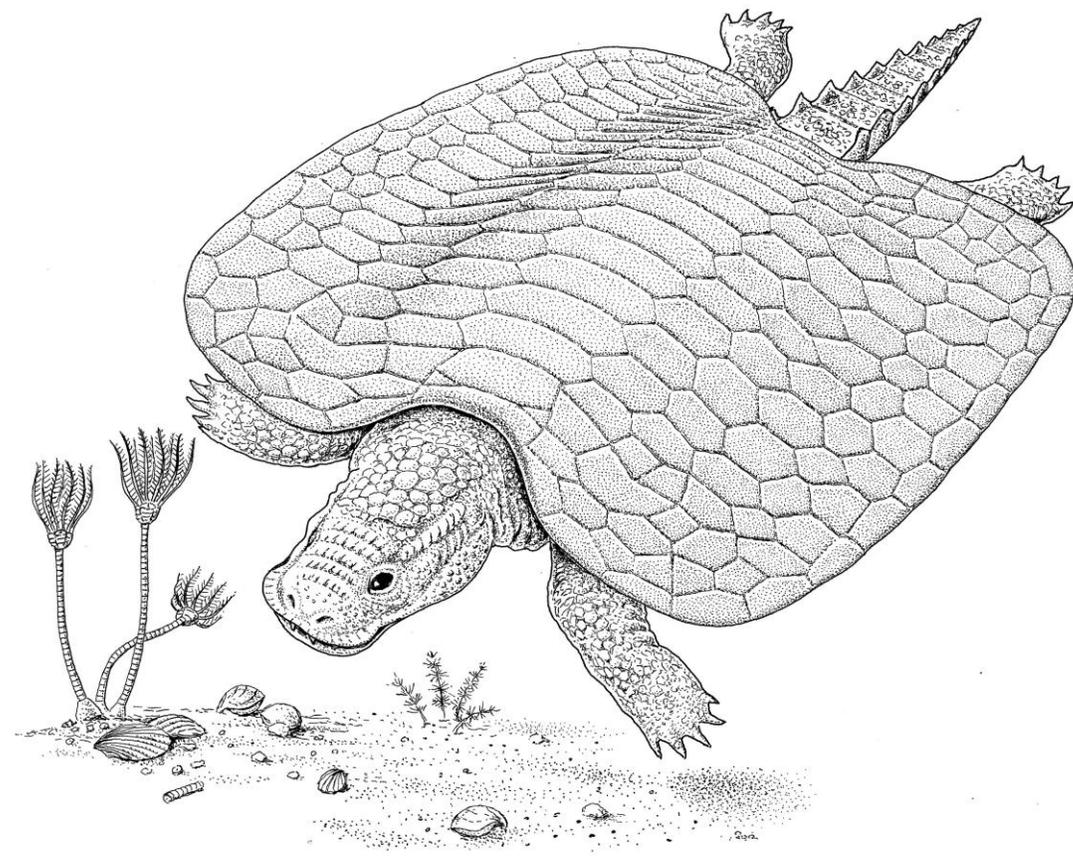
Placodus

https://en.wikipedia.org/wiki/Placodontia#/media/File:Placodus_gigas_2.JPG

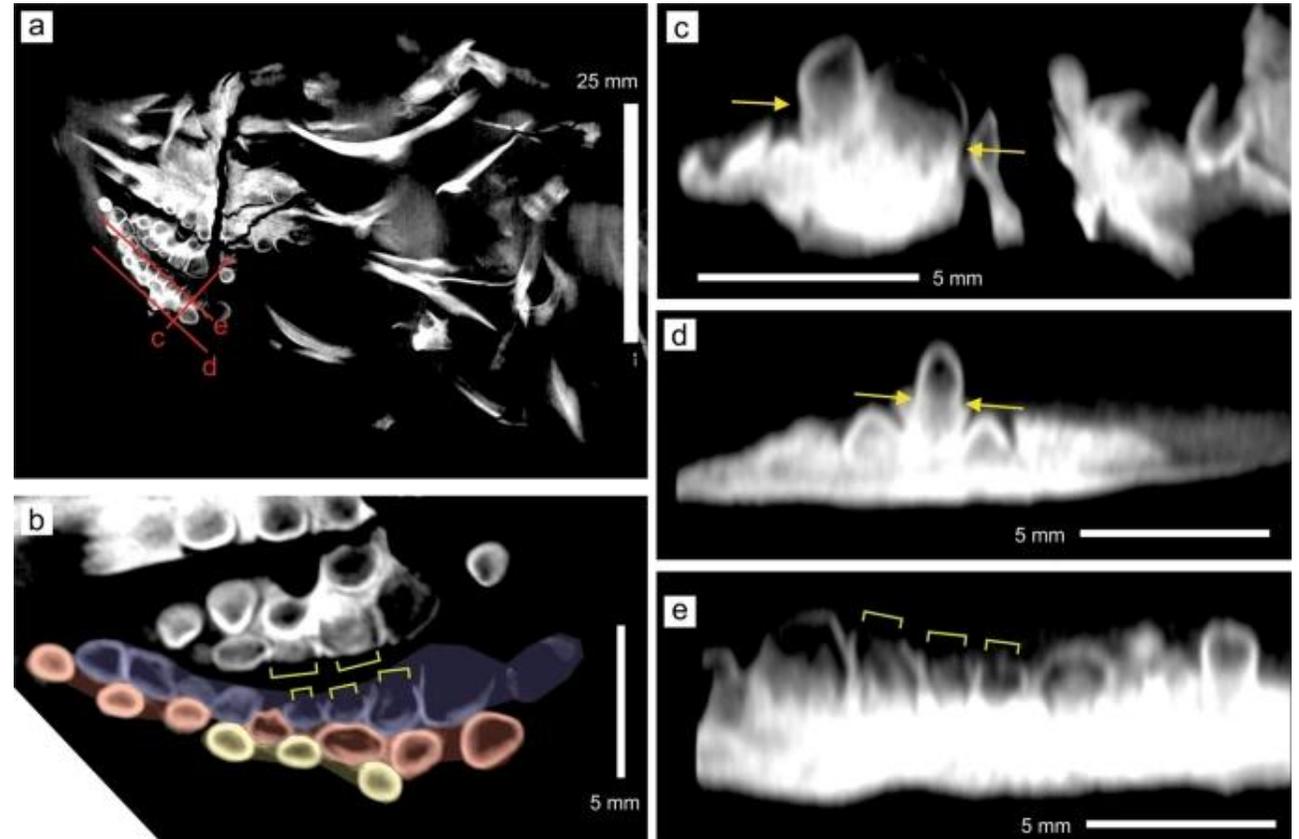
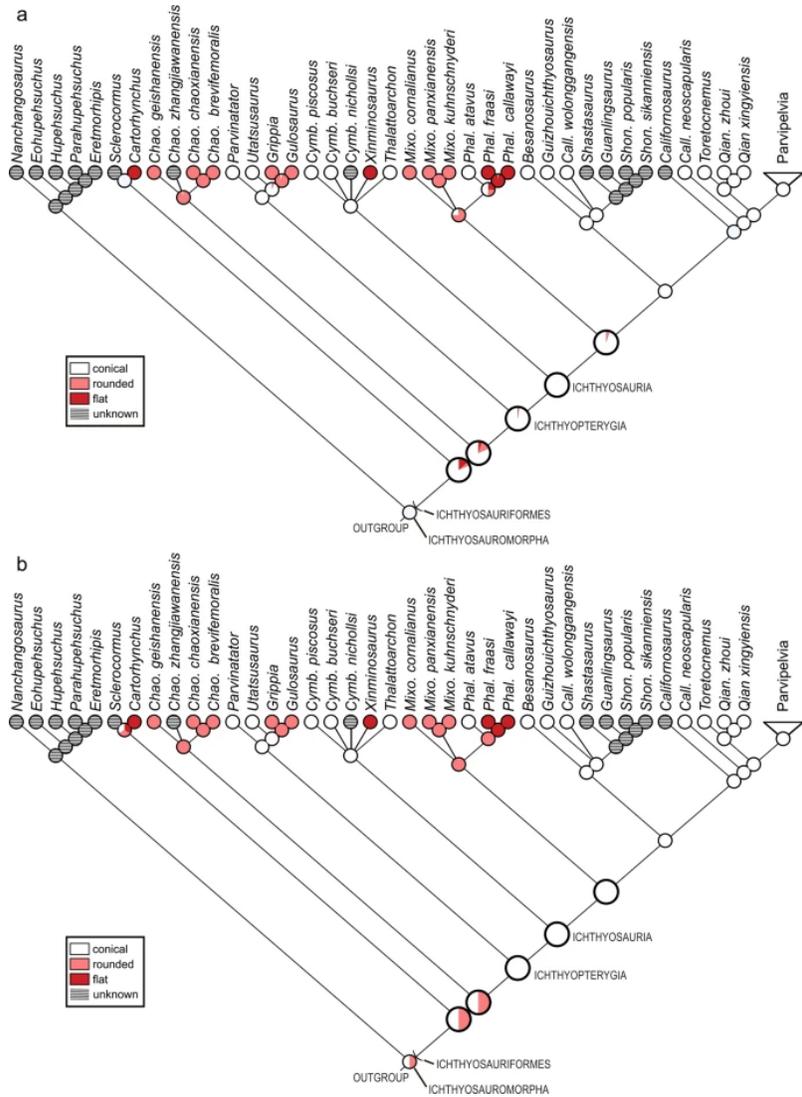


Macroplacus

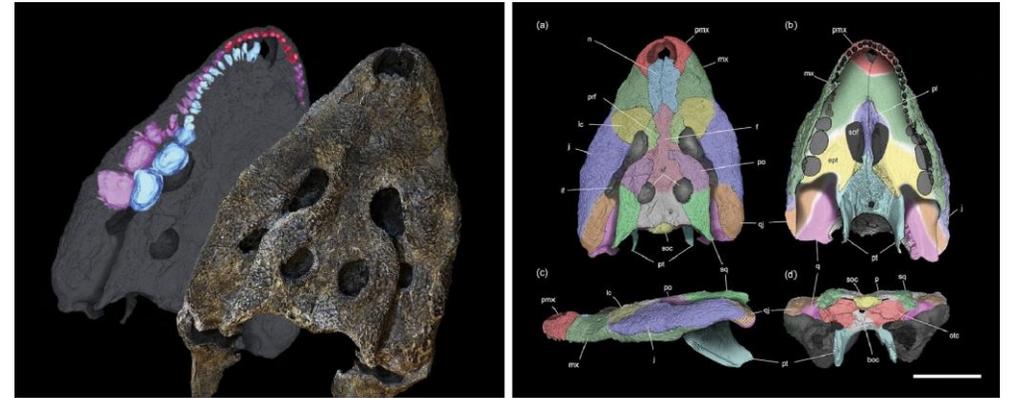
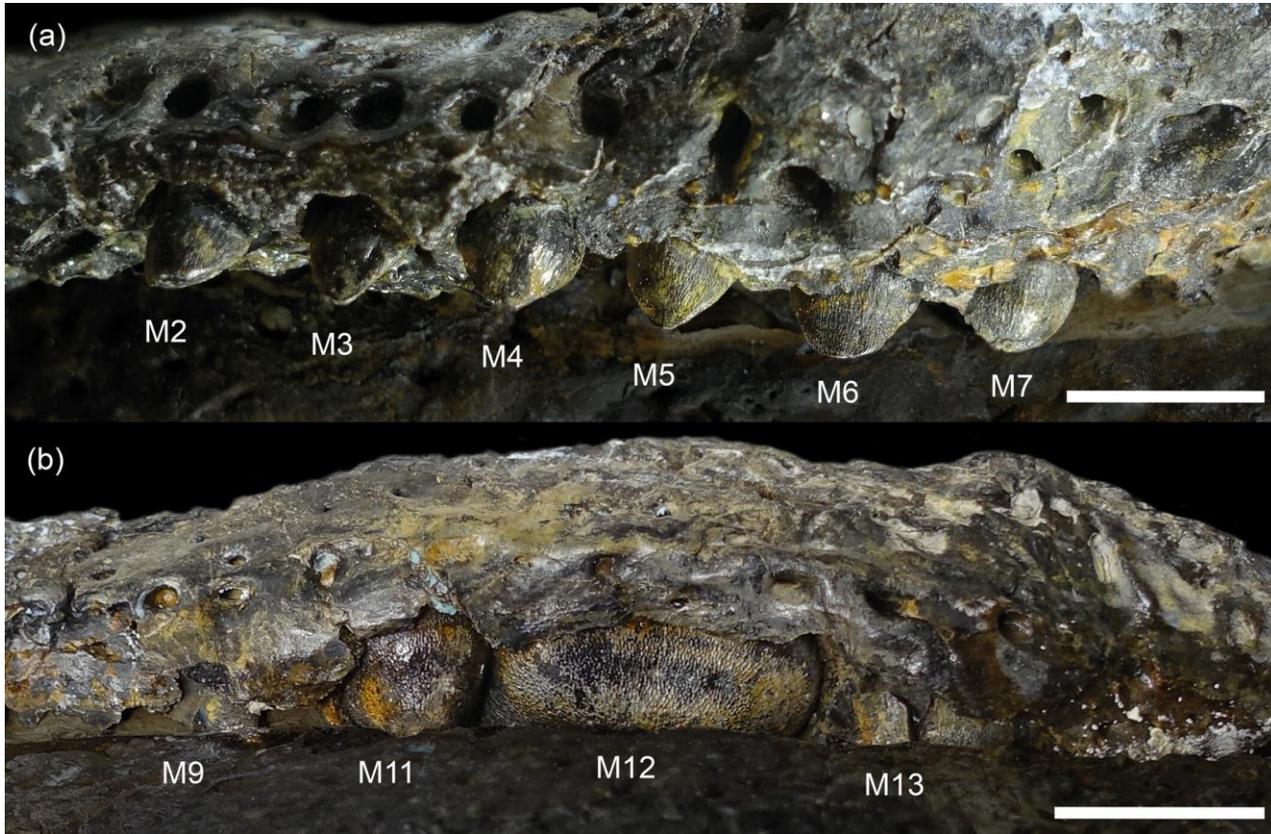
https://en.wikipedia.org/wiki/Placodontia#/media/File:Macroplacus_raeticus.JPG



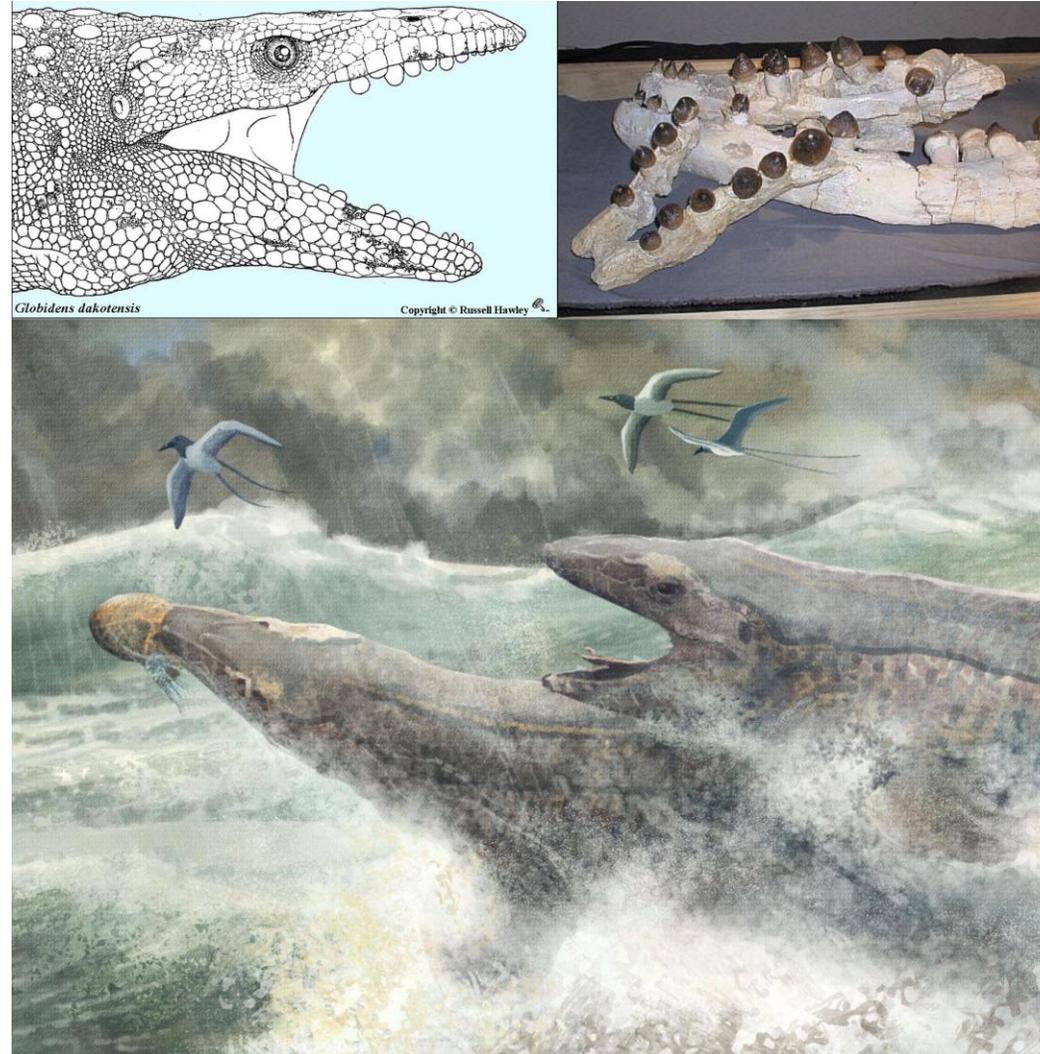
Najłatwiejsza specjalizacja?



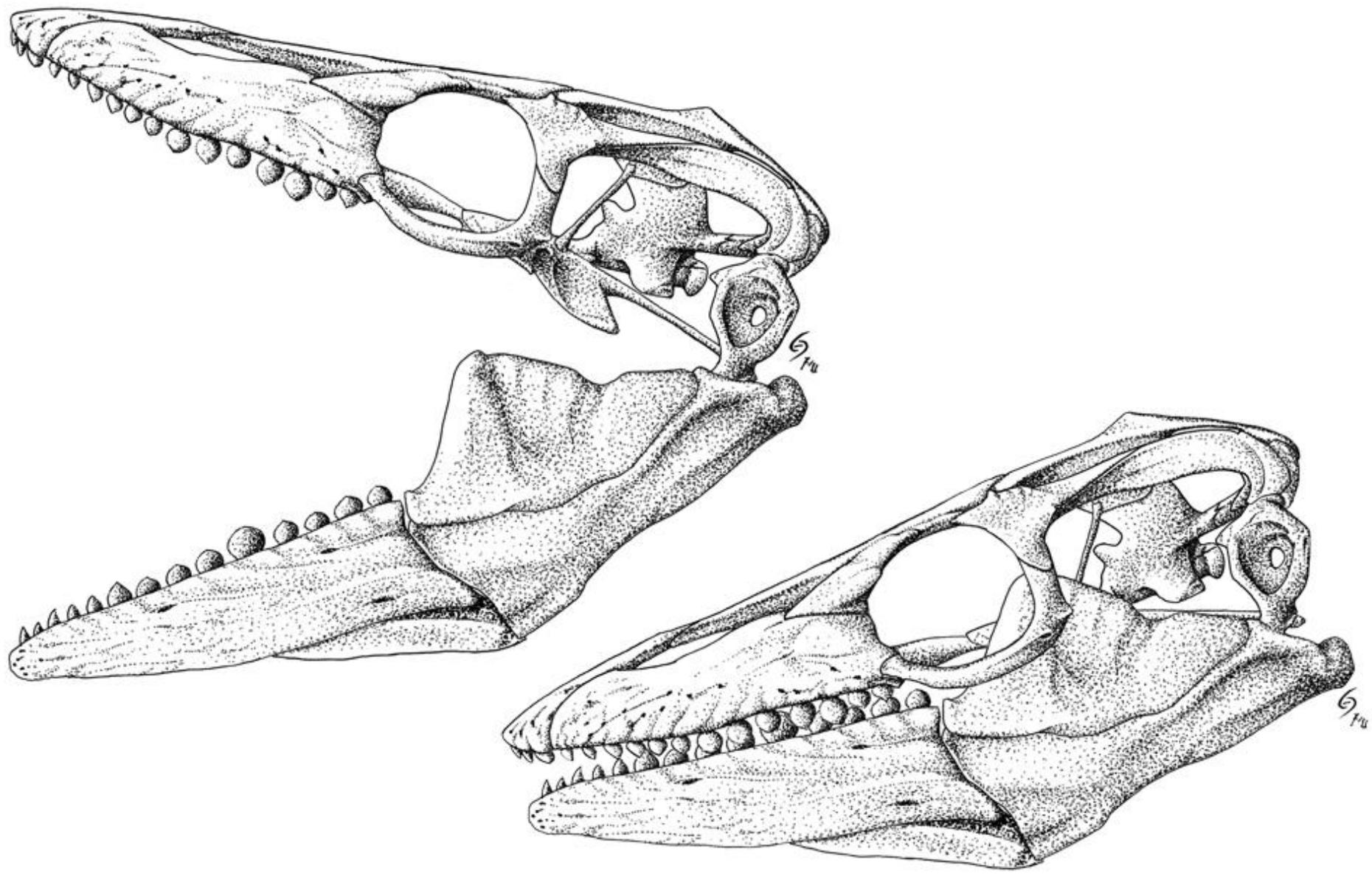
Acynodon adriaticus



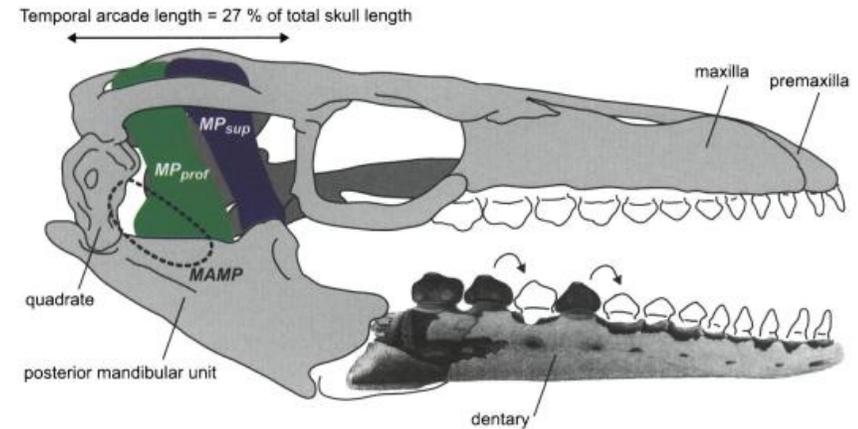
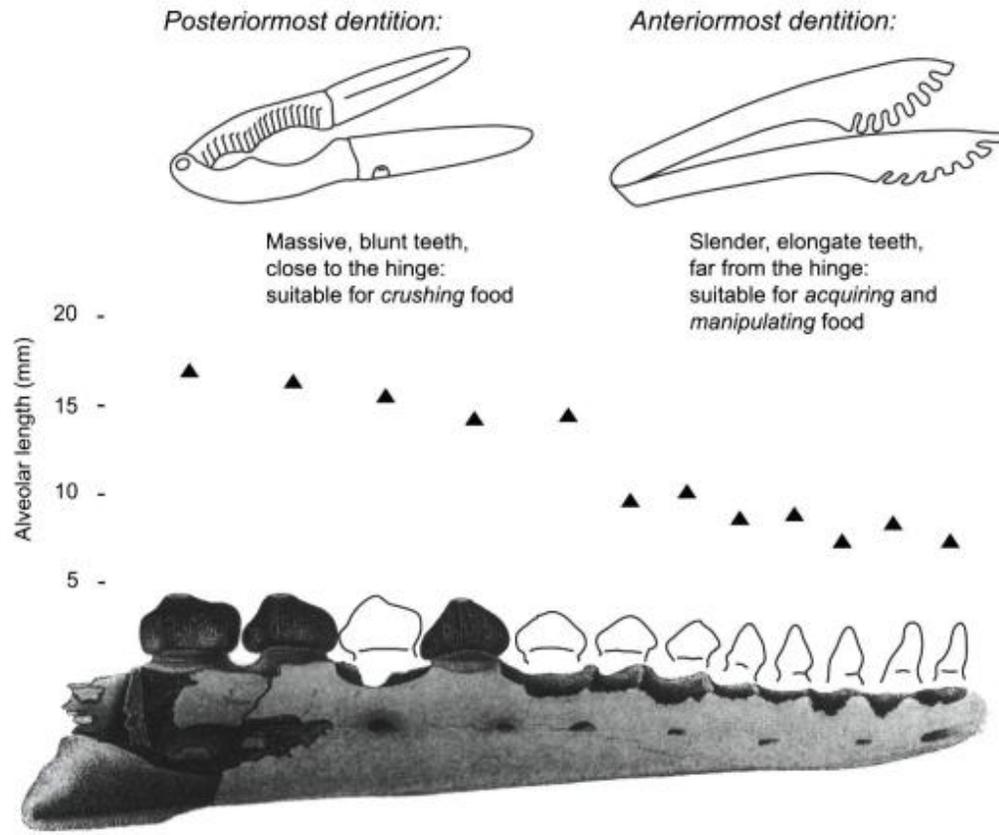
Globidens – durofagiczny mozazaur



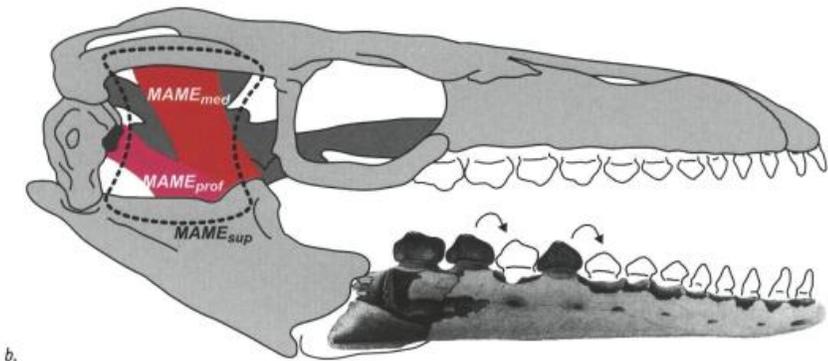
<https://i.redd.it/ls65vt3h8r321.jpg>



Biomechanika durofagii

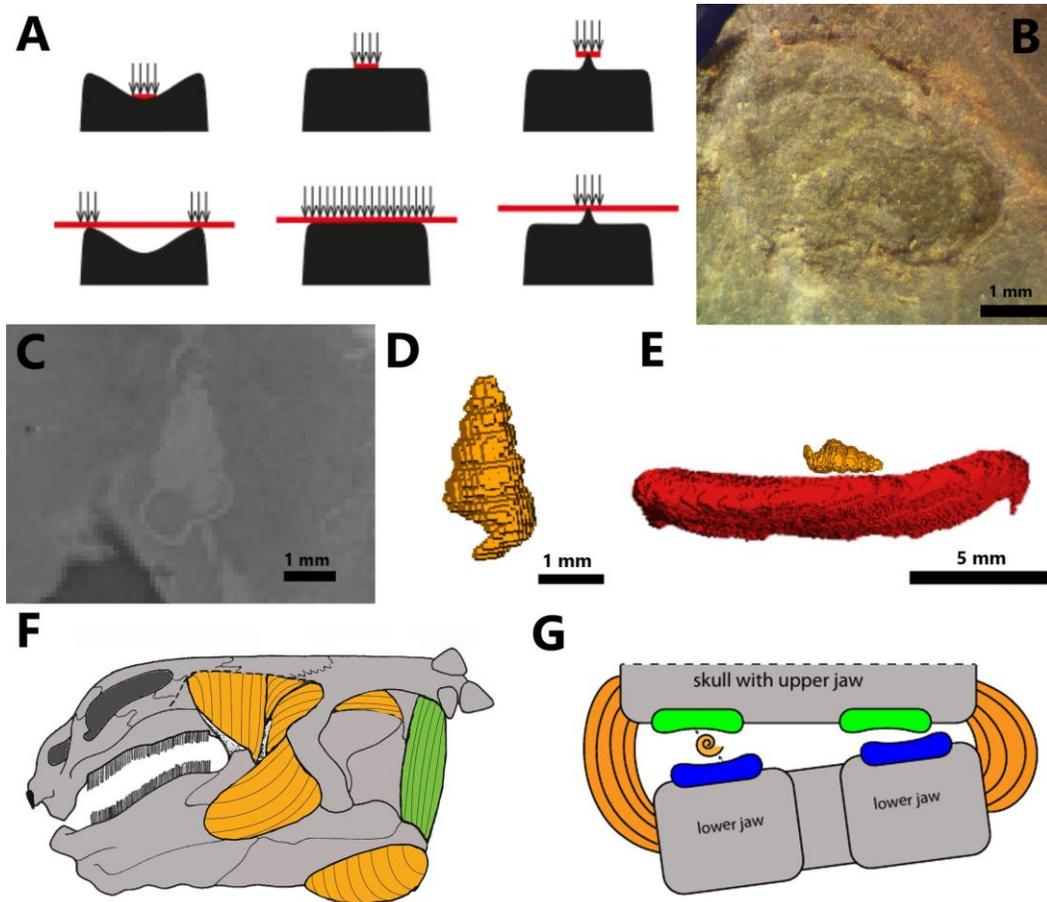


a.

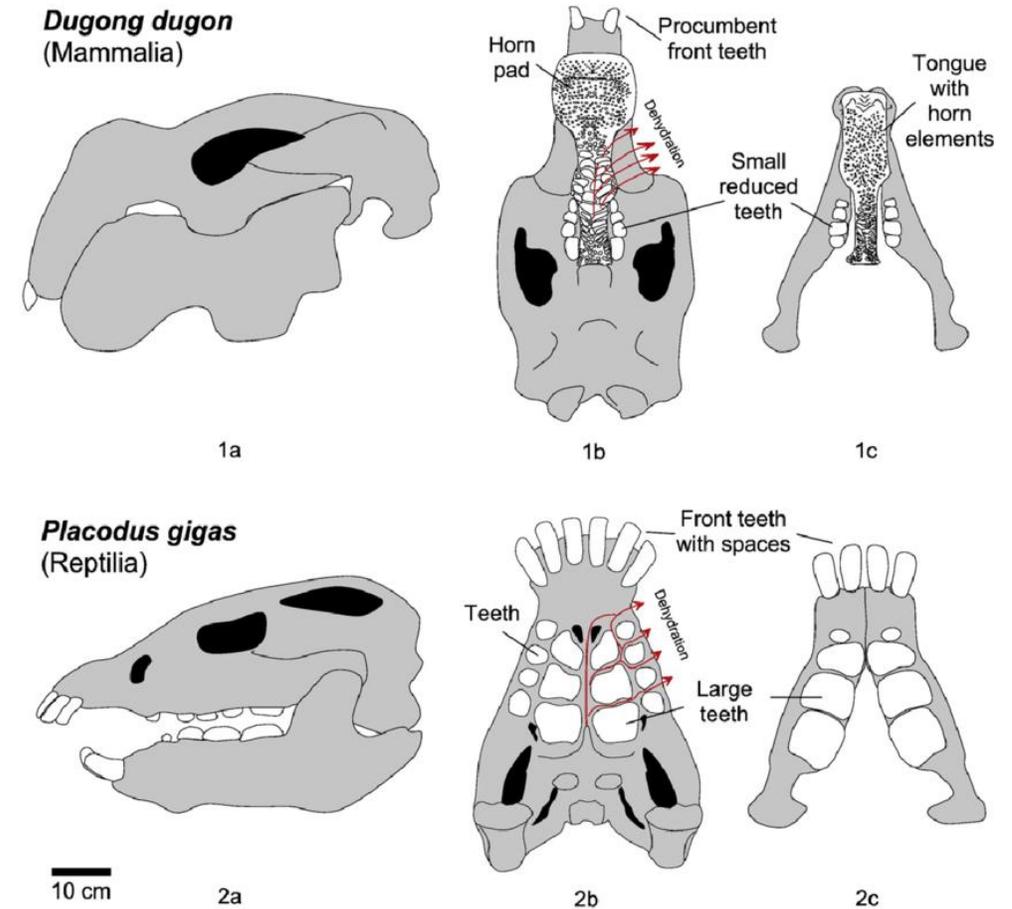


b.

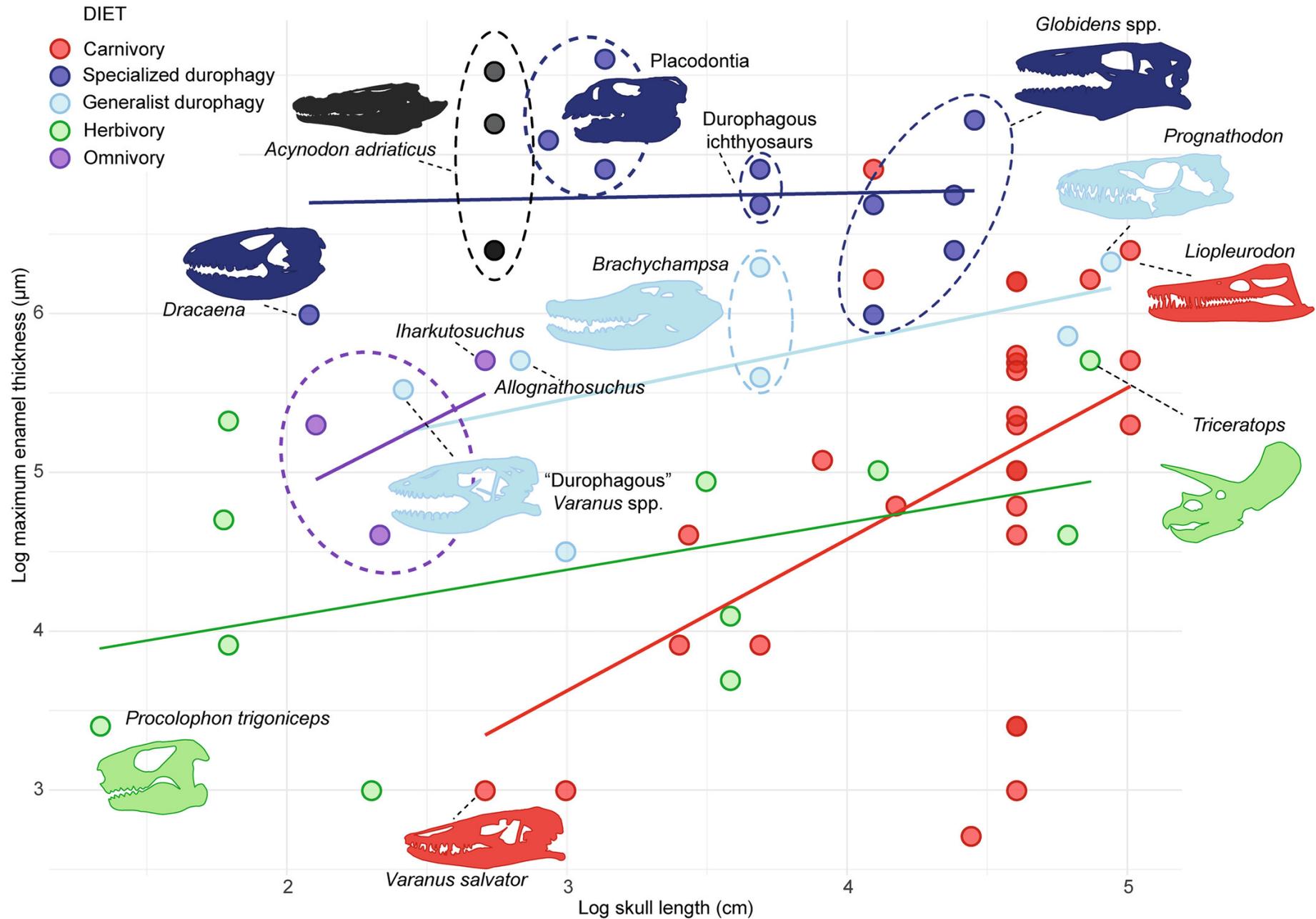
Durofagia prowadzi do rozbudowy obszaru skroniowego czaszki



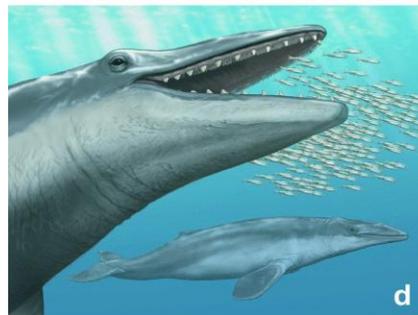
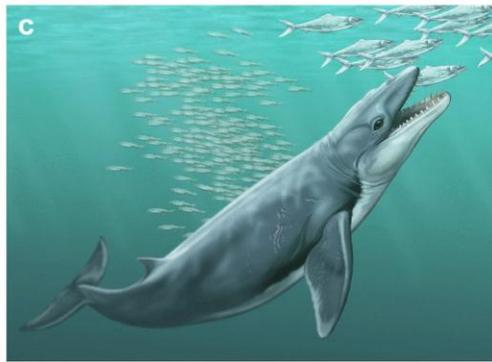
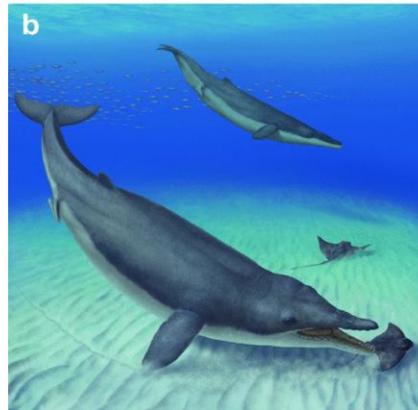
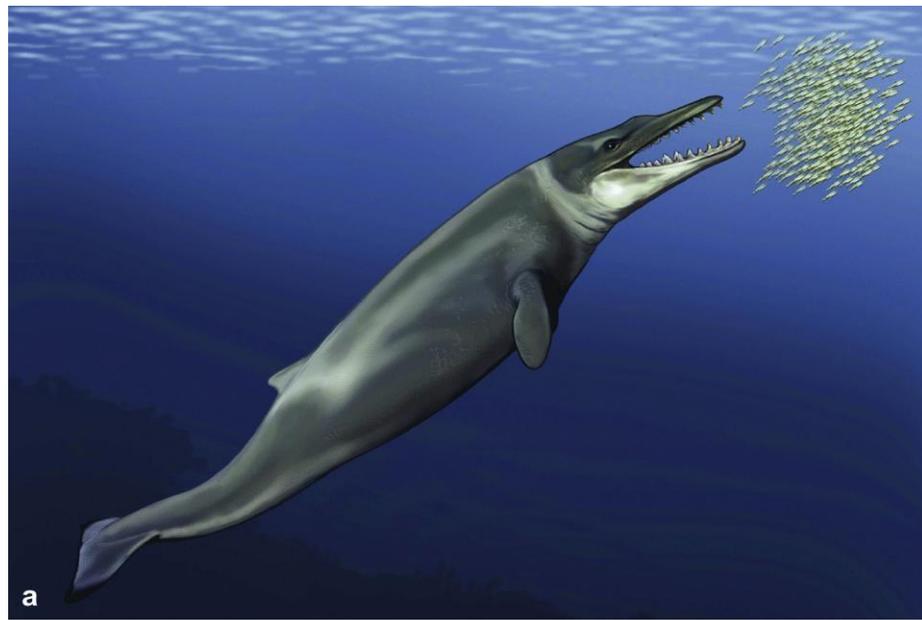
Pommery et al., 2021

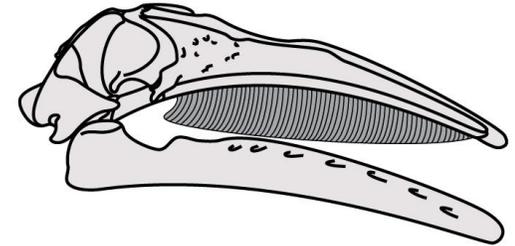
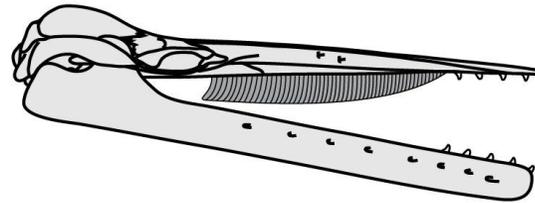
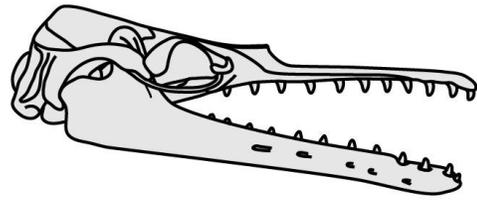
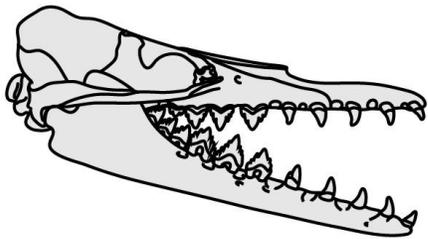
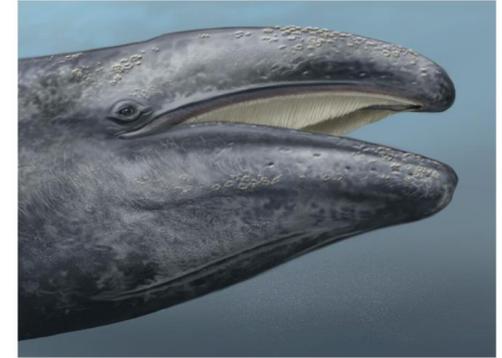
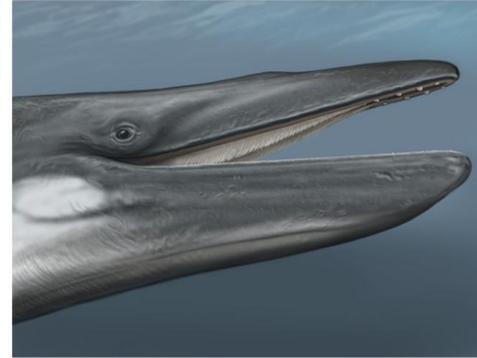
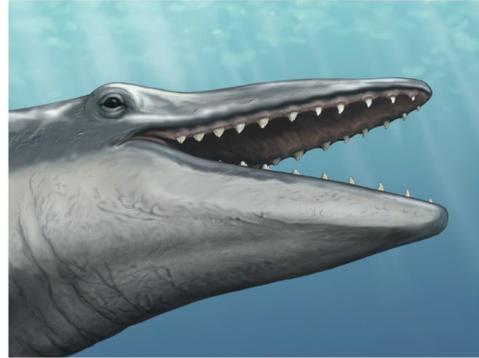
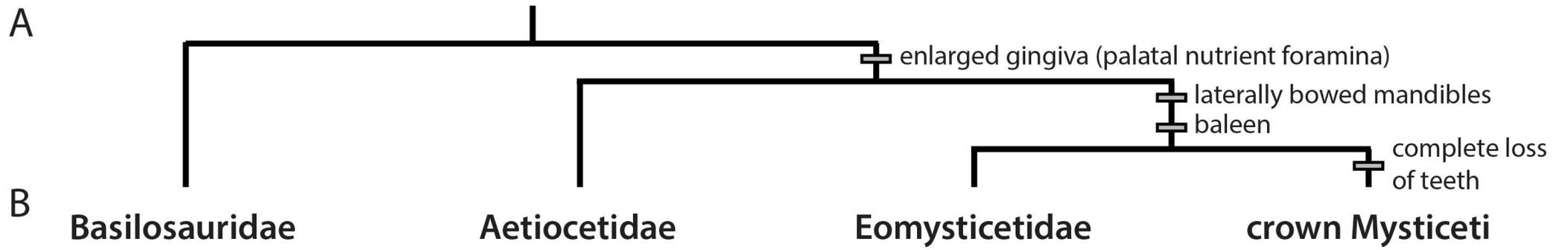


Diedrich, 2010









C

biting + intraoral suction + simple sieving

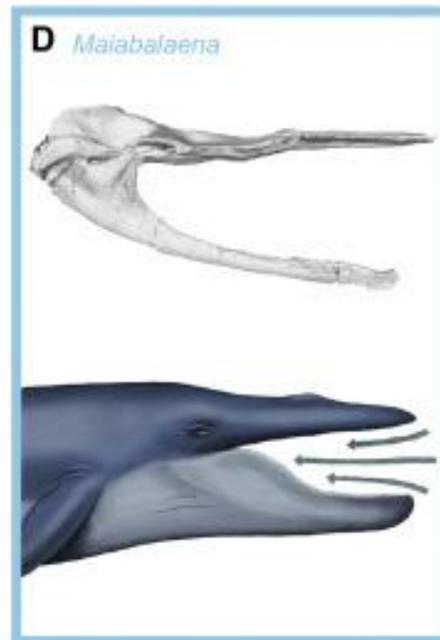
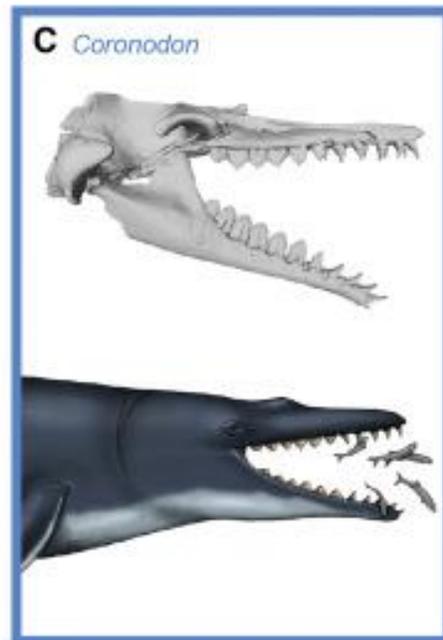
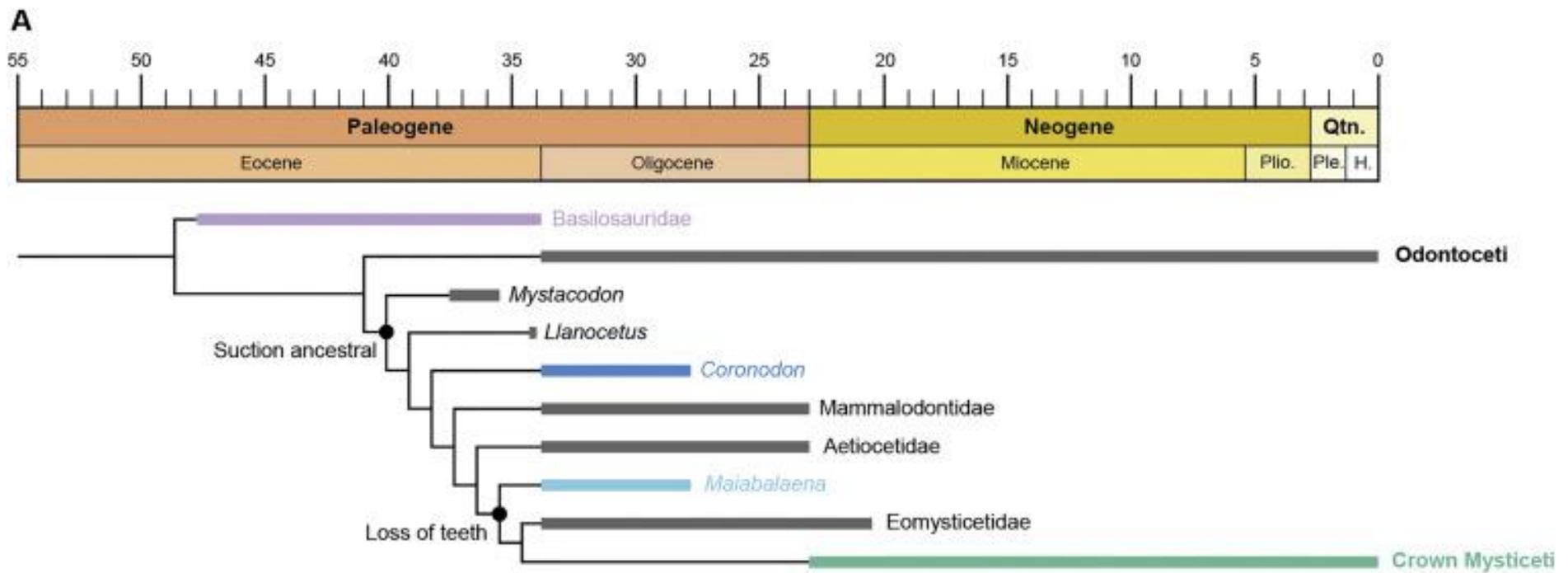
suction + simple sieving

suction + baleen filtering

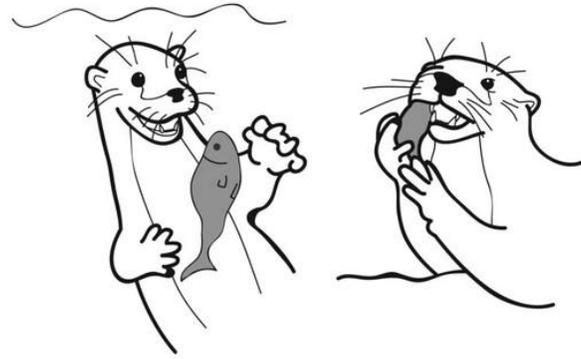
ram + baleen filtering

Mysticeti

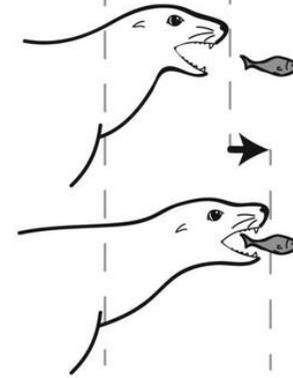
Chaeomysticeti (teeth reduced or absent, baleen-bearing)



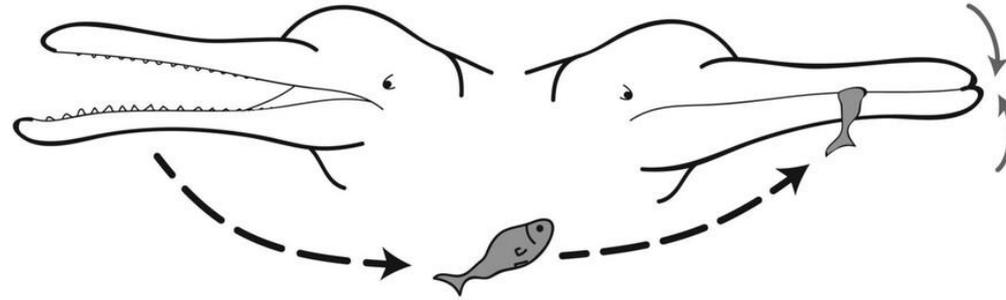
(a) grappling with forelimbs



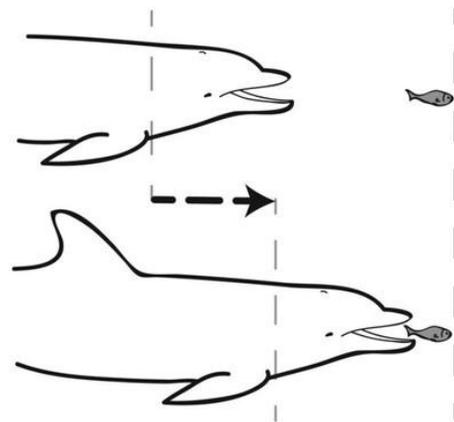
(b) anterior snapping



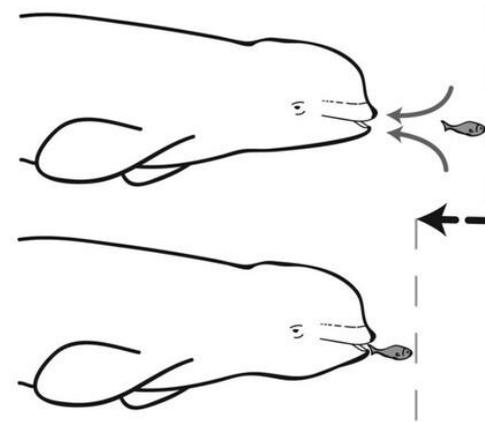
(c) lateral snapping



(d) ram prey capture



(e) suction prey capture

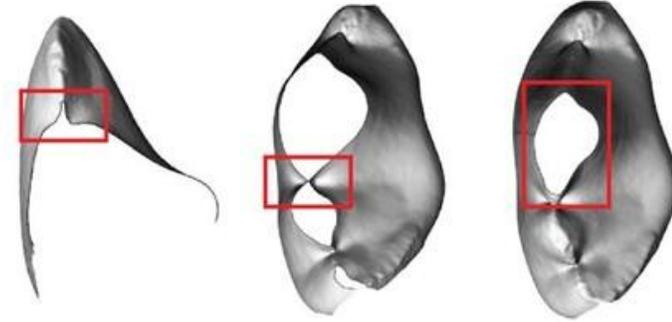


(a)

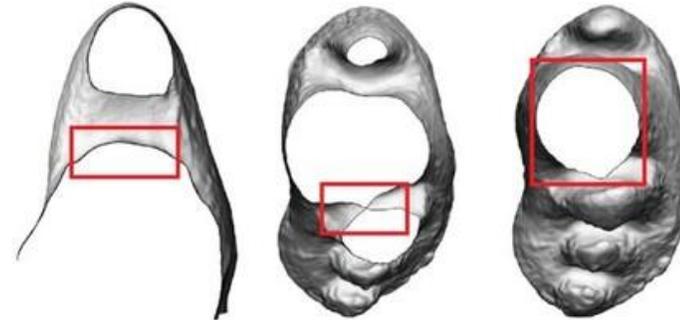
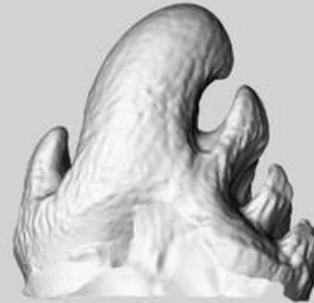


cross sections

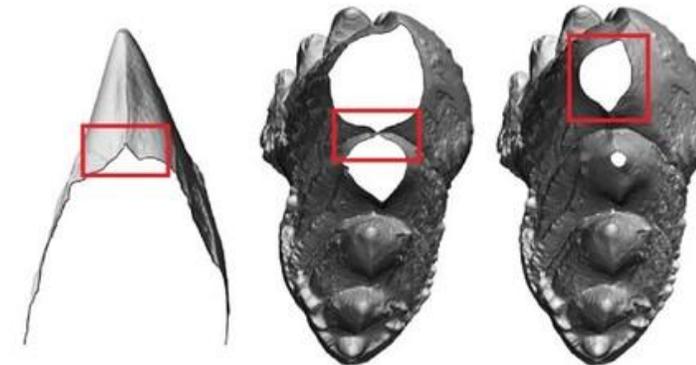
notch transverse	notch horizontal	main cusp horizontal
---------------------	---------------------	-------------------------

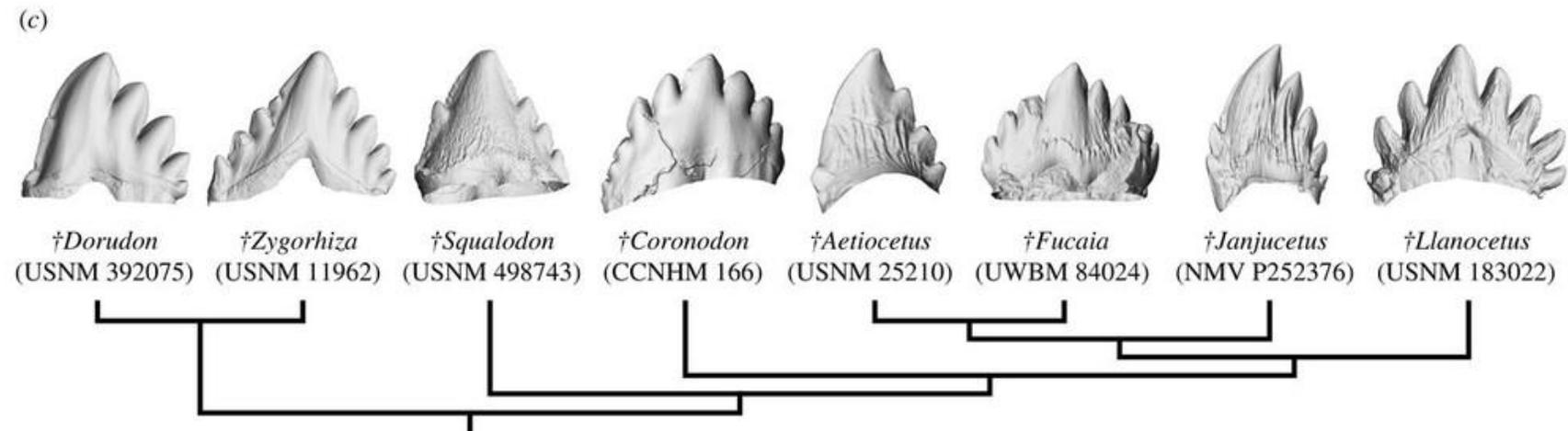
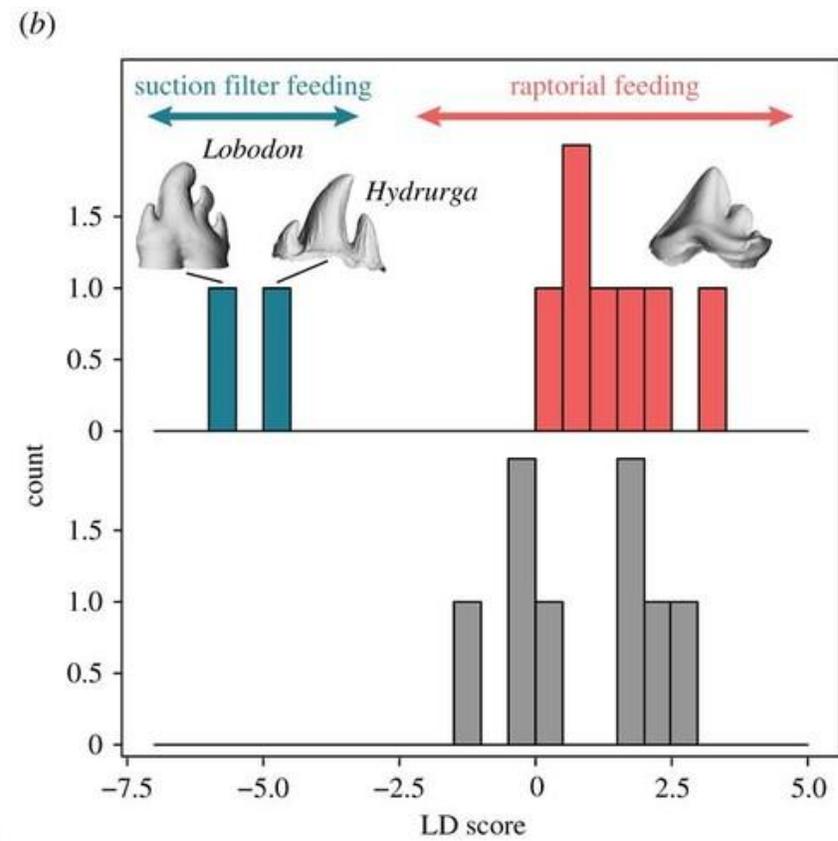
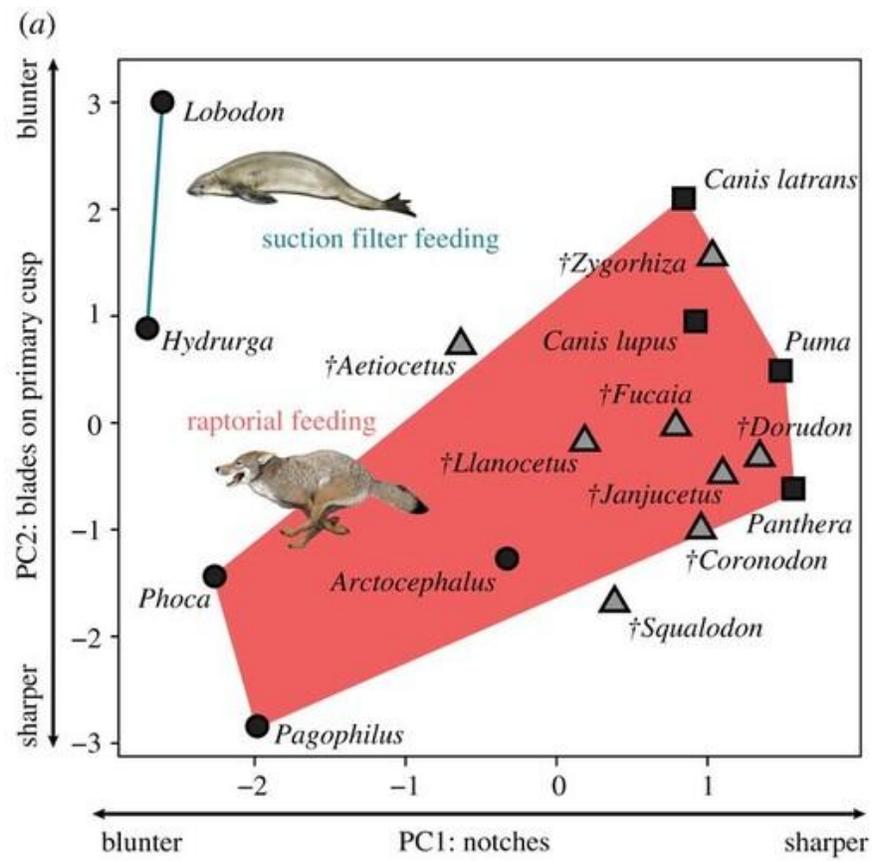


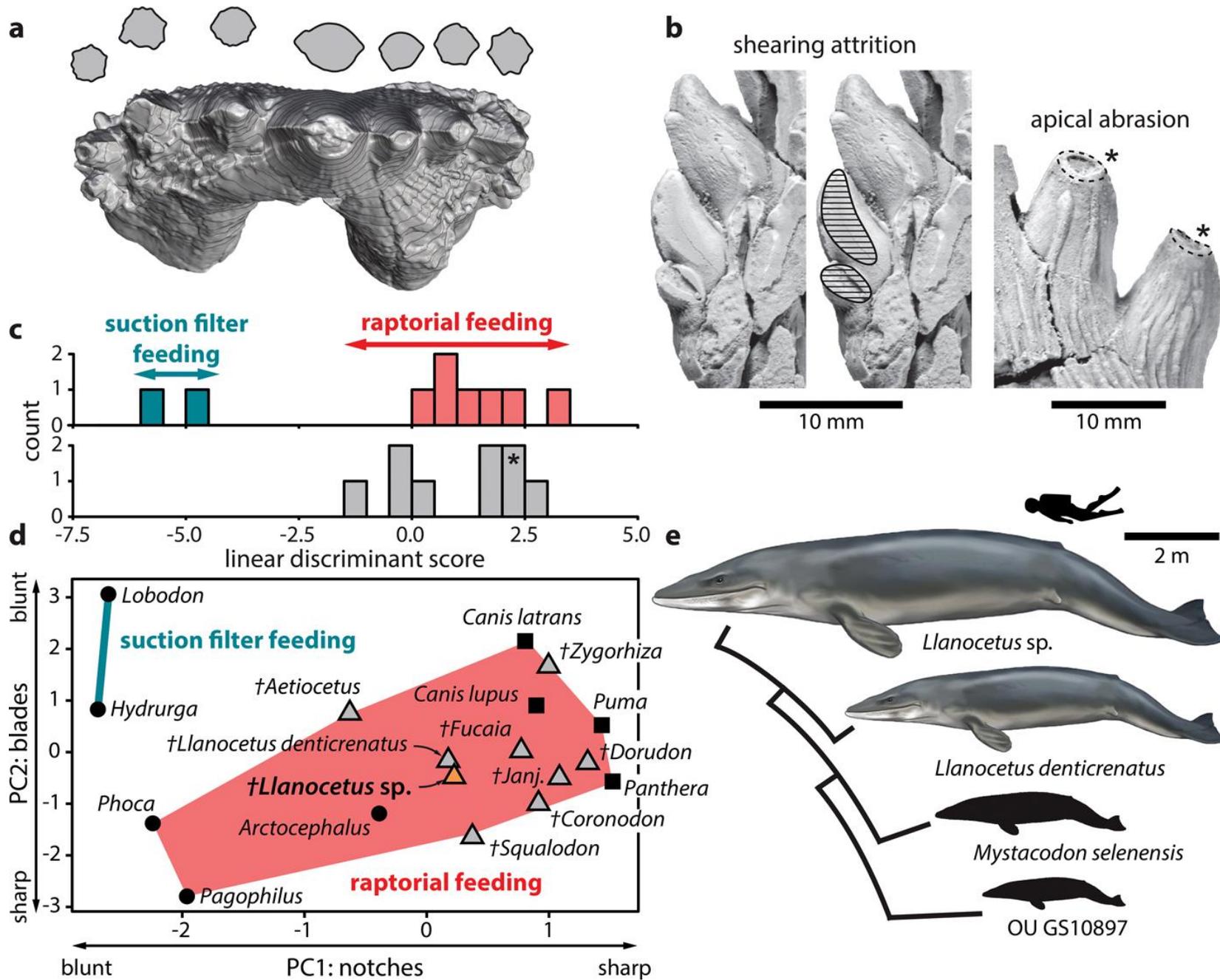
(b)

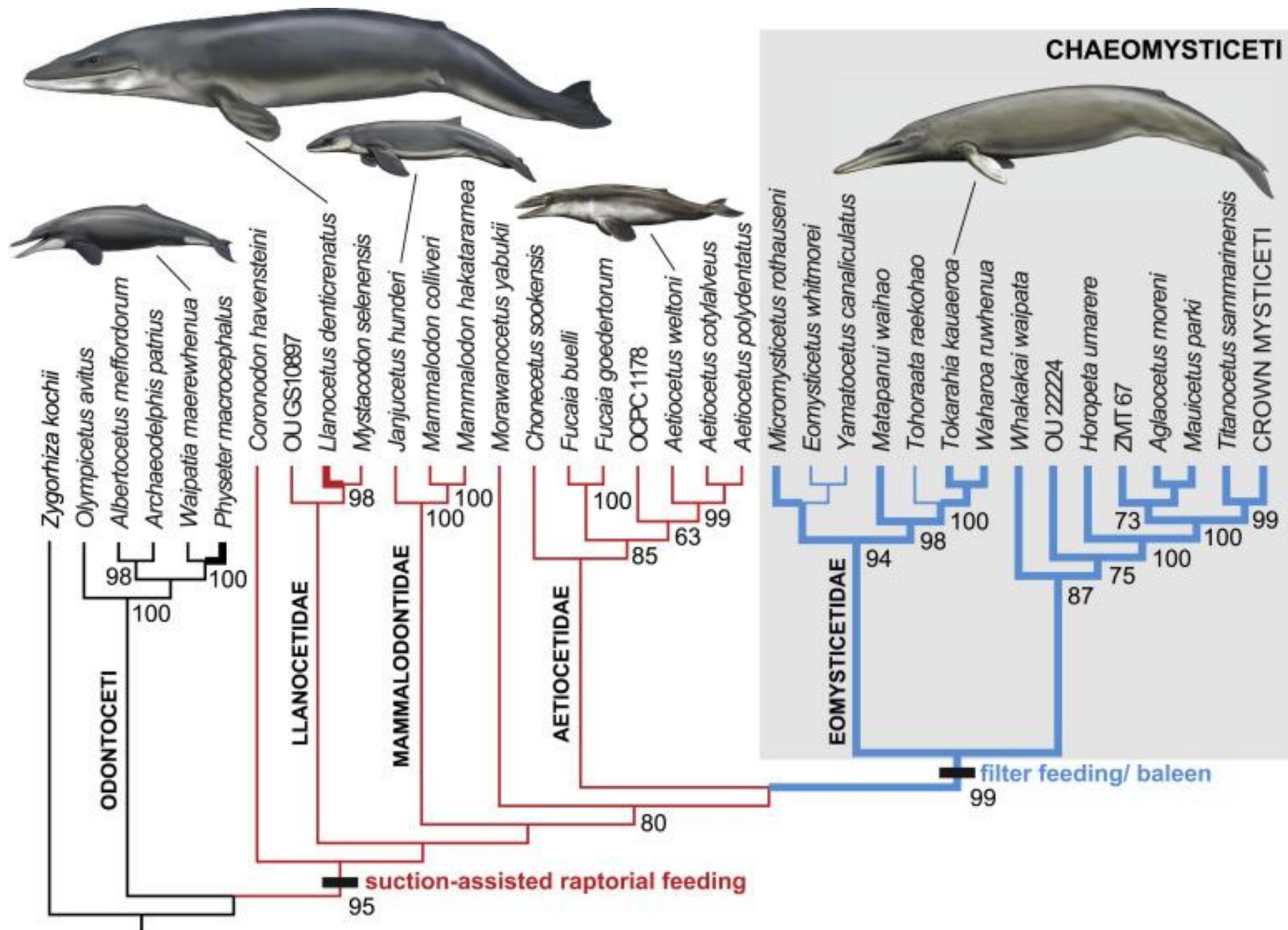


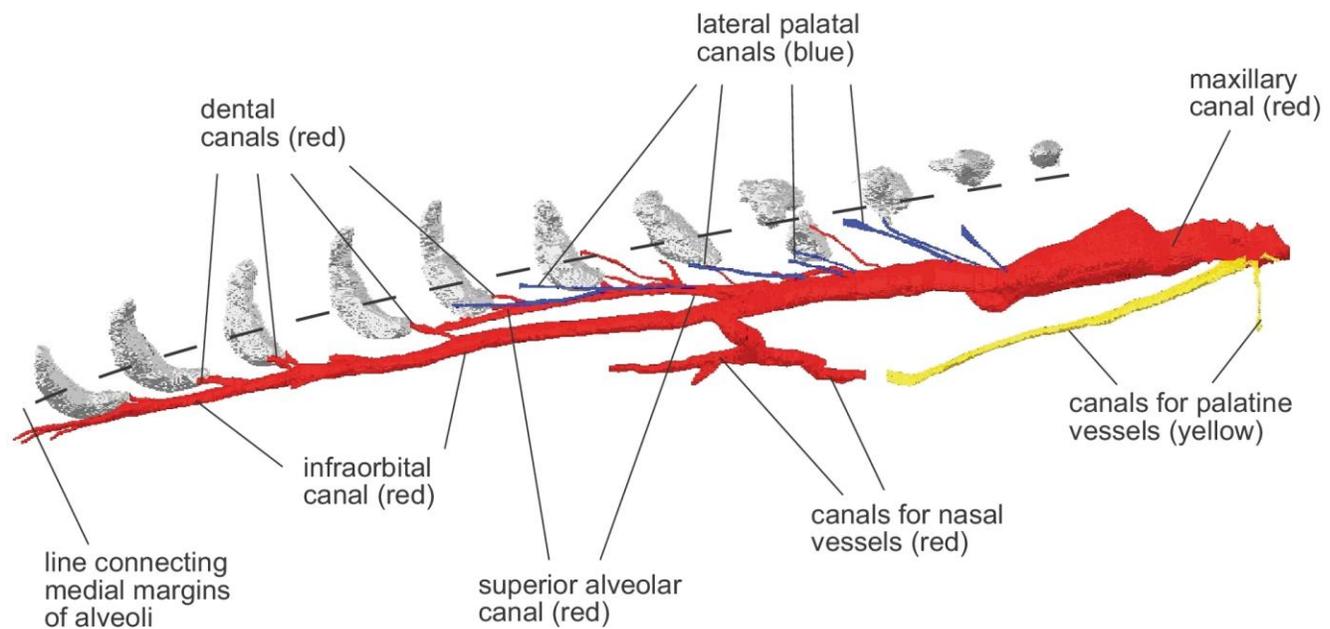
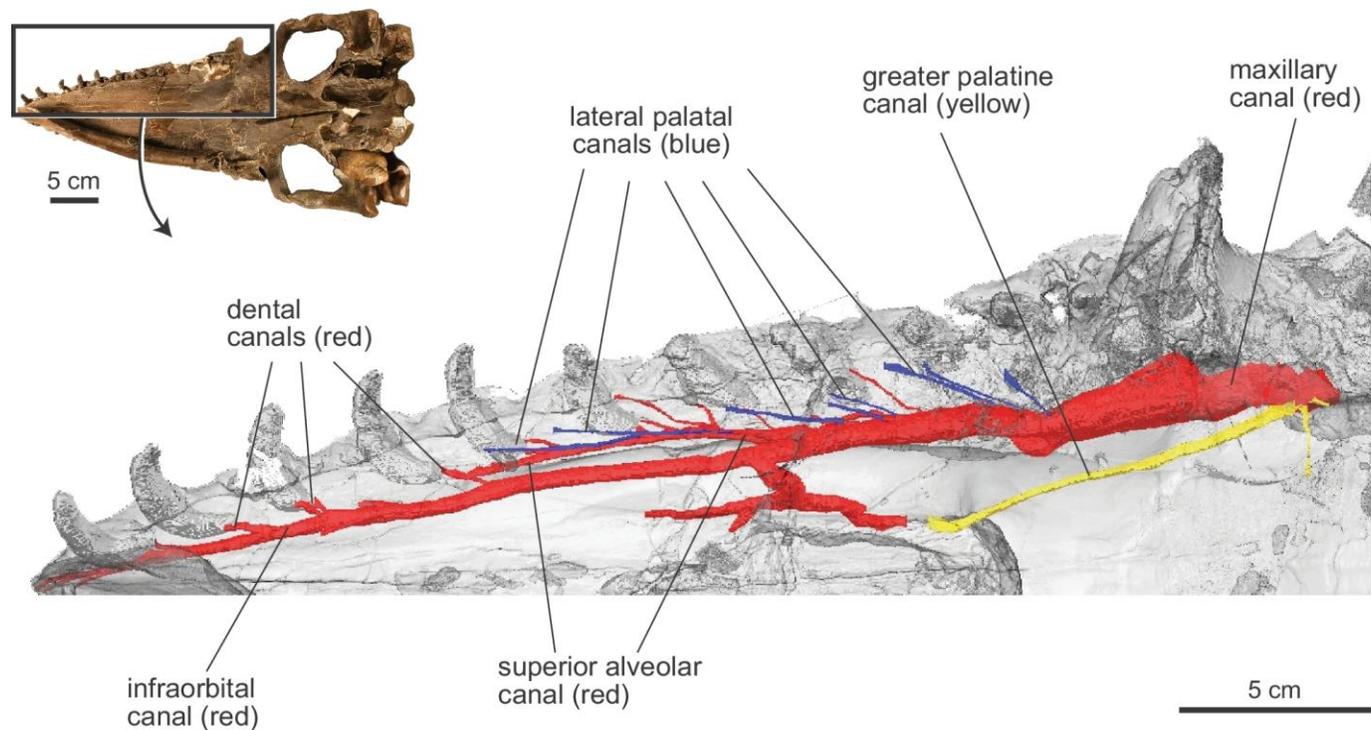
(c)

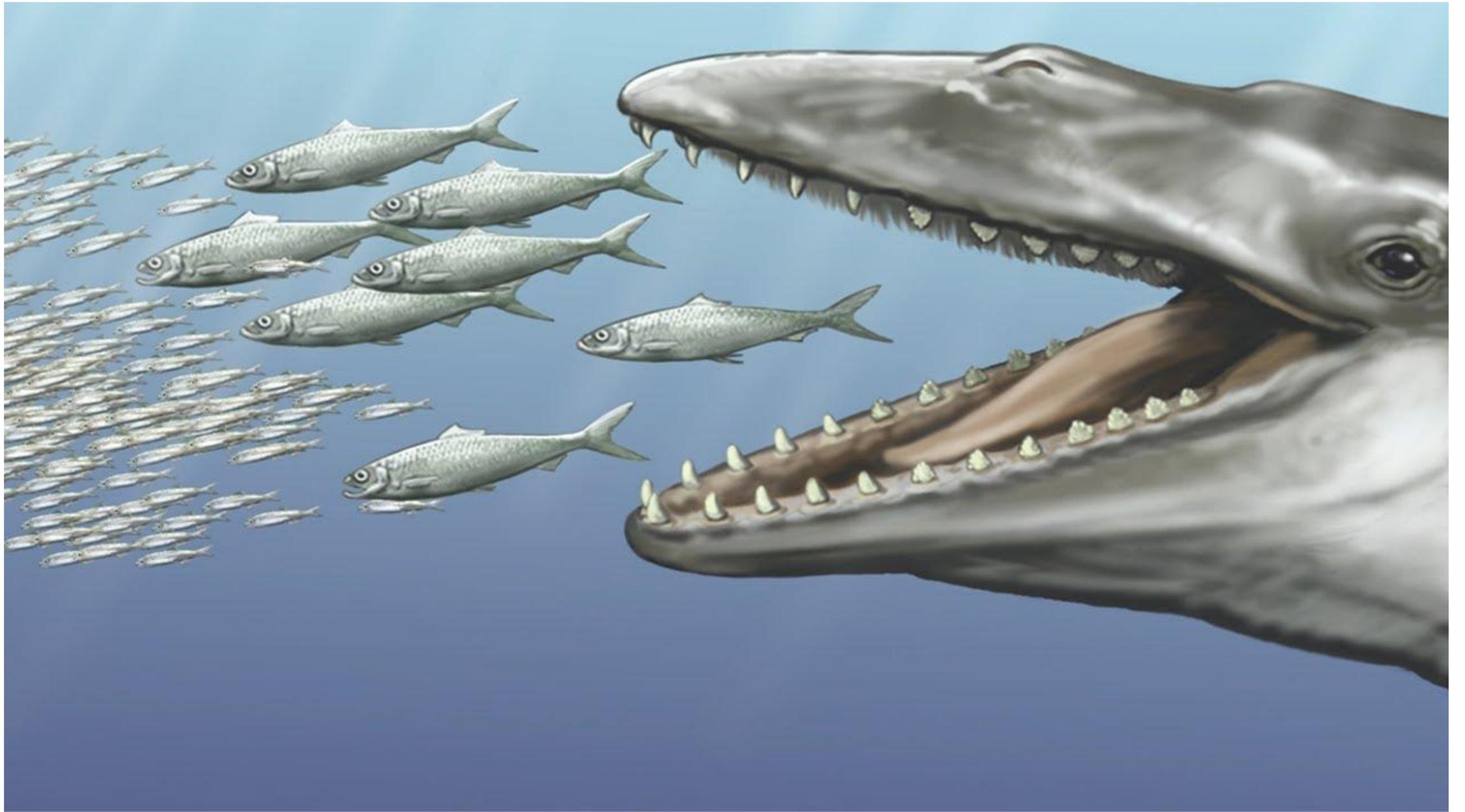


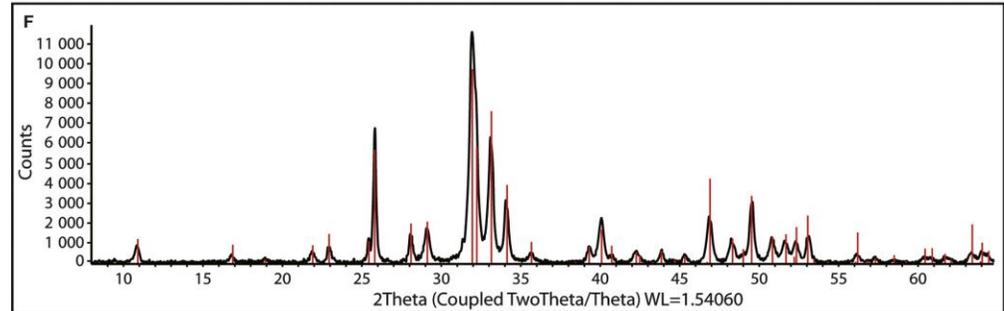
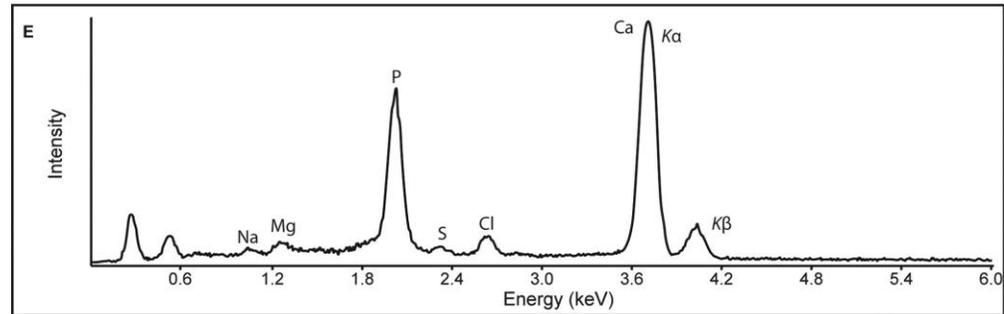
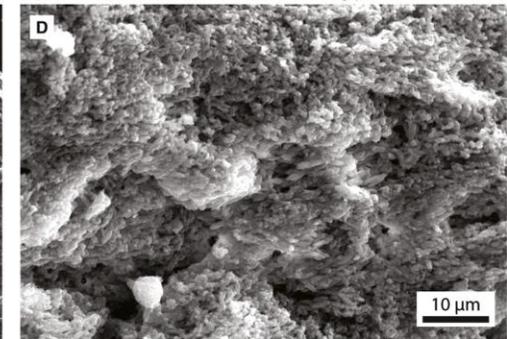
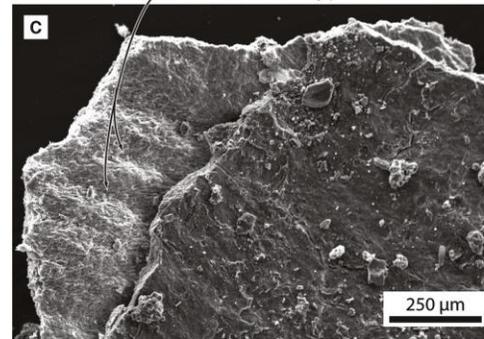
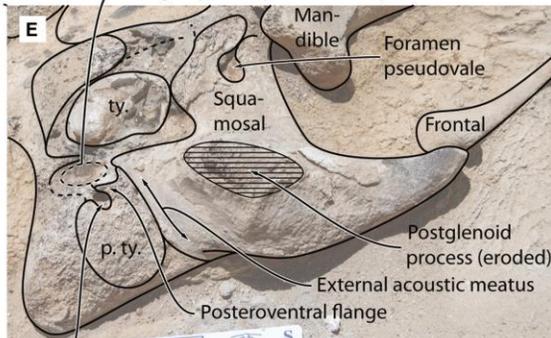
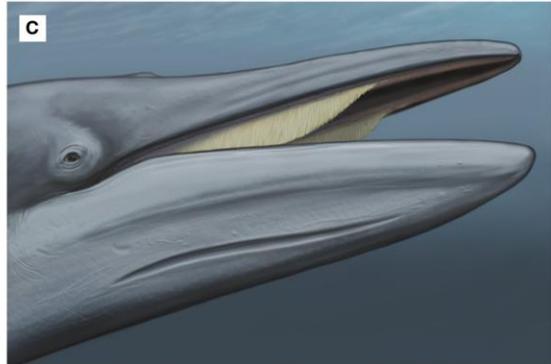
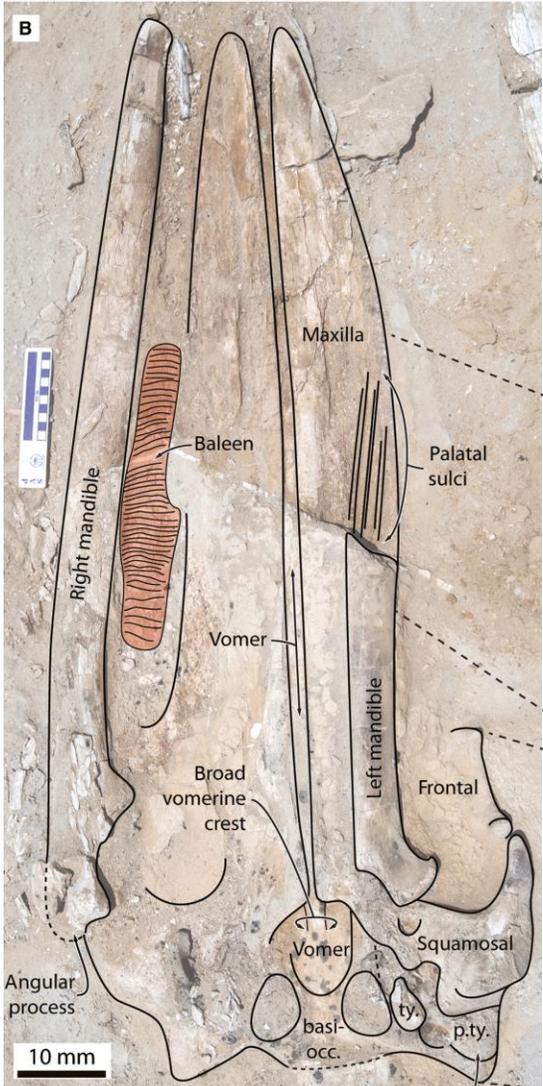


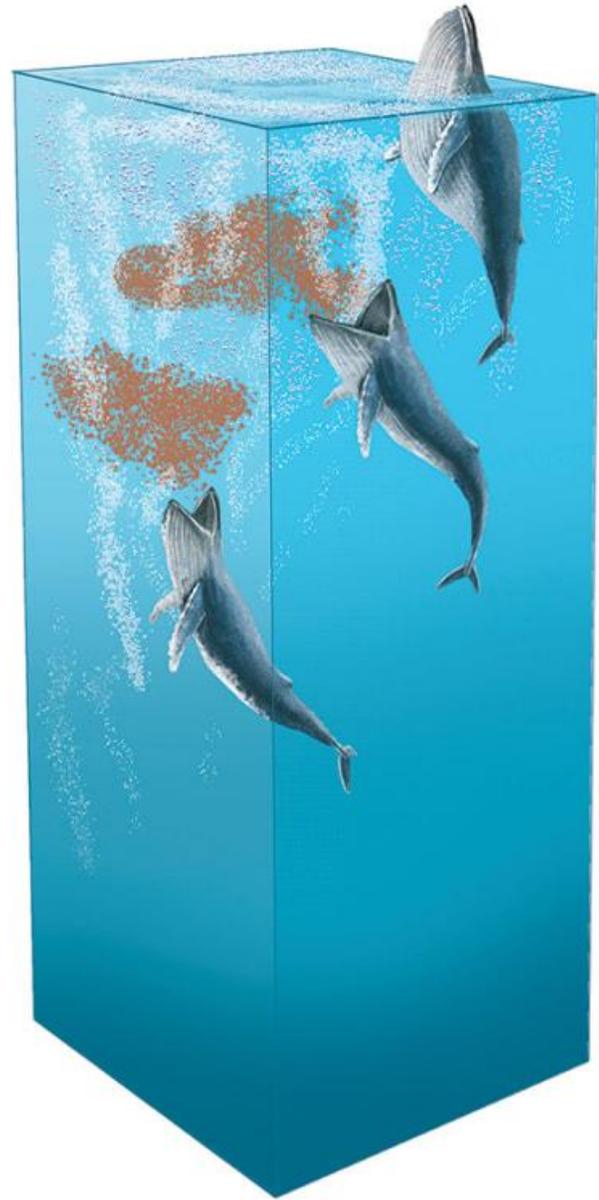
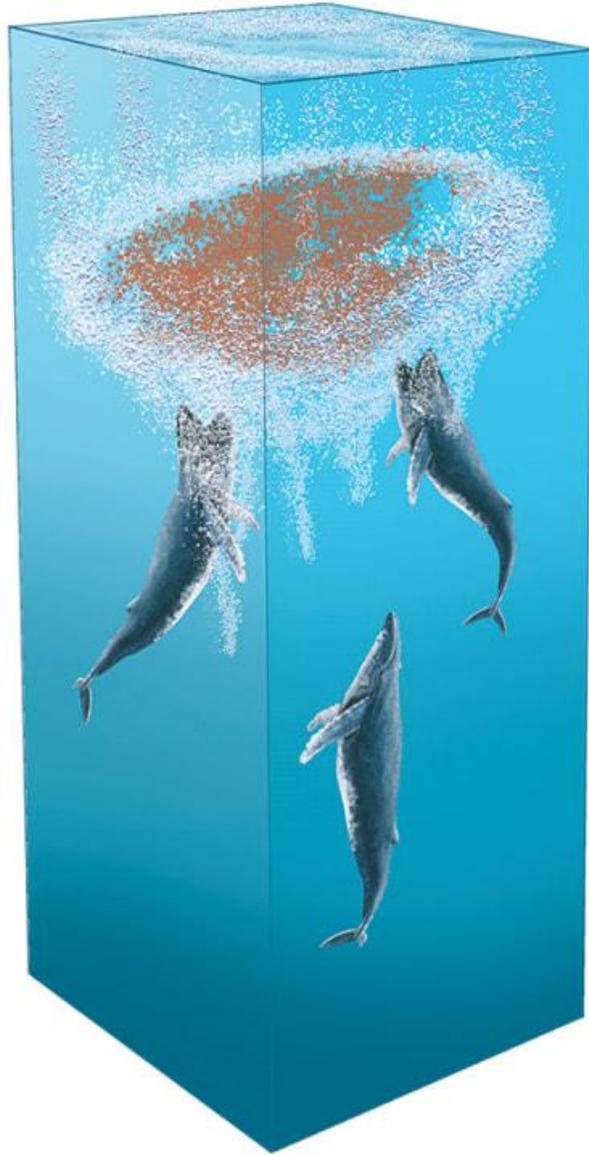
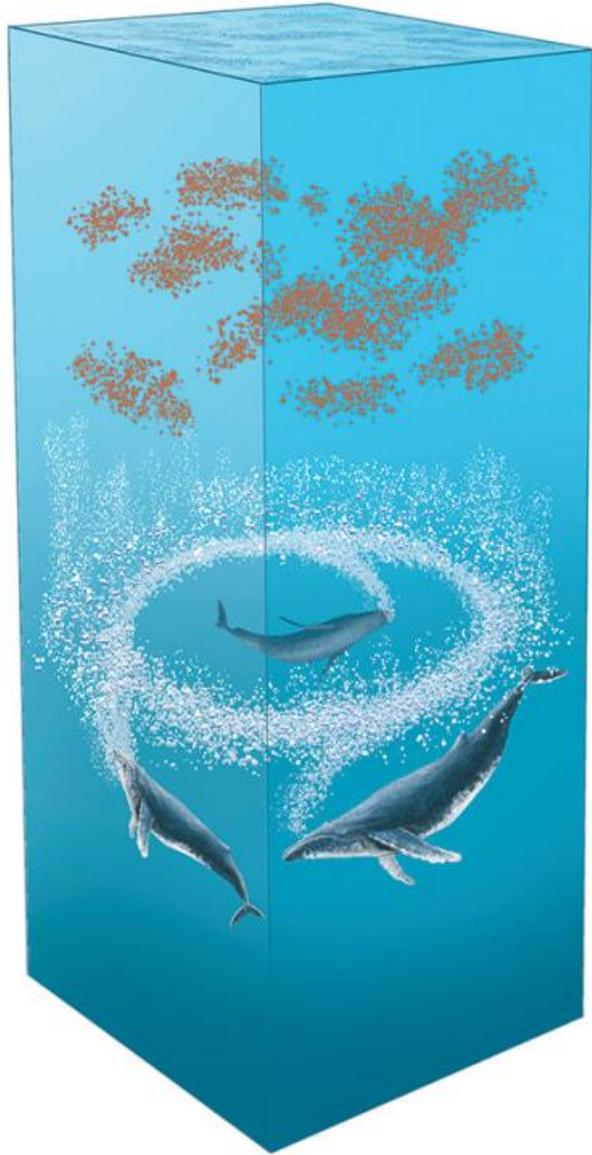




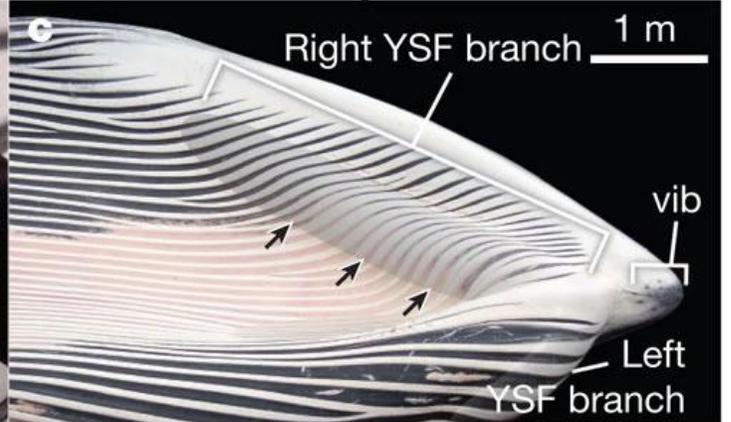
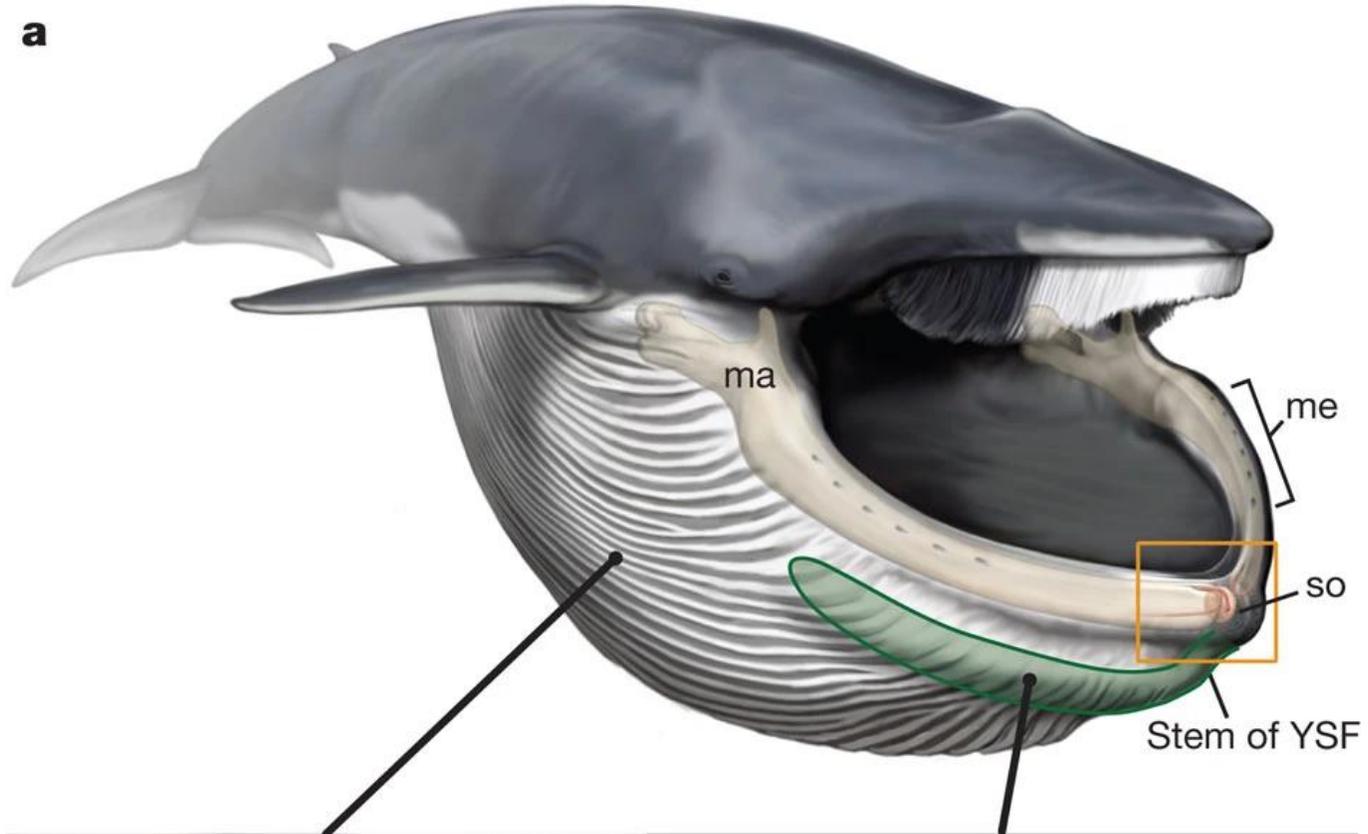


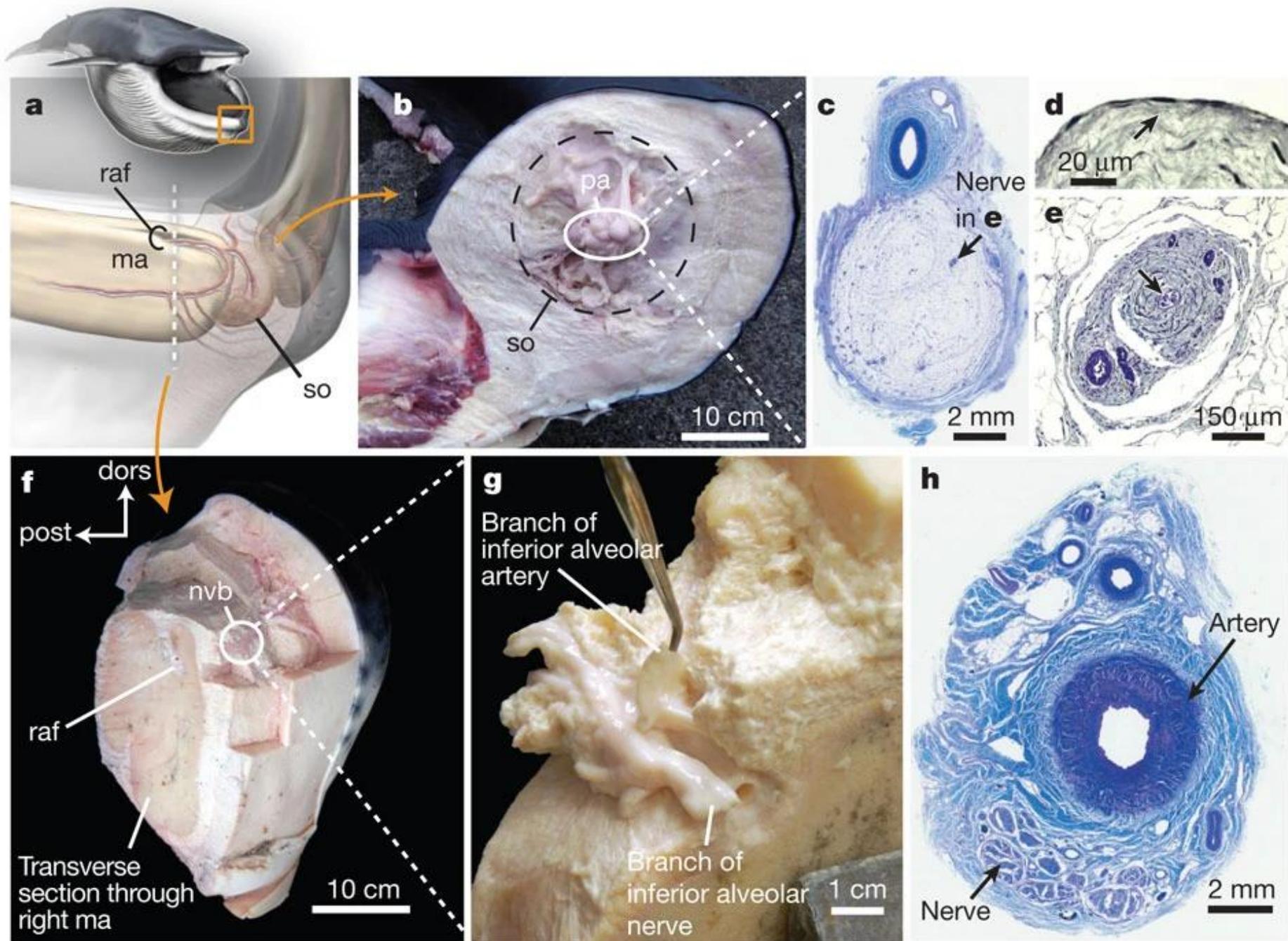


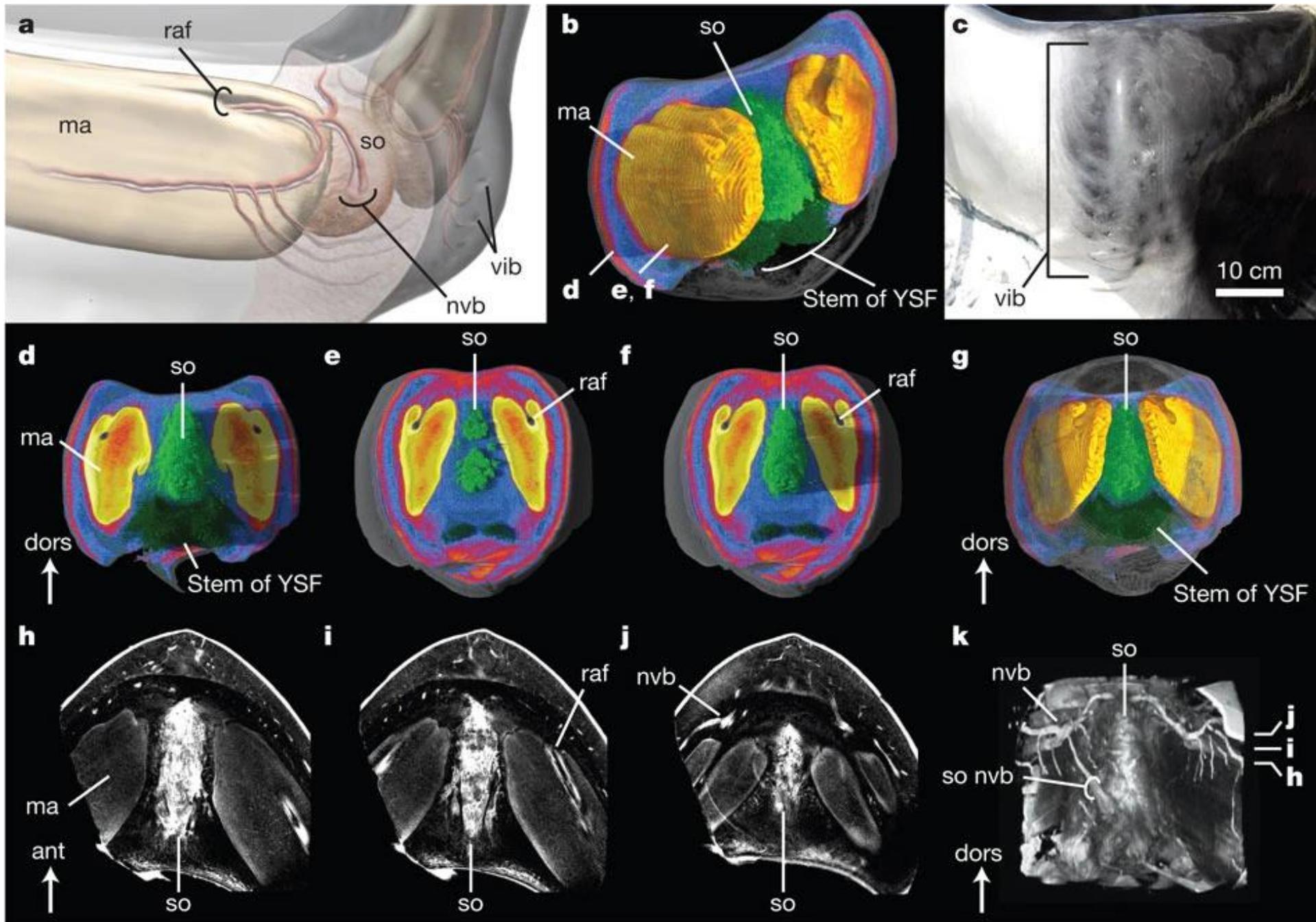


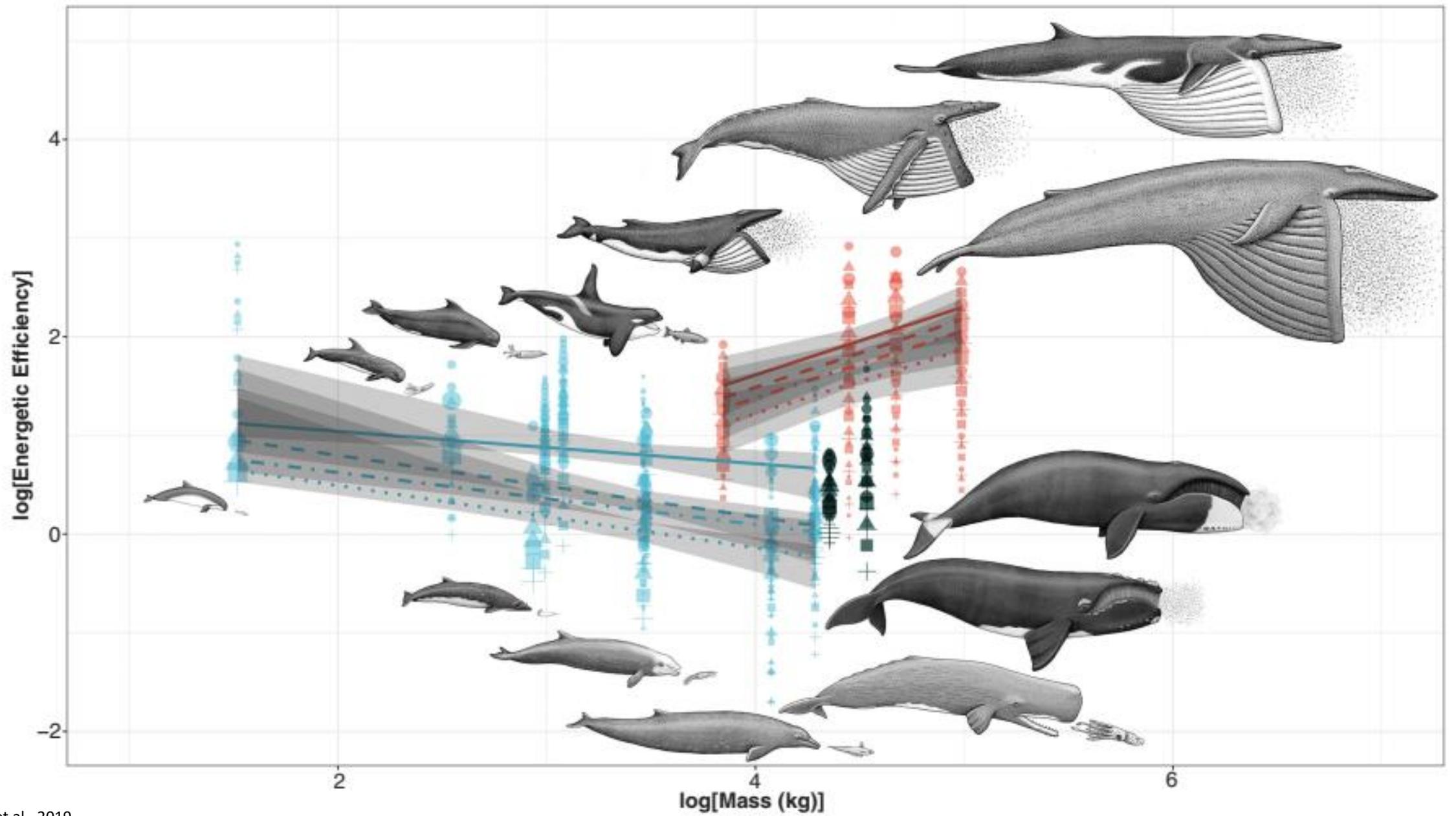




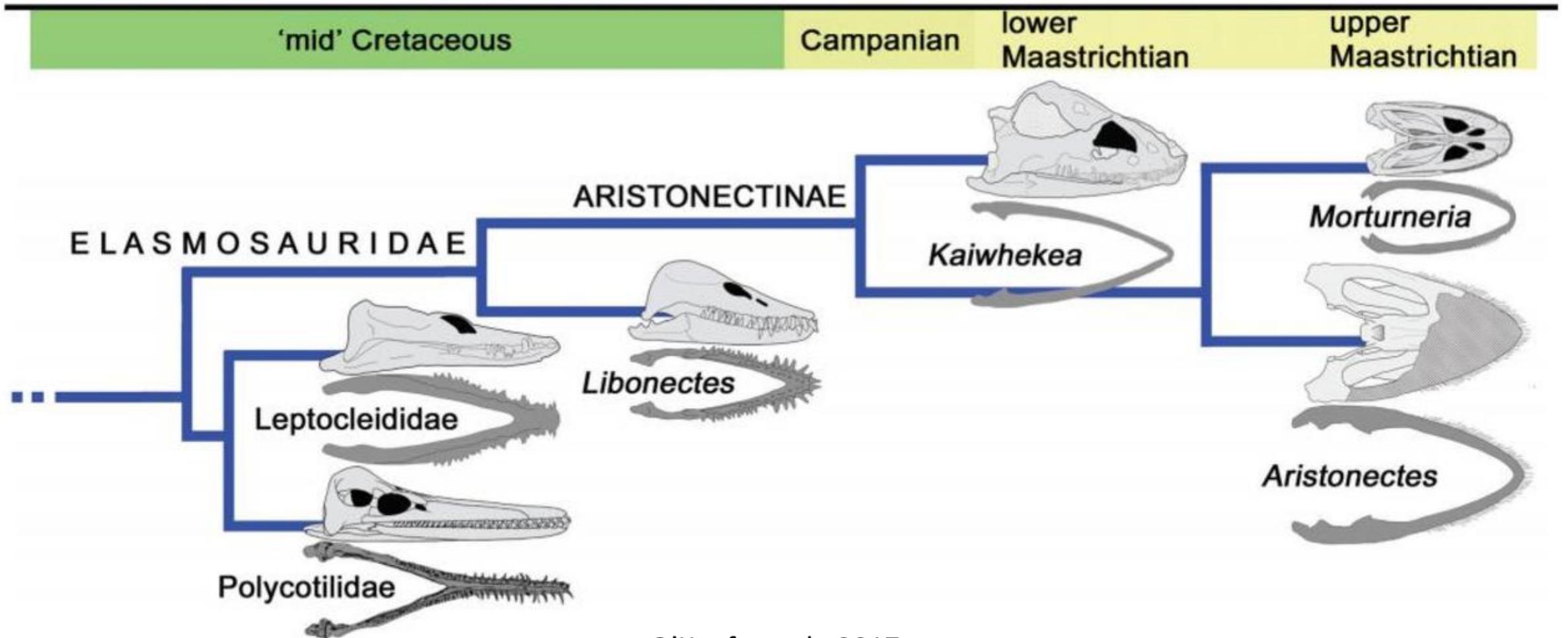








Ewolucja adaptacji pokarmowych plezjozaurów



O'Keefe et al., 2017

Morturneria – filtrujący plezjozaur z Antarktyki

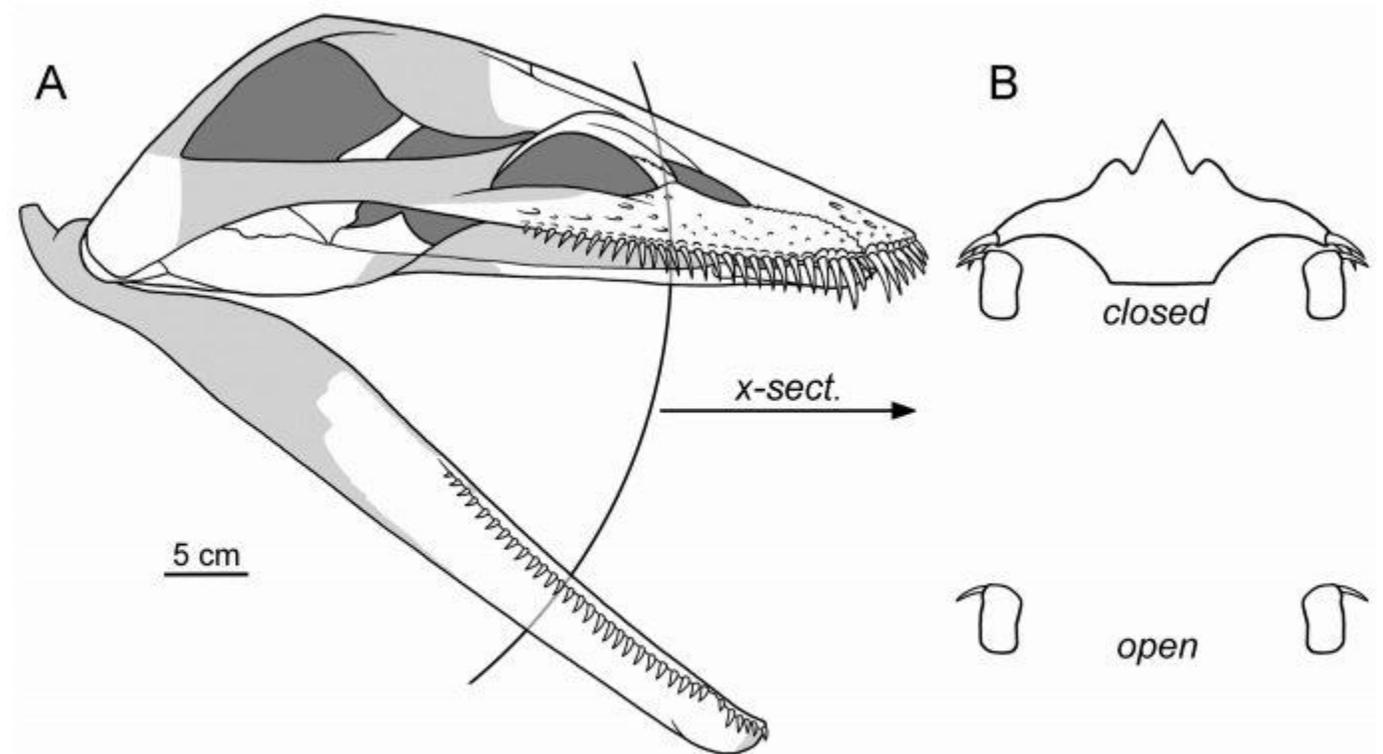
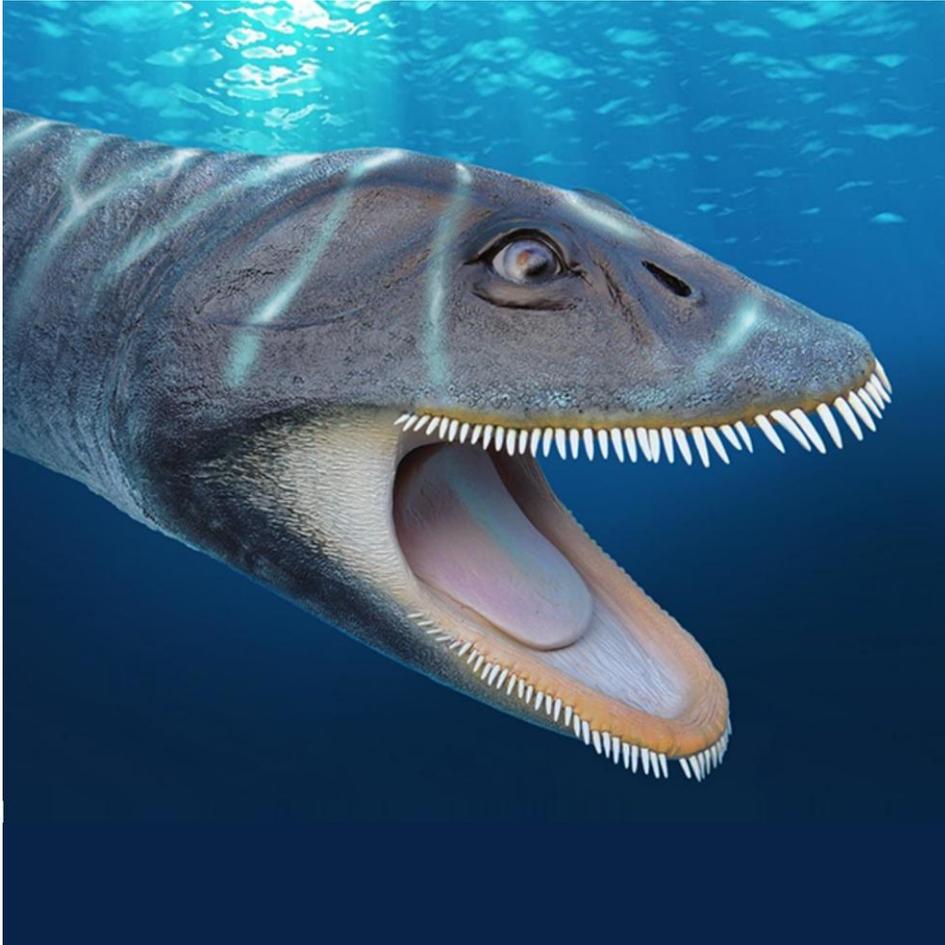
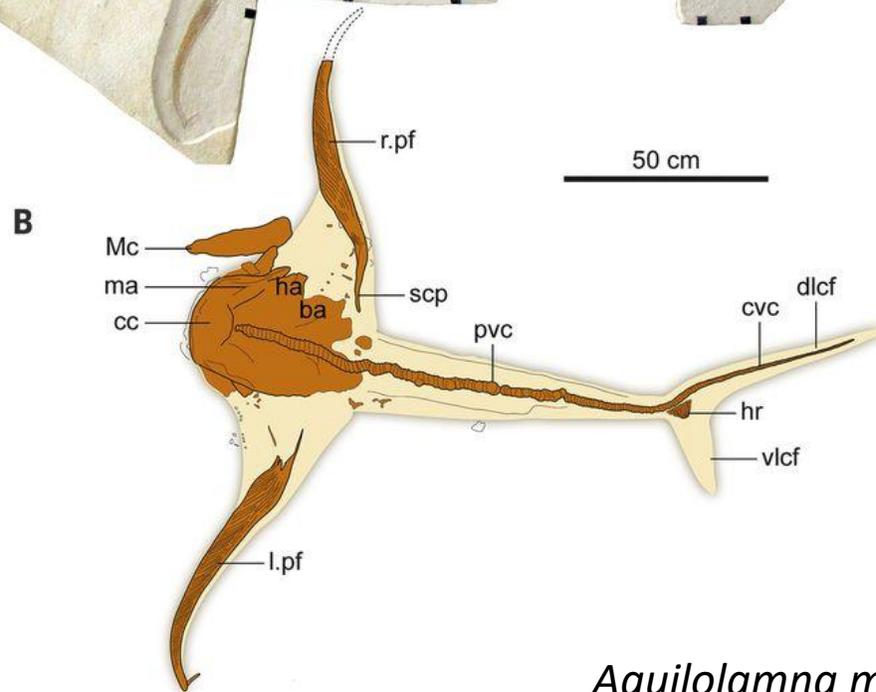


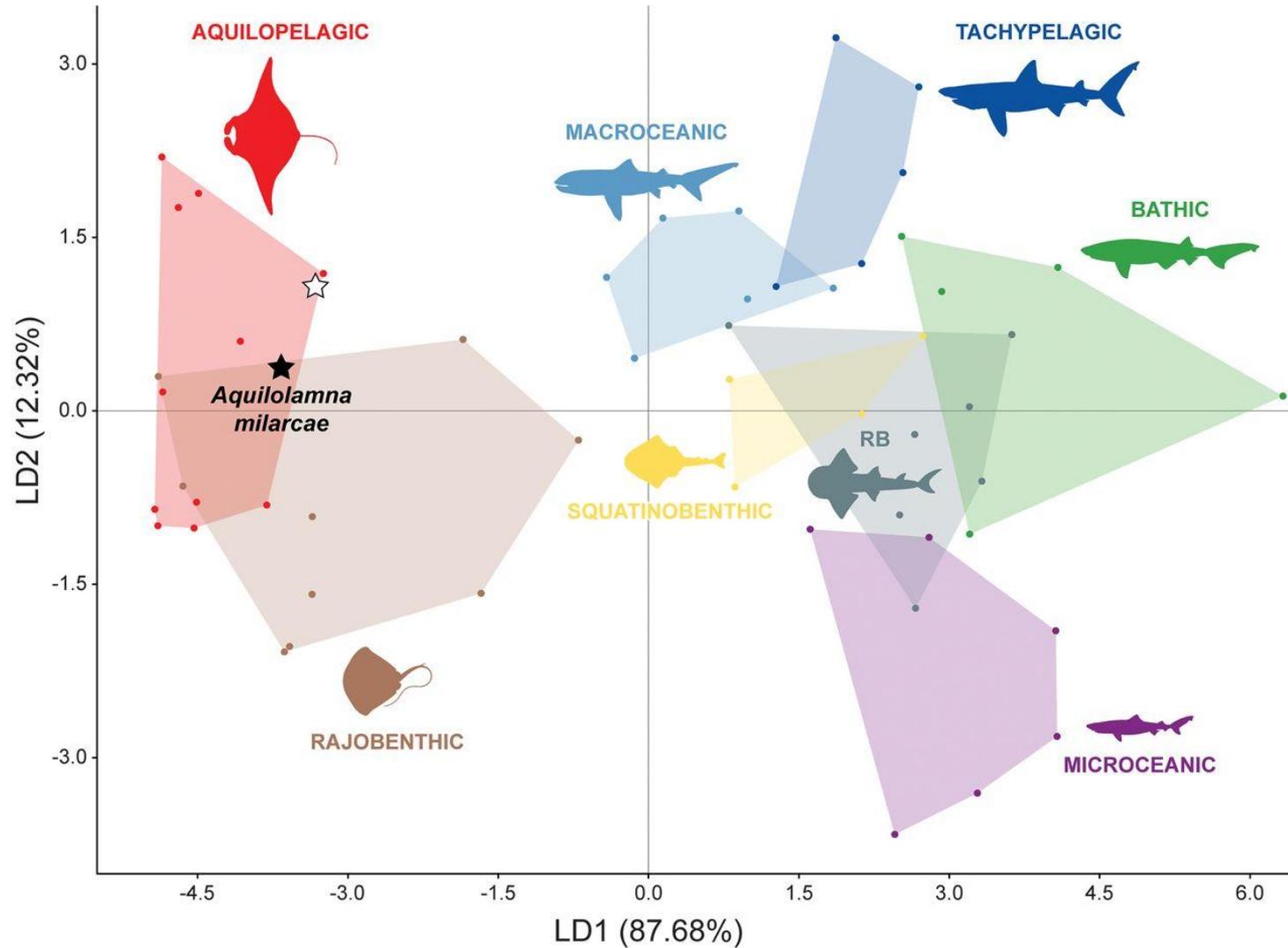
FIGURE 8. Mandibular and oral cavity morphology of *Morturneria*. **A**, the mandible in articulation with mouth open; **B**, a cross-section of the skull along the indicated arc, demonstrating the large volume of the oral cavity, as well as the oblique interdigitation of the tooth combs and the arching of the palate. Dark gray shading indicates skull fenestrae; light gray shading indicates reconstructed portions of the skull.



Aquilolamna milarcae
Vullo et al., 2021



Ekomorfologia chrzęstnoszkieletowych



Mantowate (Mobulidae)

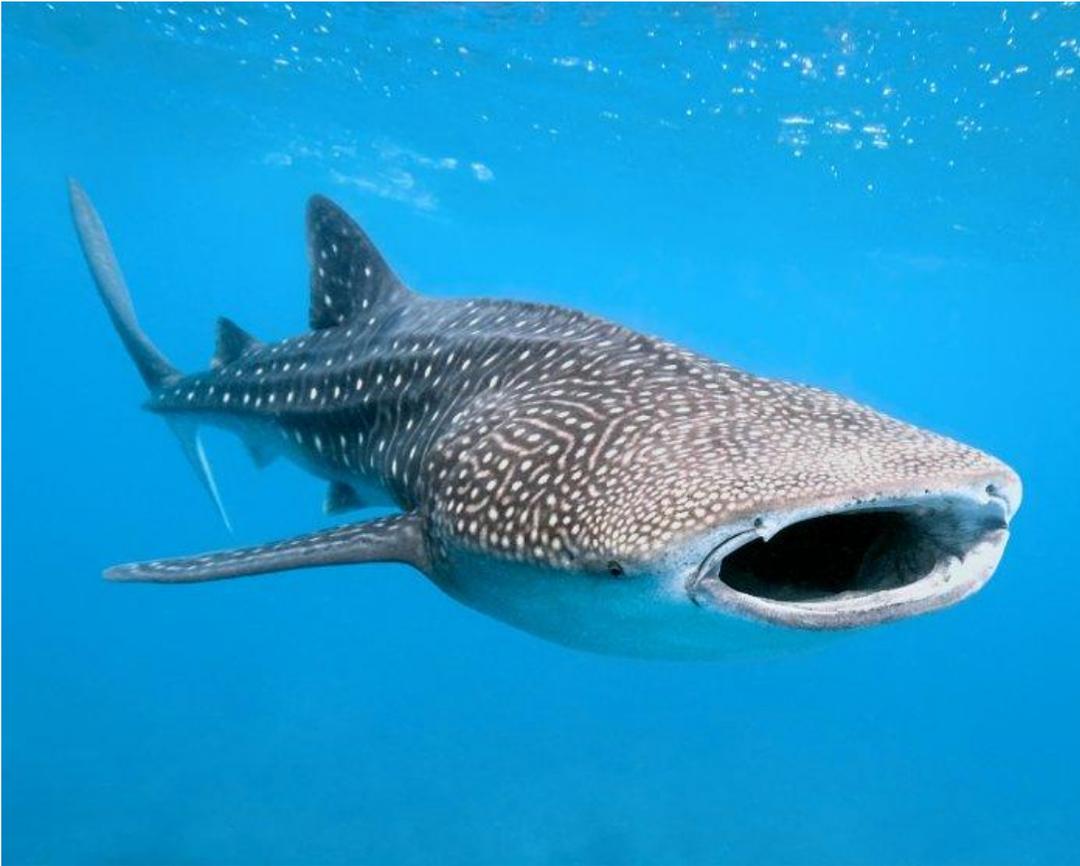


<https://www.cms.int/sites/default/files/species/Mobula%20hypostoma%20dorsal%20female.jpg>



<https://www.nhm.ac.uk/content/dam/nhmwww/discover/mobula-rays/mobula-ray-full-width.jpg>

Rekin wielorybi (Rhincodontidae)



<https://www.auxbulles.com/img/requin-baleine-rhincodon-typus-03.jpg>



[https://shark-references.com/images/species/Rhincodon_typus_\(C\)_Simon_Pierce%20\(39\).jpg](https://shark-references.com/images/species/Rhincodon_typus_(C)_Simon_Pierce%20(39).jpg)

Rekin długoszar (Cetorhinidae)



http://a-z-animals.com/media/animals/images/original/basking_shark1.jpg



<https://animalinfoworld.com/wp-content/uploads/Basking-Shark-725x498.jpg>



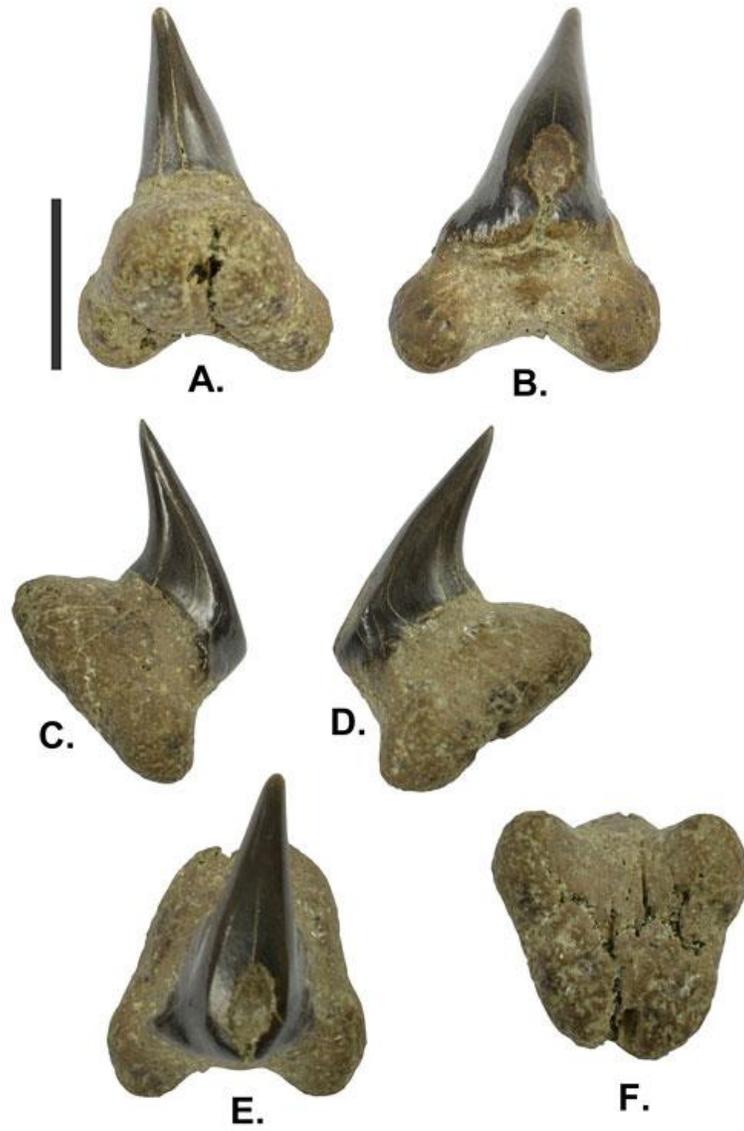
Rekin wielkogębowy (Megachasmaidae)



https://img.zoo-club.org/img/akulabolsherotayapelagicheskayafotoopisa_0AECOD3.jpg

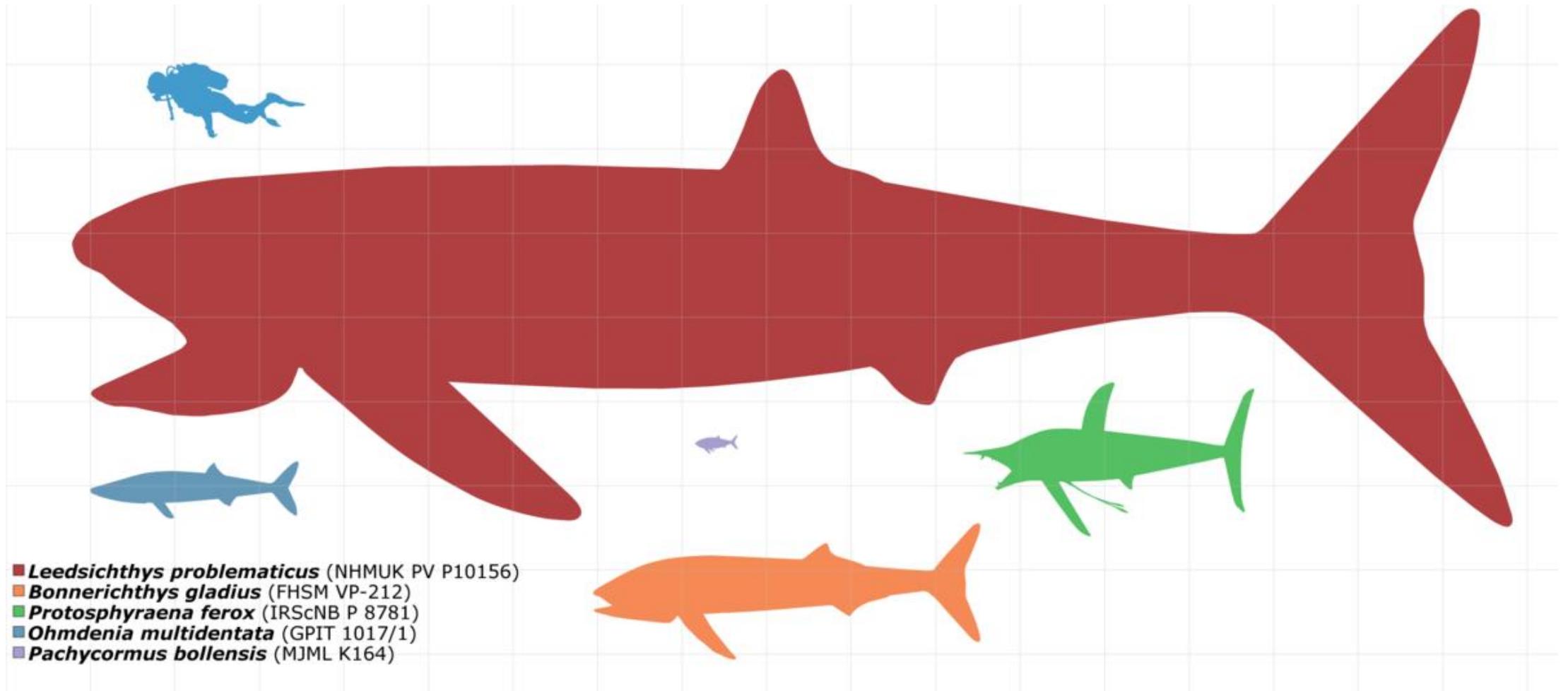


<https://ianimal.ru/wp-content/uploads/2011/02/akyla-bolsherot25.jpg>



Schutter & Everaert 2020

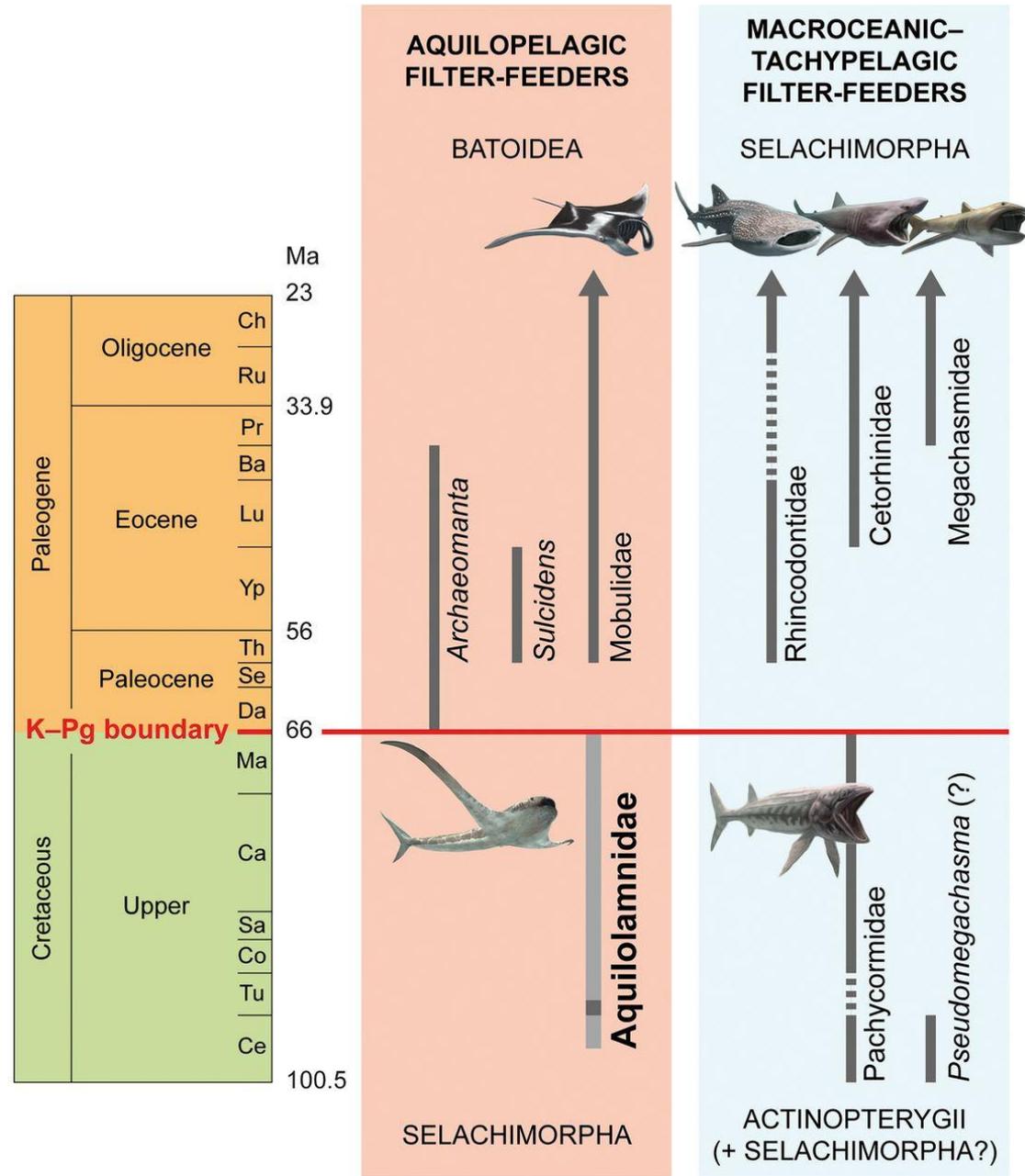
Pachycormiformes – mezozoiczne lewiatany





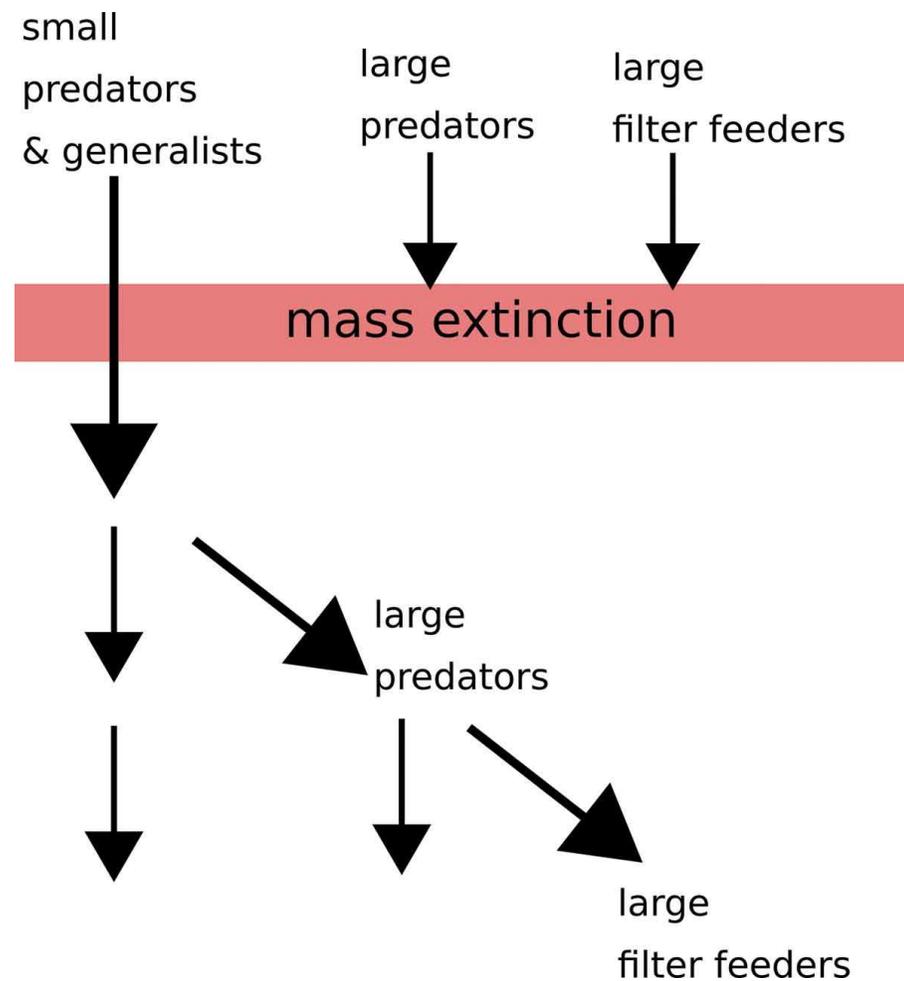
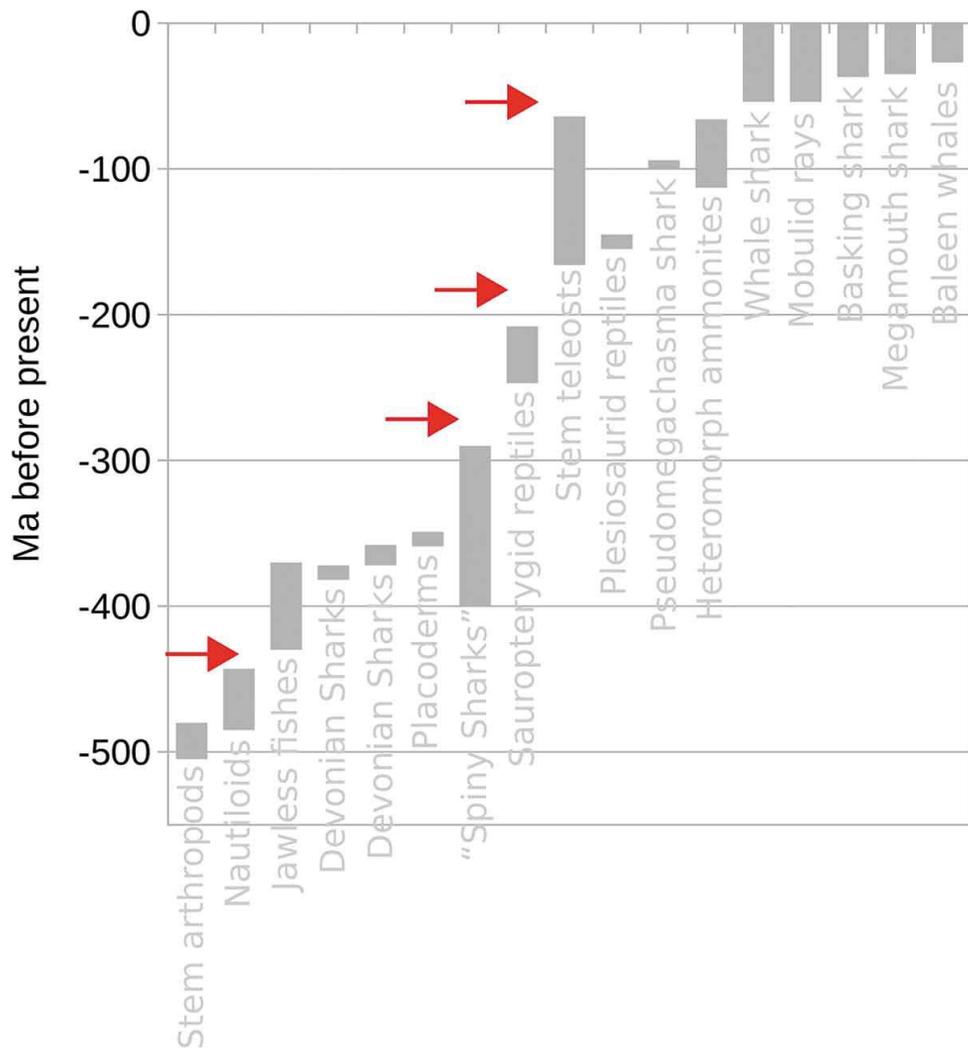






Vullo et al., 2021

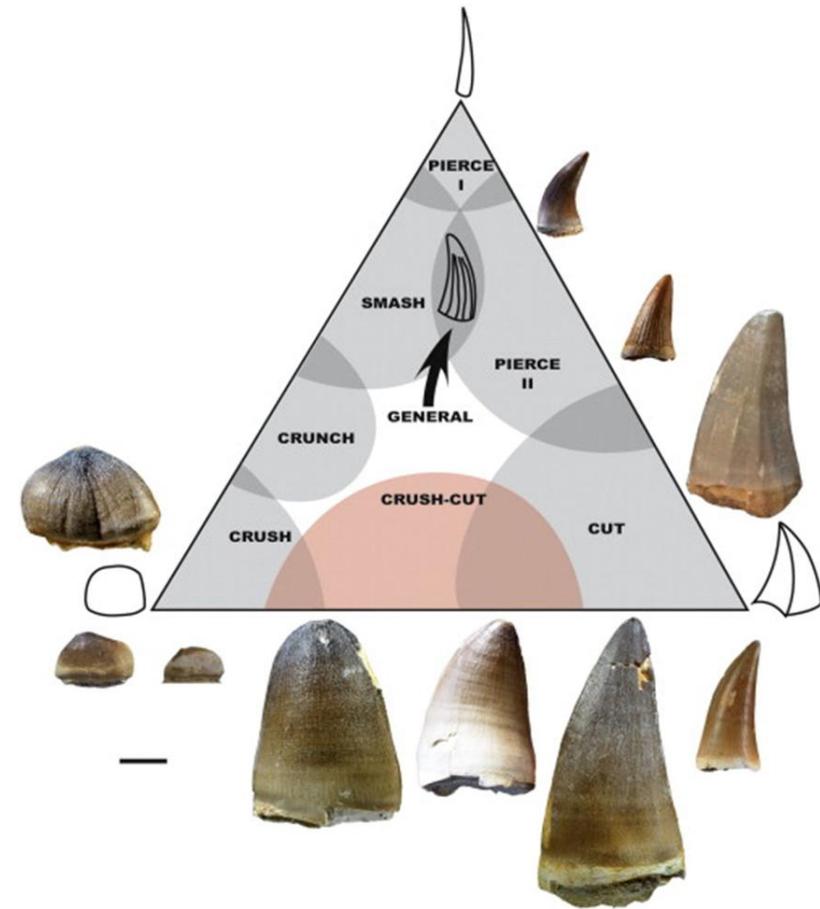
Pelagiczne filtratory mogą wyewoluować jedynie z wielkich drapieżników



Stiefel, 2020

Ewolucja specjalizacji pokarmowych w morzach

- Generalistom pokarmowym najłatwiej przetrwać epizody wymierań.
- Durofagia pojawia się najszybciej ze wszystkich specjalizacji.
- Makrodrapieżnictwo wymaga dużej bazy pokarmowej.
- Filtracja wymaga najdłuższego czasu geologicznego i makrodrapieżnych przodków.



Bardet et al., 2015