



Walking with Whales: The Origin and Evolution of Cetaceans

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Outline

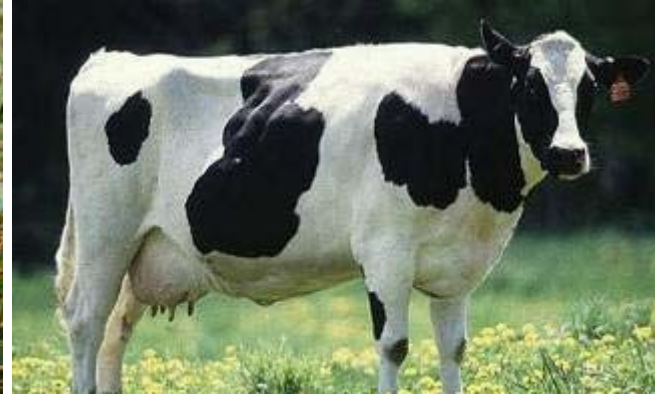
- I. Brief introduction to cetaceans
- II. Historical perspectives on cetacean origins
- III. Fossil record of the earliest cetaceans
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- V. Summary and concluding remarks

What is a whale?

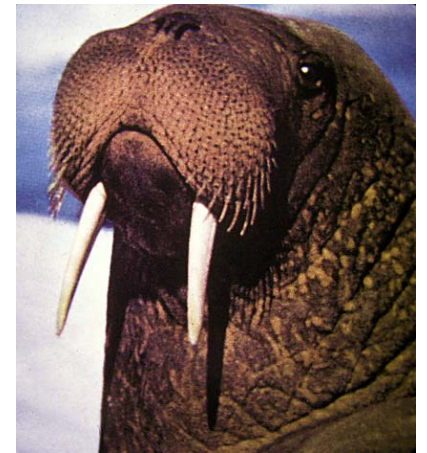
- Whales are **MAMMALS**
 - Breathe atmospheric oxygen
 - Feed their young with milk from mammary glands
 - Live birth with placenta
 - Presence of hair
 - Large brains
 - Many skeletal features
 - Double occipital condyle
 - Dentary-squamosal jaw joint
 - Three middle ear bones
 - Socketed teeth in some
 - ...and many more

But whales are also
SECONDARILY AQUATIC

Most mammals are **TERRESTRIAL**



Some mammals are **SECONDARILY AQUATIC**



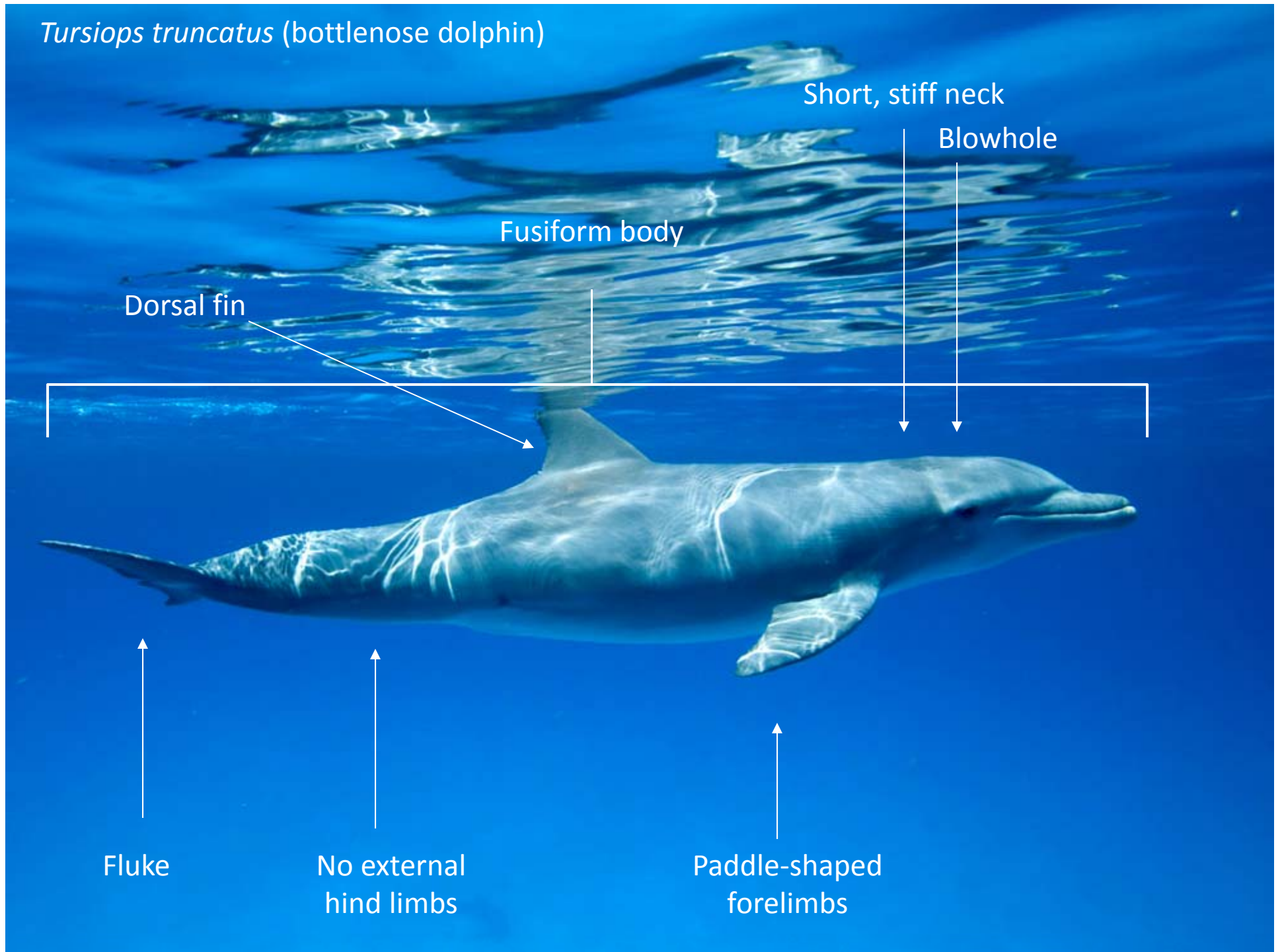
Order Cetacea (Latin: *cetus* = whale)

Odontocetes (toothed whales)

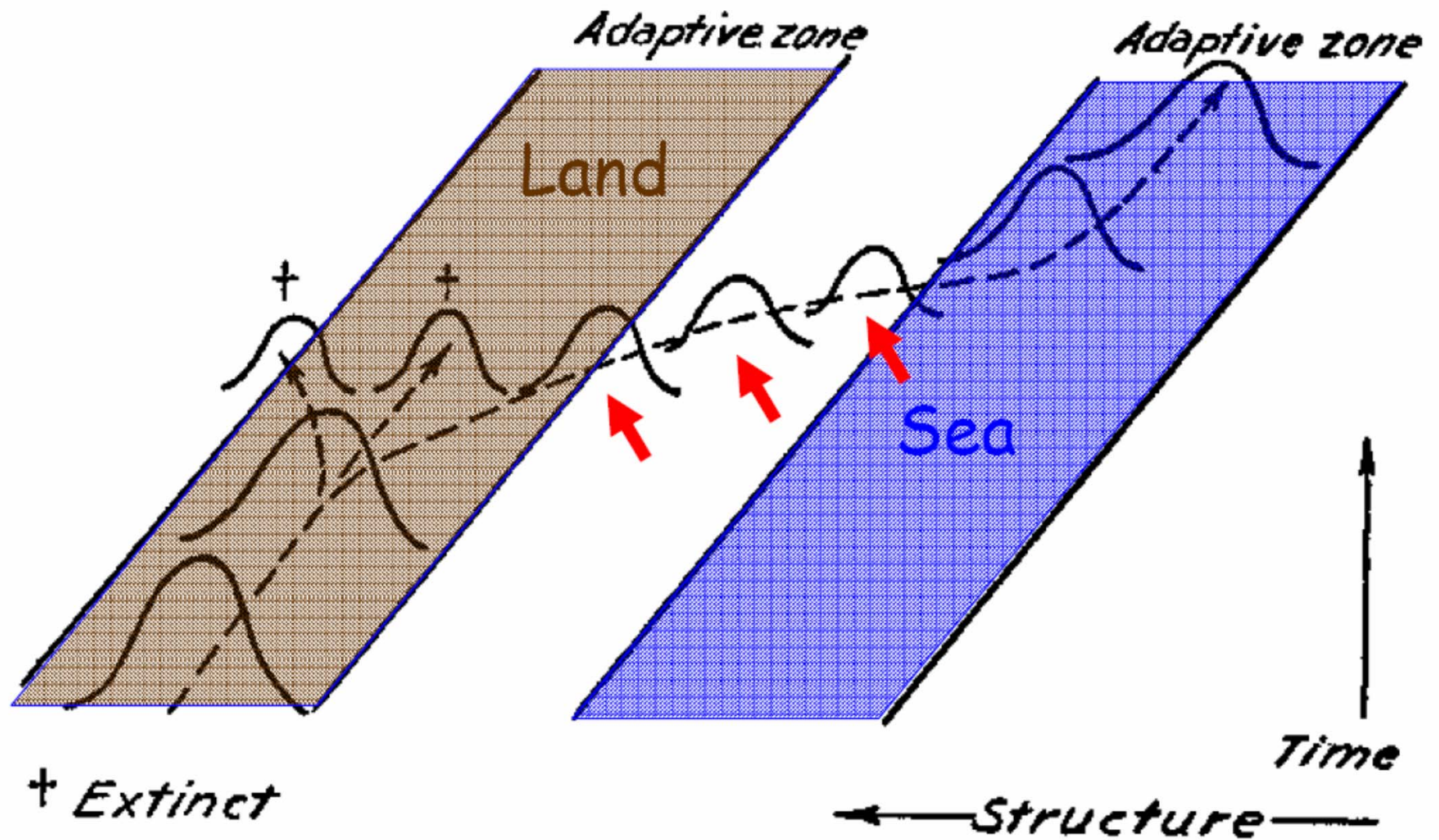
Mysticetes (baleen whales)



Tursiops truncatus (bottlenose dolphin)



Drastic change in adaptive zone



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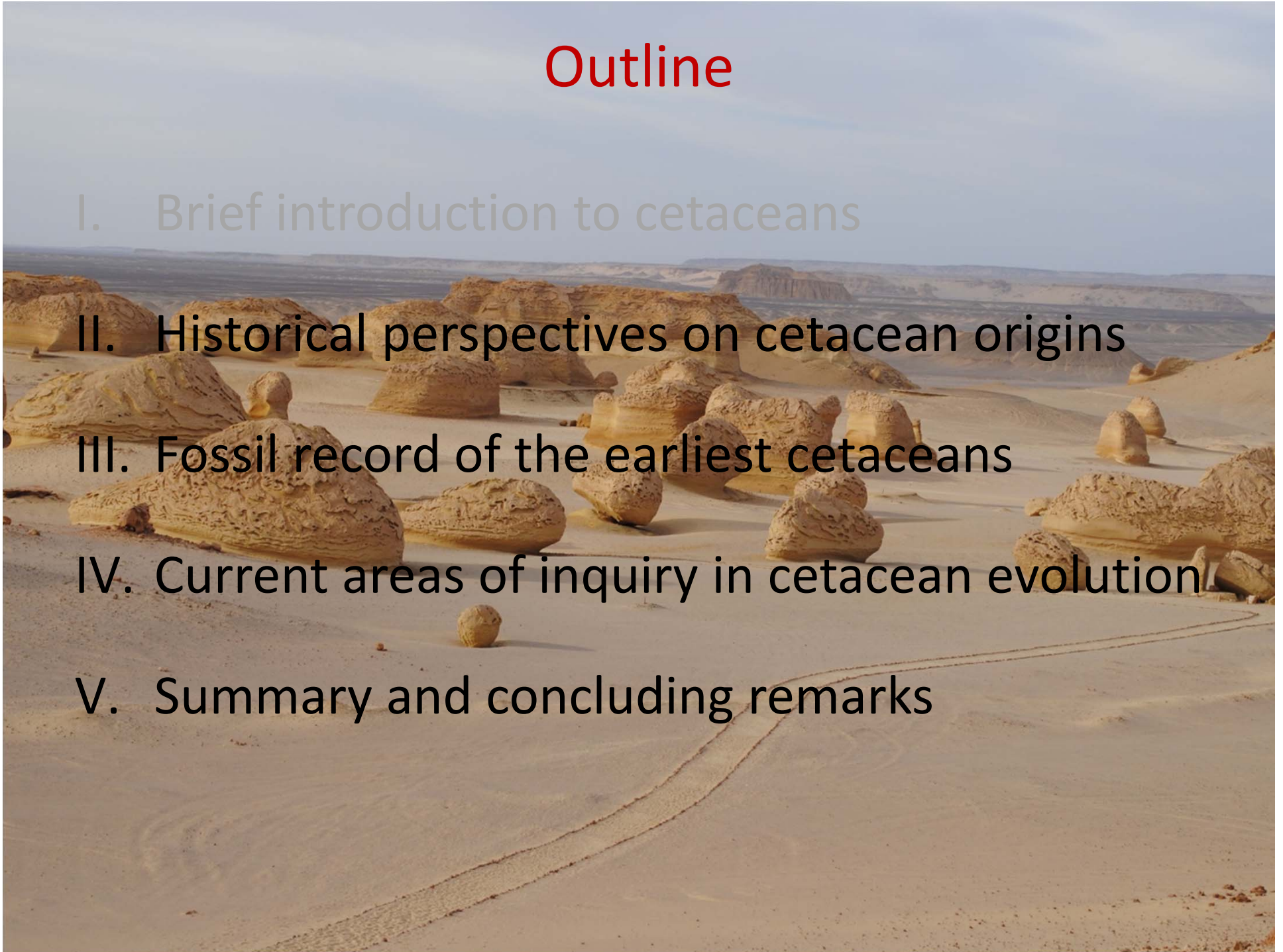
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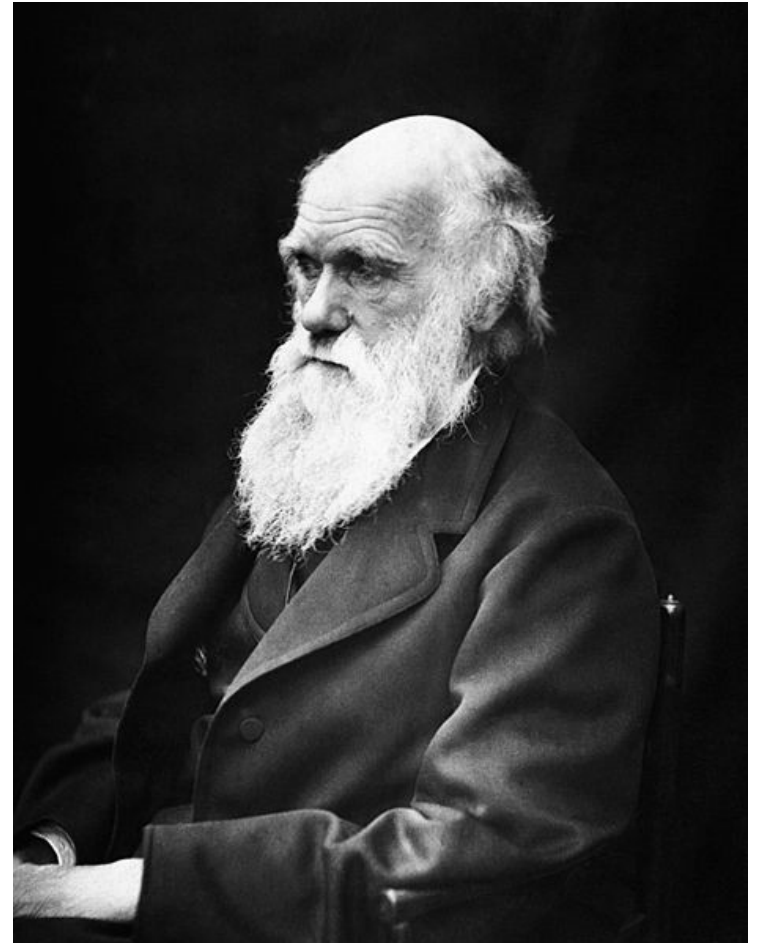
V. Summary and concluding remarks



1859: Charles Darwin

“In North America the black bear was seen by Hearne swimming for hours with widely open mouth, thus catching, like a whale, insects in the water. Even in so extreme a case as this, if supply of insects were constant, and if better adapted competitors did not already exist in the country, I can see no difficulty in a race of bears being rendered, by natural selection, more and more aquatic in their structure and habits, with larger and larger mouths, till a creature was produced as monstrous as a whale.”

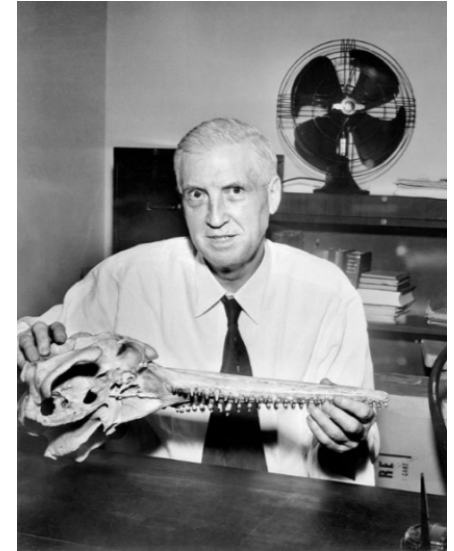
- from *The Origin of Species* (ch.6)



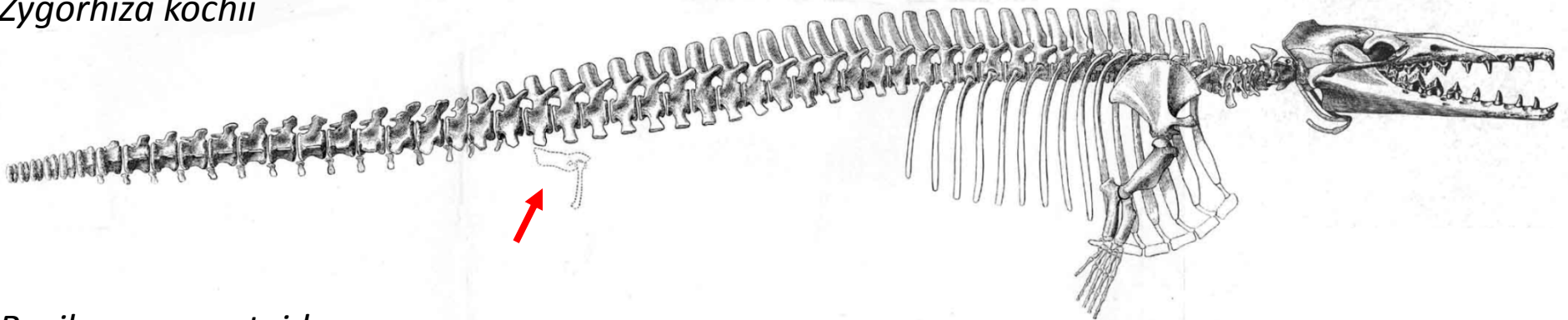
1936: Remington Kellogg

“A Review of the Archaeoceti”

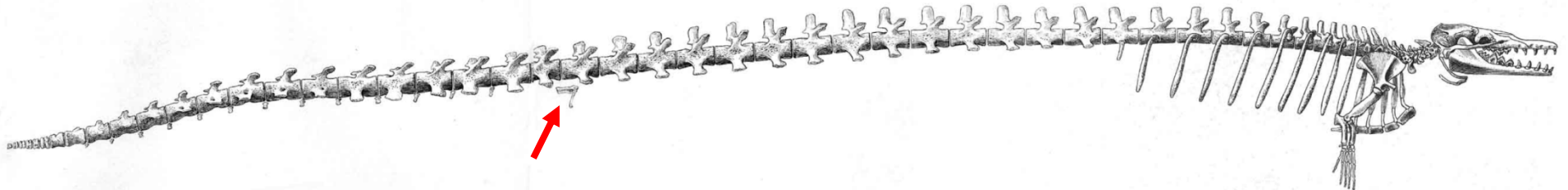
- North American and Egyptian whales
- All clearly fully aquatic



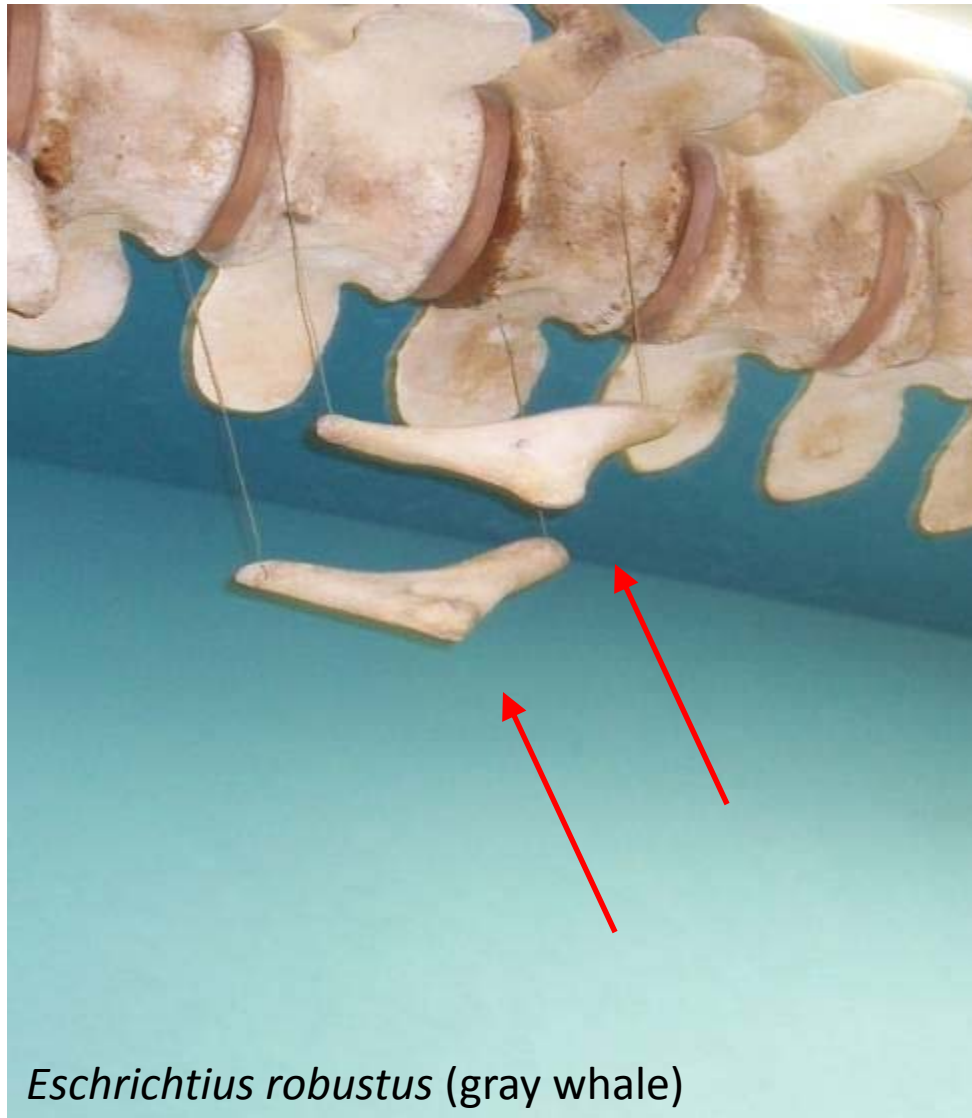
Zygorhiza kochii



Basilosaurus cetoides



Hind limb vestiges in modern cetaceans



1945: George Gaylord Simpson

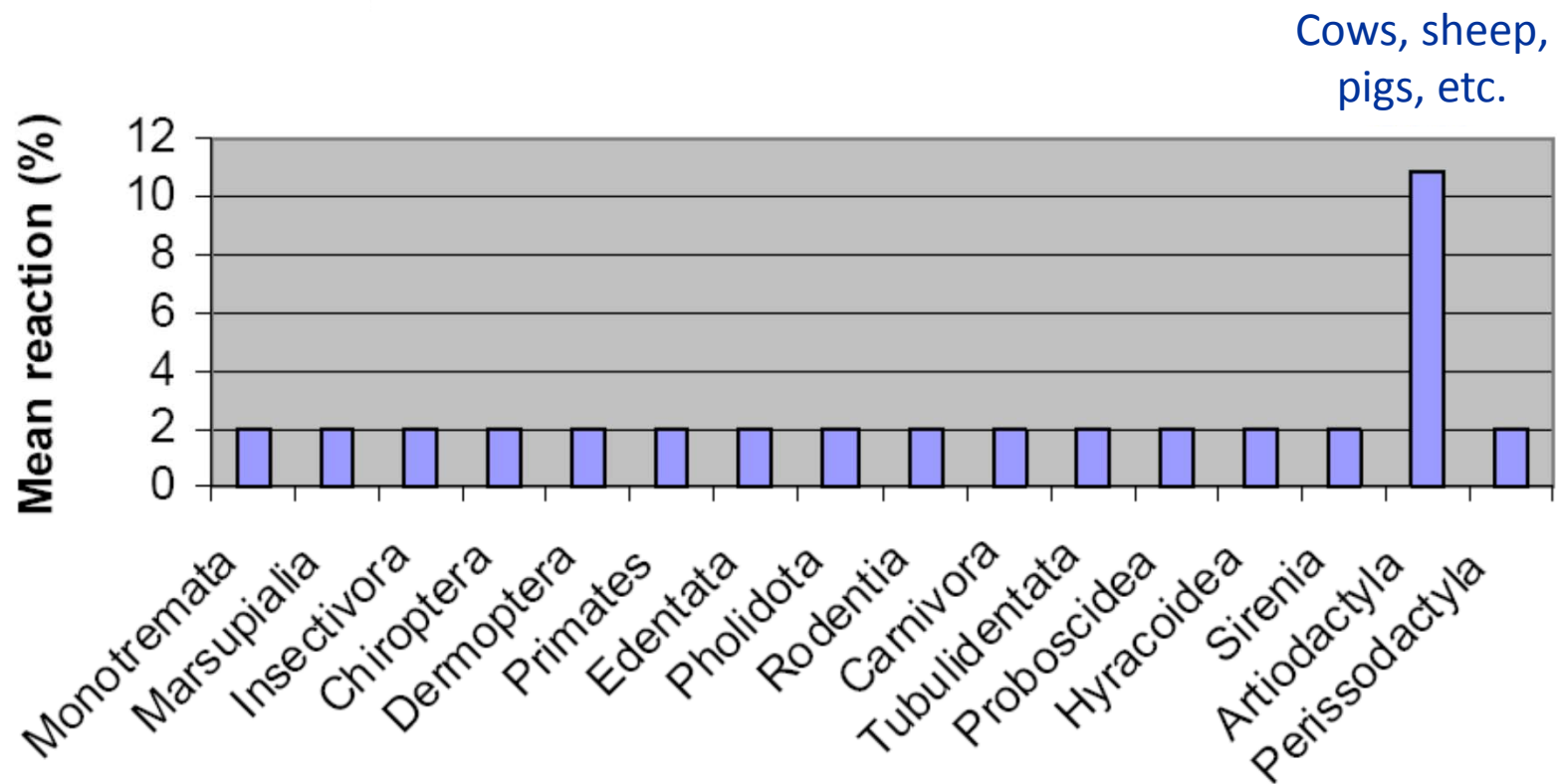
“Because of their perfected adaptation to a completely aquatic life, [...] the cetaceans are on the whole the most peculiar and aberrant of mammals. Their place in the sequence of cohorts and orders [of mammalian classification] is open to question and is indeed quite impossible to determine in any purely objective way.”

- from *Classification of Mammals*

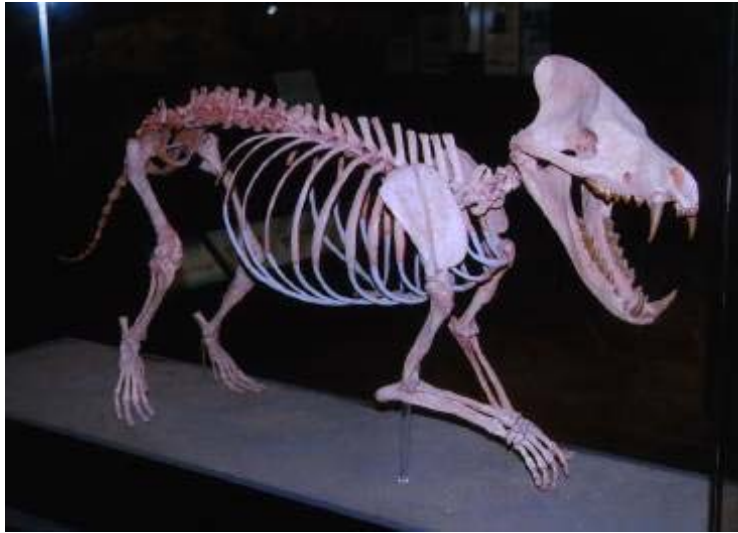


1950: Boyden and Gemeroy

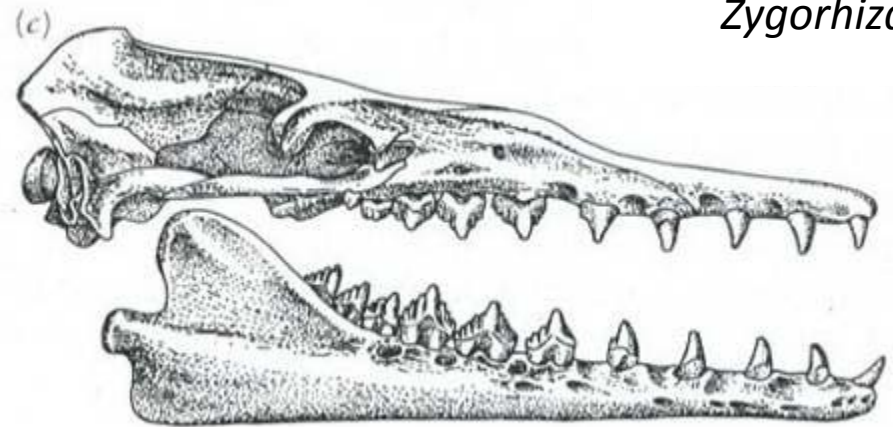
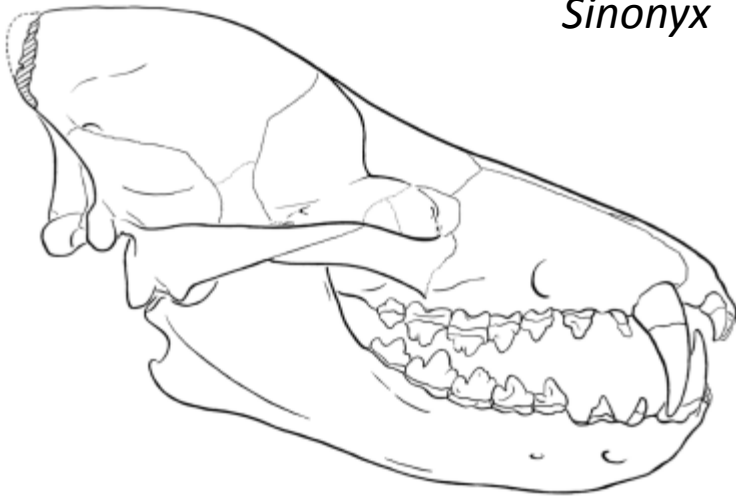
Cetacea Heterologous/Homologous Precipitin Tests (identical would yield 100%)



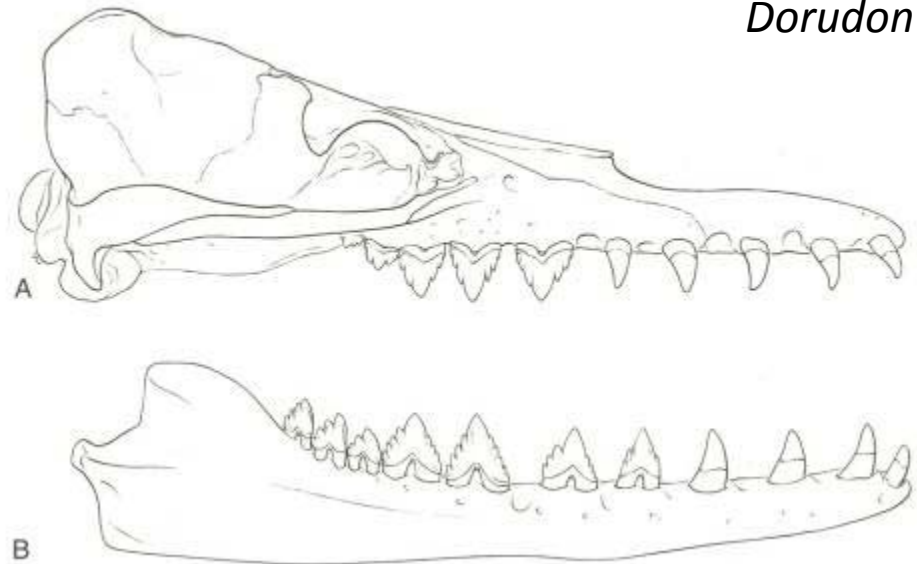
Mesonychids and Cetaceans



Sinonyx



Zygorhiza



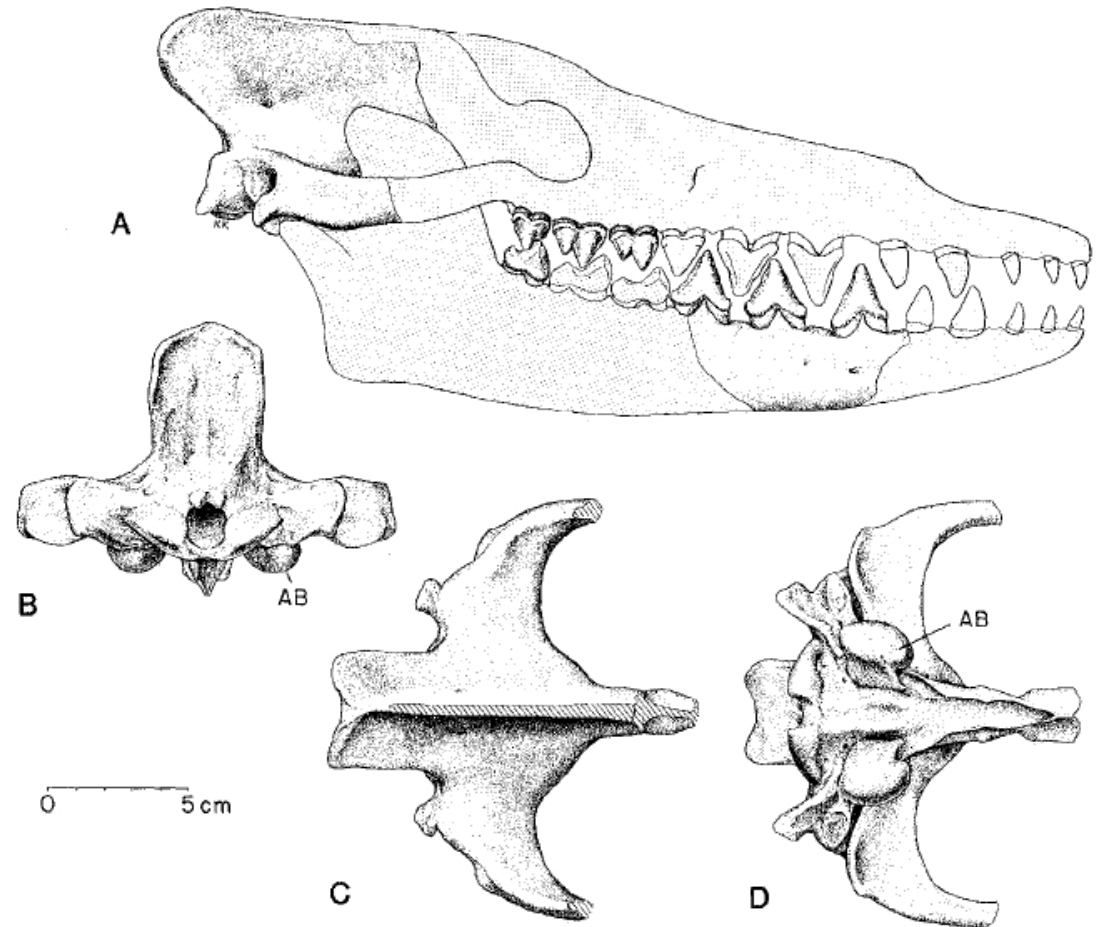
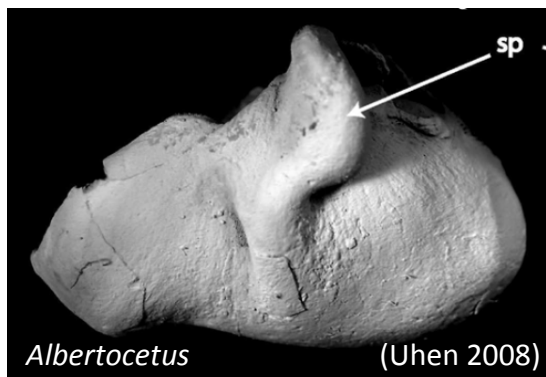
Dorudon

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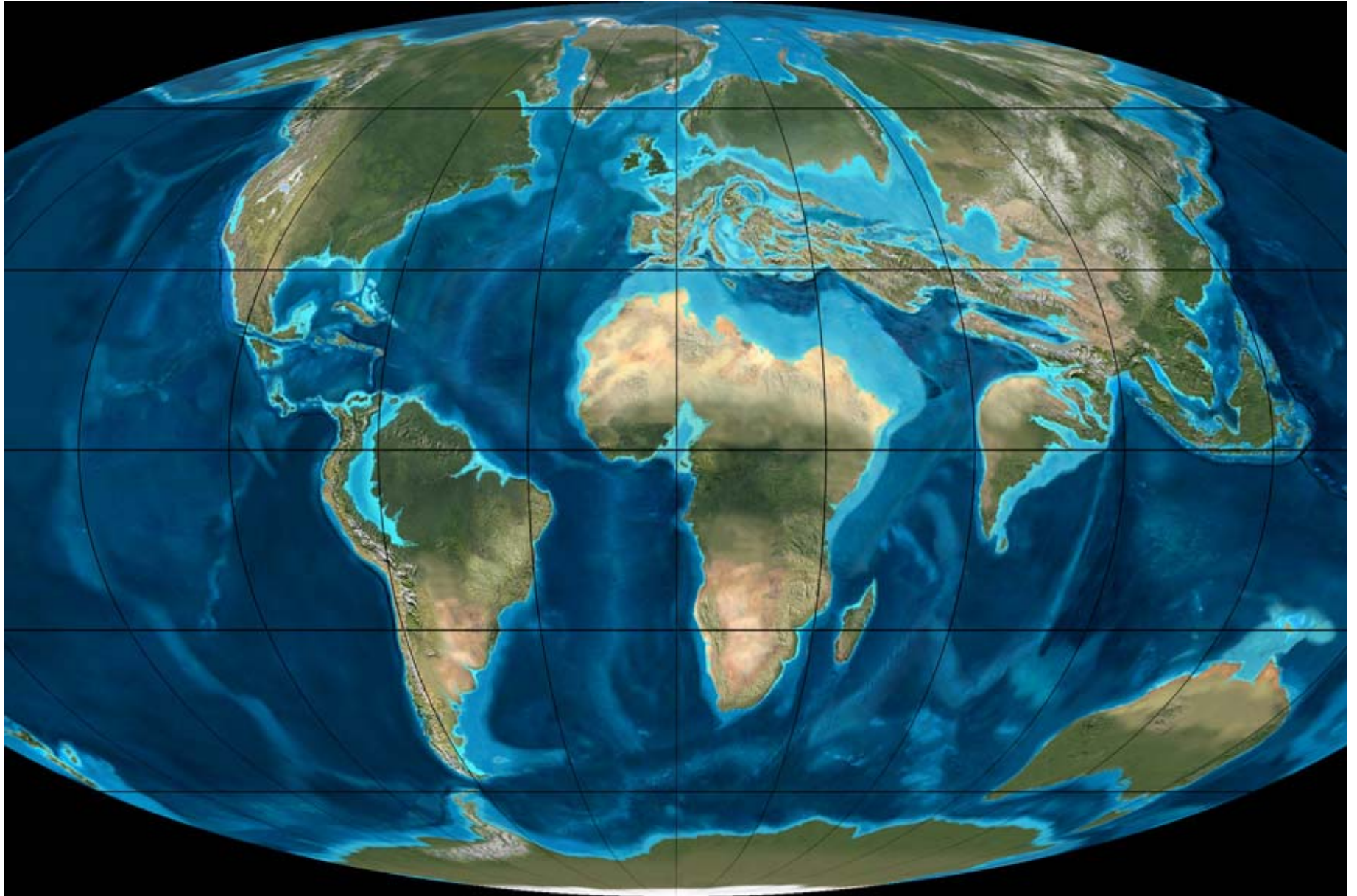
1981: *Pakicetus inachus*

- Pakistan (50 Ma)
- Fluvial sediments bordering ancient Tethys Sea
- Dentition similar to mesonychids
- Dense auditory bullae other ear features seen ***only in cetaceans***

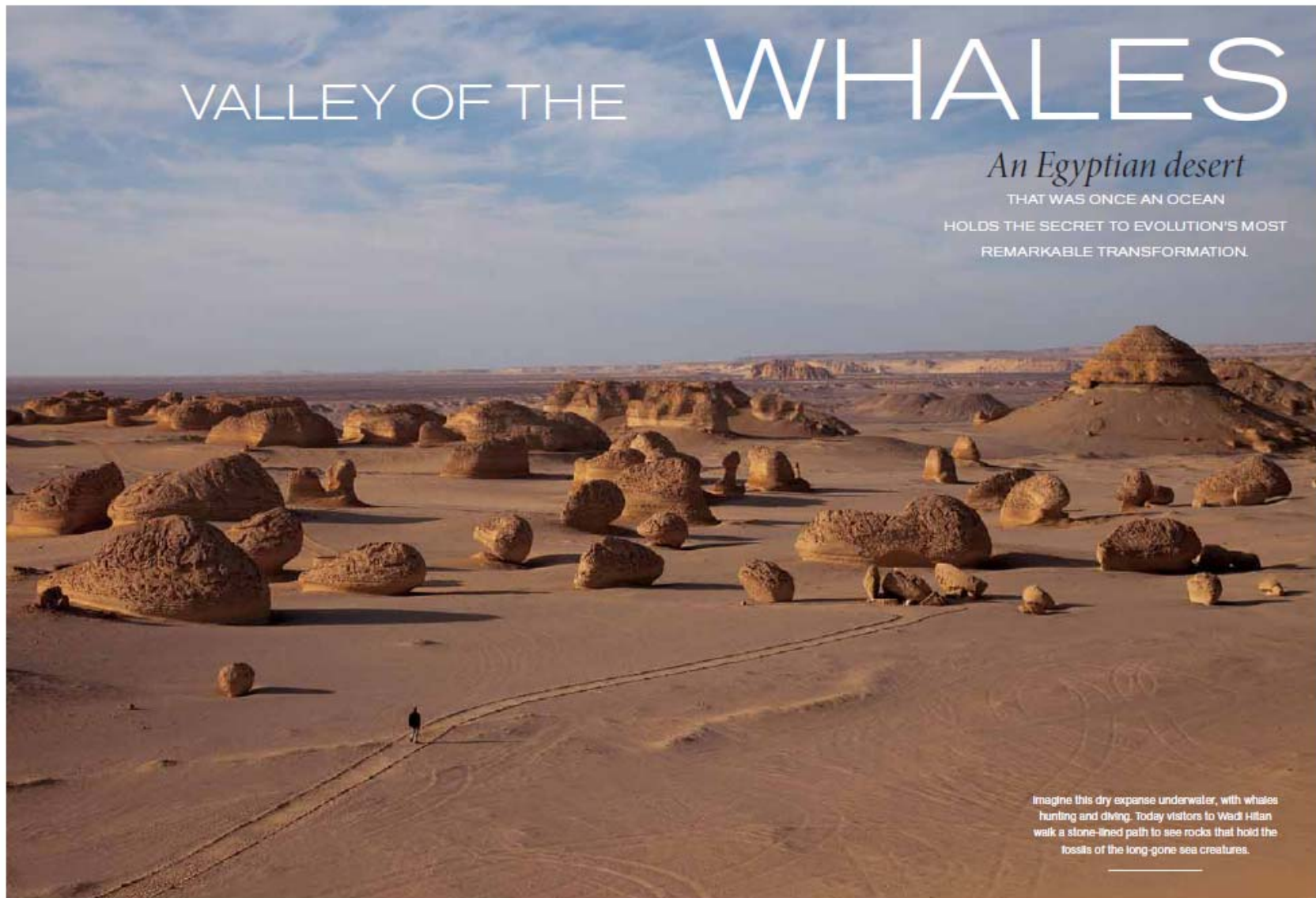


Gingerich and Russell 1981, Gingerich et al. 1983

Eocene Epoch (50 Ma)



Wadi Al-Hitan, Egypt



Wadi Al-Hitan, Egypt



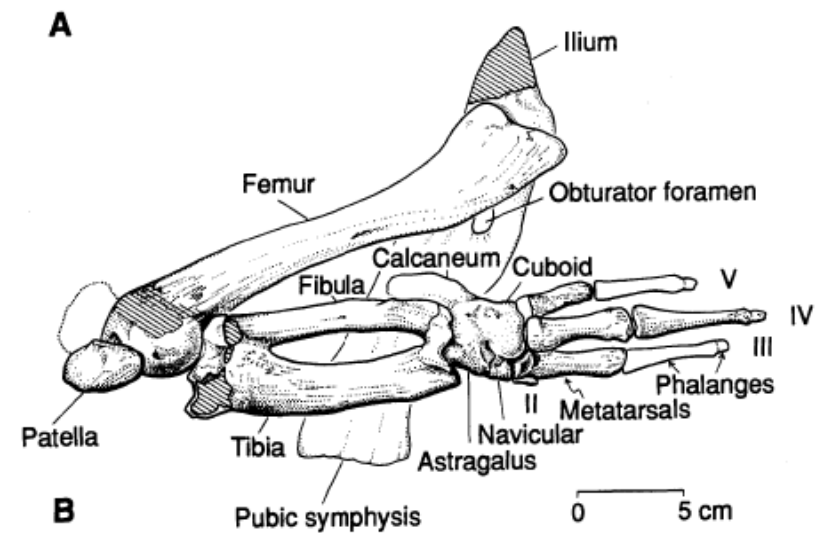
Wadi Al-Hitan, Egypt



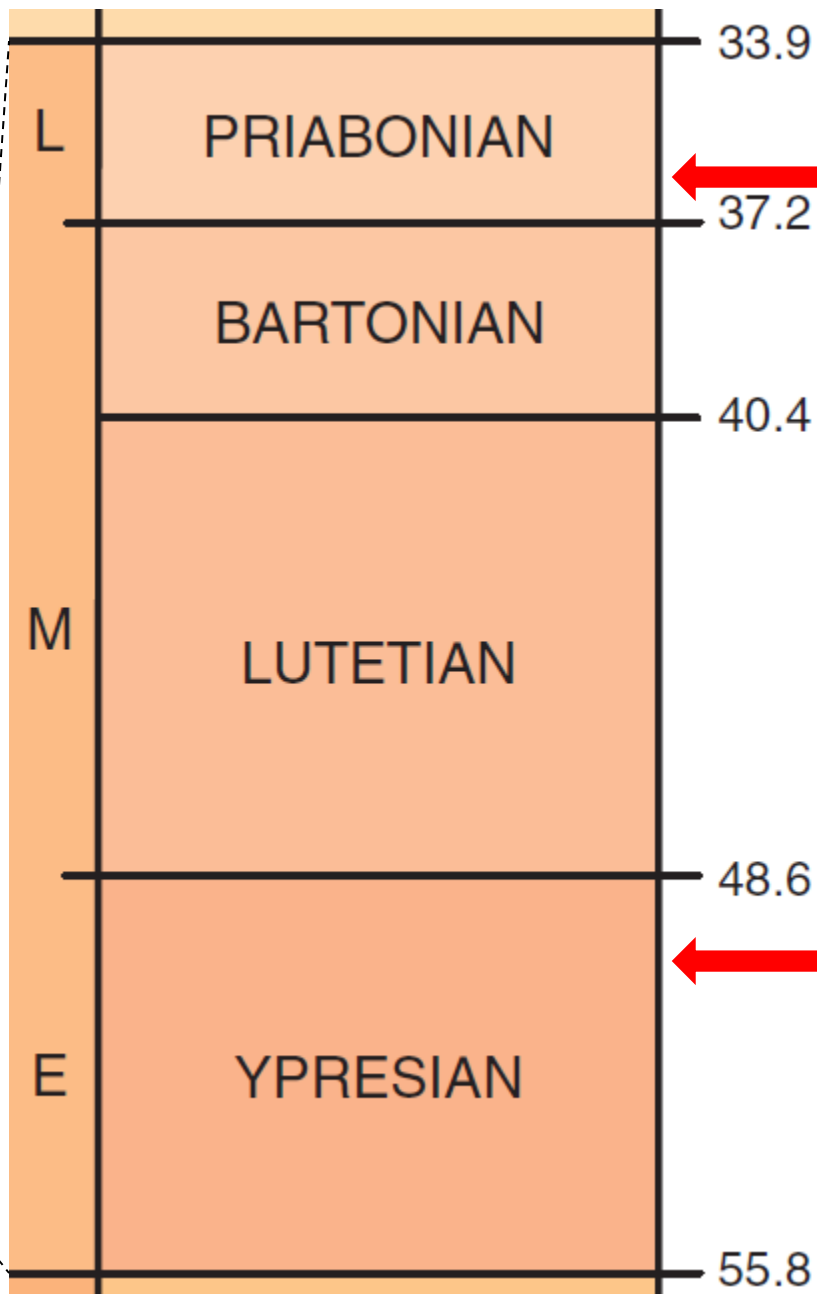
1990: *Basilosaurus isis*



- Egypt (37 Ma)
- Marine shales and sandstones
- Strap-like pelvic bones detached from sacrum, well-formed joint surfaces on femur



Era	Period	Epoch
CENOZOIC	QUATERNARY	HOLOCENE
		PLEISTOCENE (ICE AGE)
	TERTIARY	PLIOCENE
		NEOGENE
		MIOCENE
		OLIGOCENE
		PALEOGENE
		EOCENE
		PALEOCENE

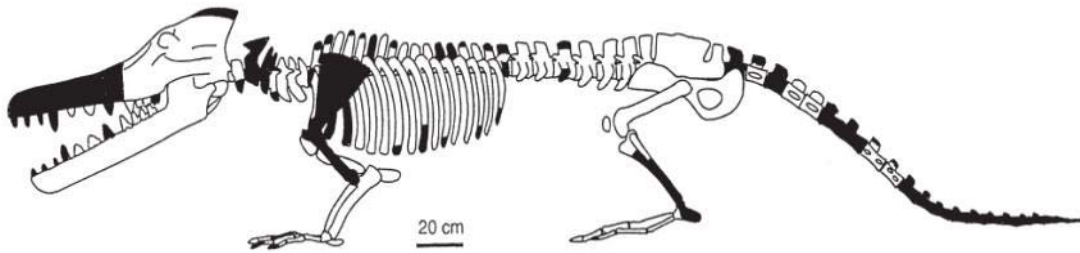


Basilosaurus

13 Million
Years

Pakicetus

1994: *Ambulocetus natans*



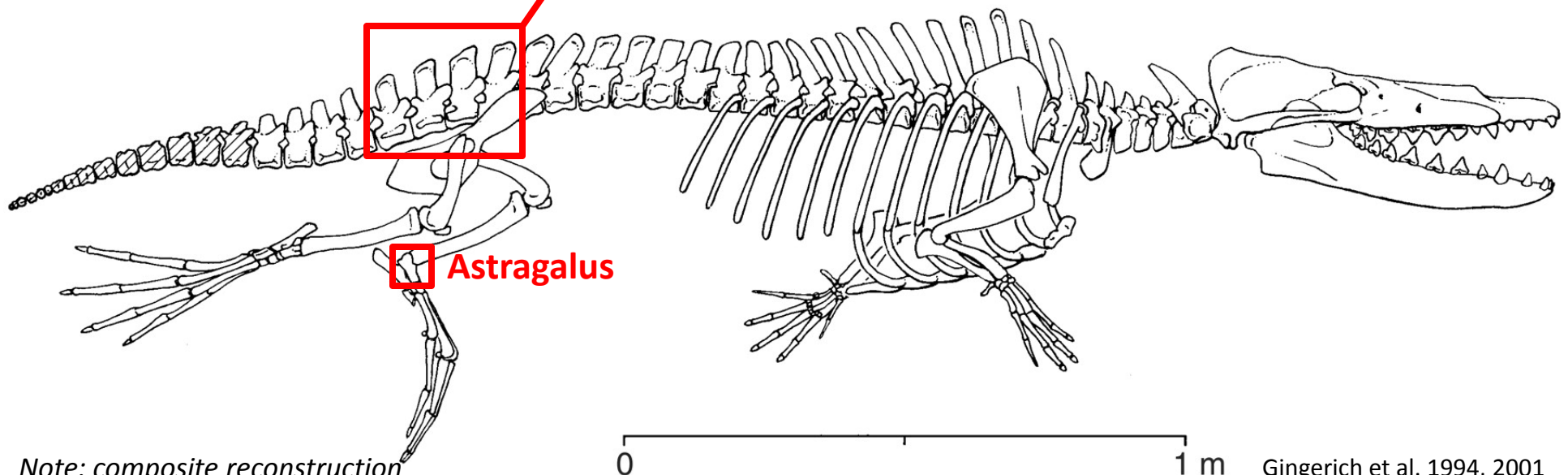
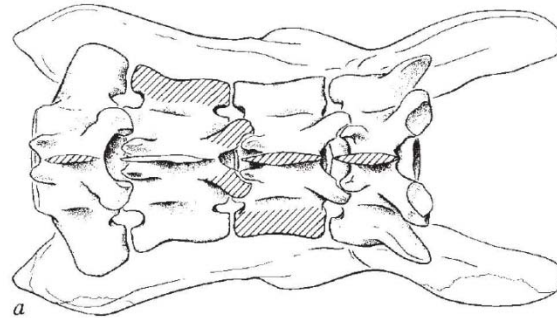
- Pakistan (47.5 Ma)
- Shallow marine deposits
- Robust limbs, fused sacrum, flexible elbow/wrist joints → capable of walking on land
- Large hind feet, seemingly powerful back and tail → proficient swimmer
- Clearly a **semiaquatic cetacean**

Note: composite reconstruction

Thewissen et al. 1994, Thewissen and Bajpai 2001

1994, 2001: *Rodhocetus* sp.

- Pakistan (46.5-47 Ma); marine shales
- Unfused sacrum → sign of increasingly flexibility for dorsoventral undulation
- Structure of hands → limited terrestrial locomotion
- Expanded feet → pelvic paddling in water



Note: composite reconstruction

Gingerich et al. 1994, 2001

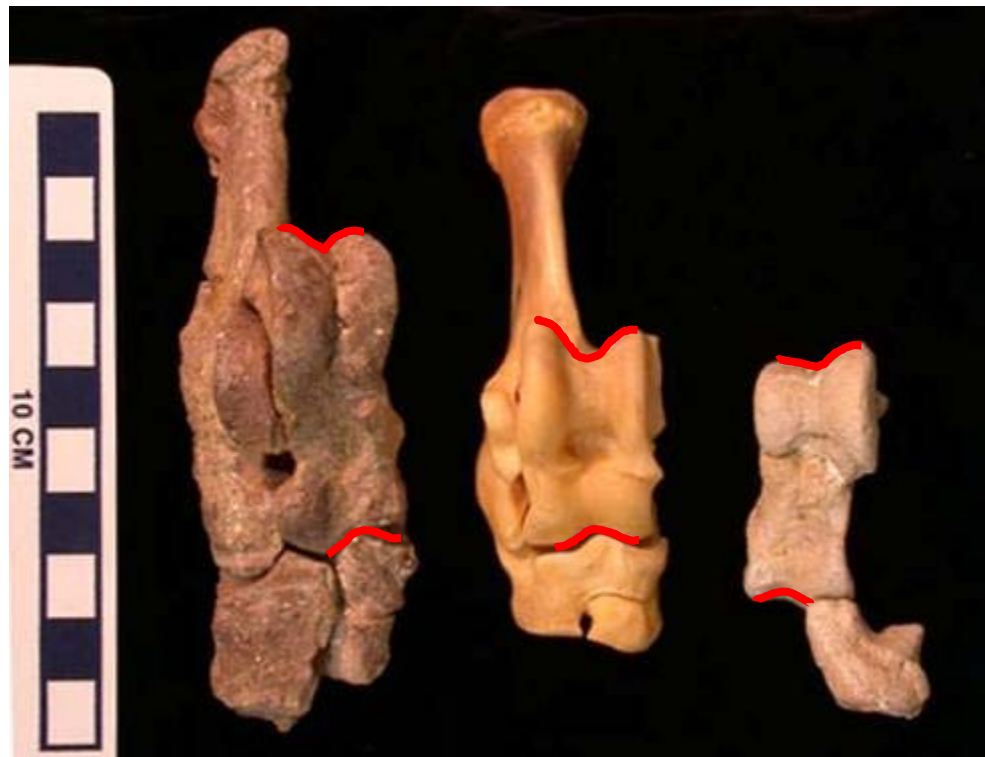
Cetacean Astragali

Canus

(most mammals)



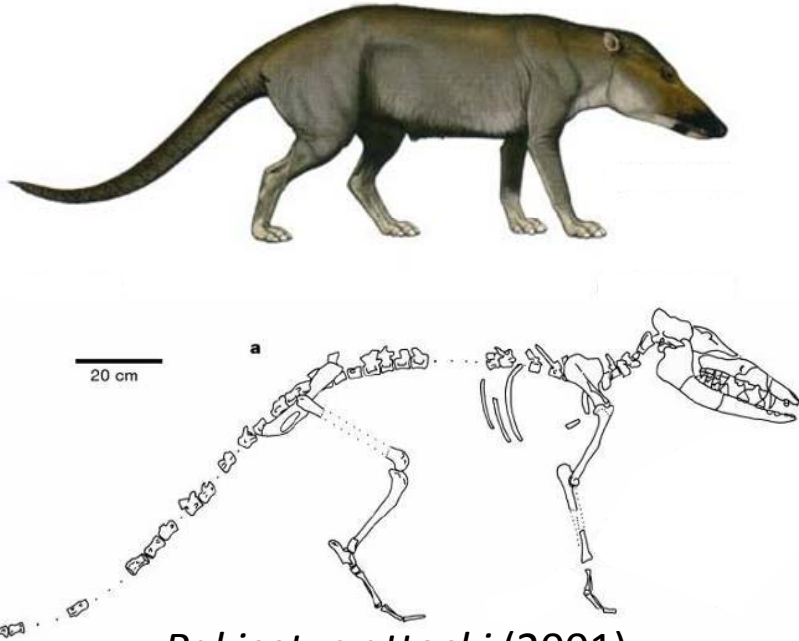
Rodhocetus Antilocapra Artiocetus



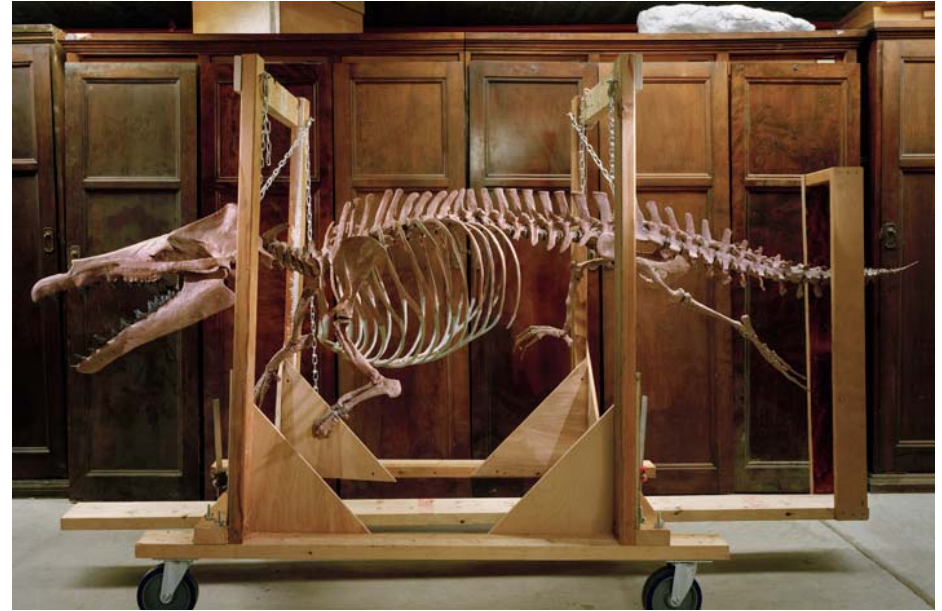
Hippopotamus



Since 2001...



Pakicetus attocki (2001)

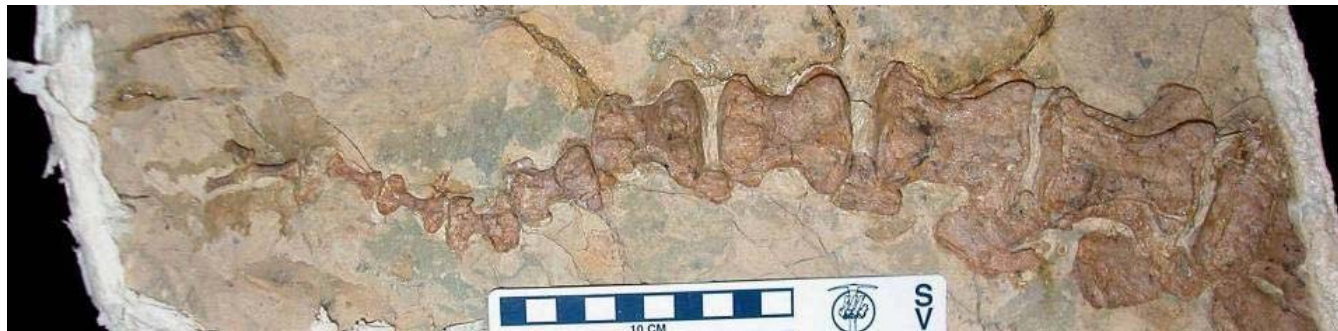
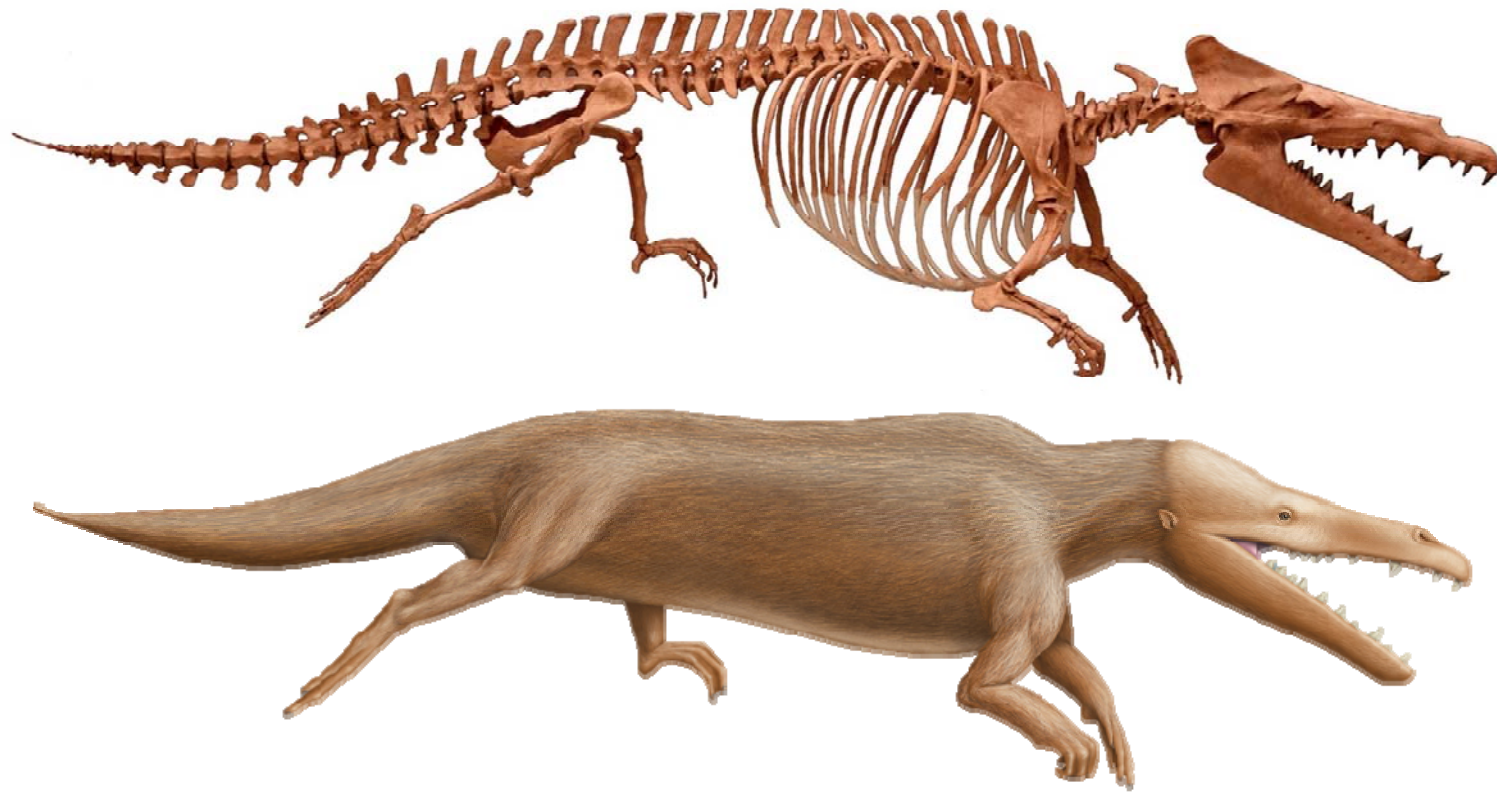


Maiacetus inuus (2009)

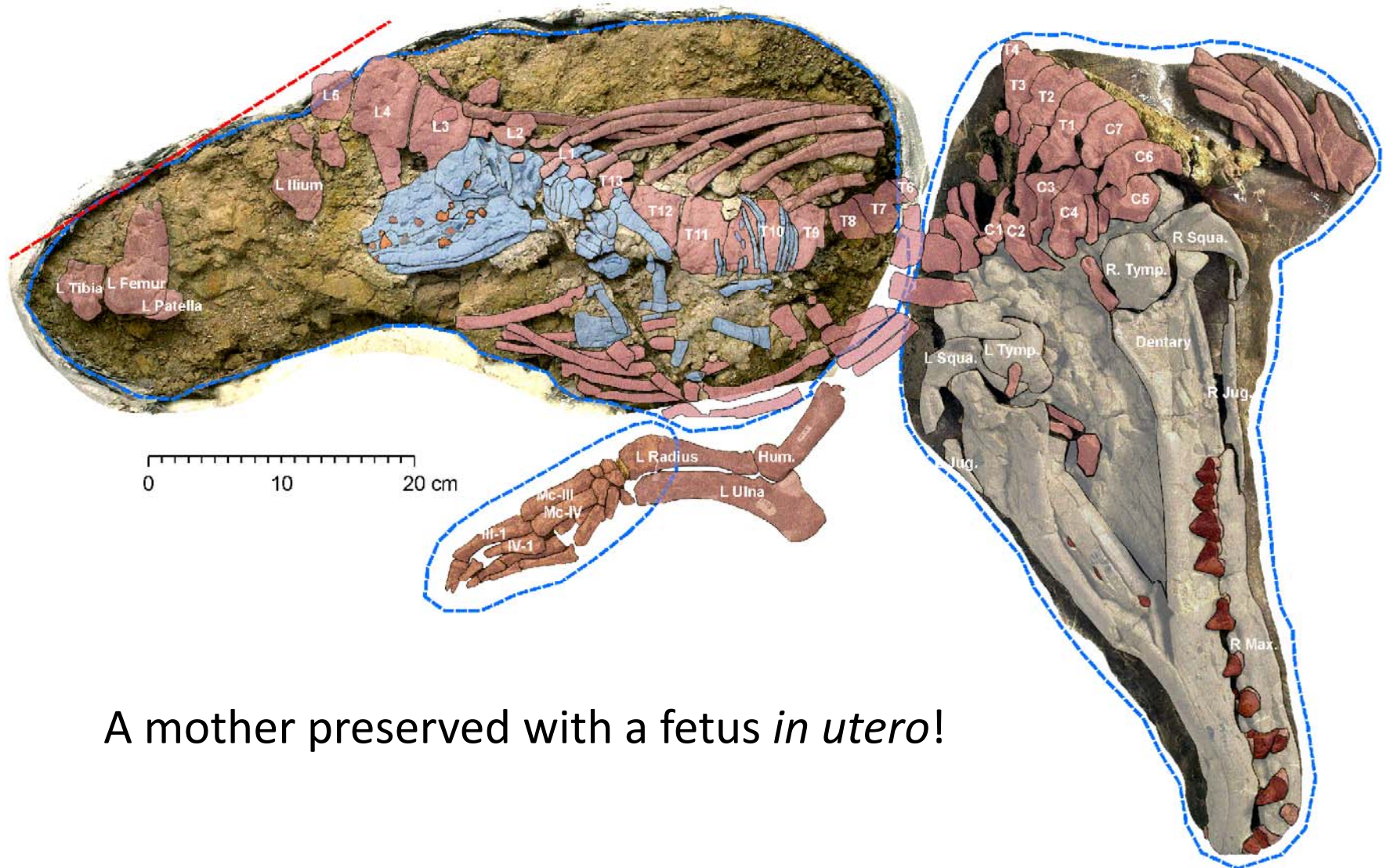


Dorudon atrox (2004)

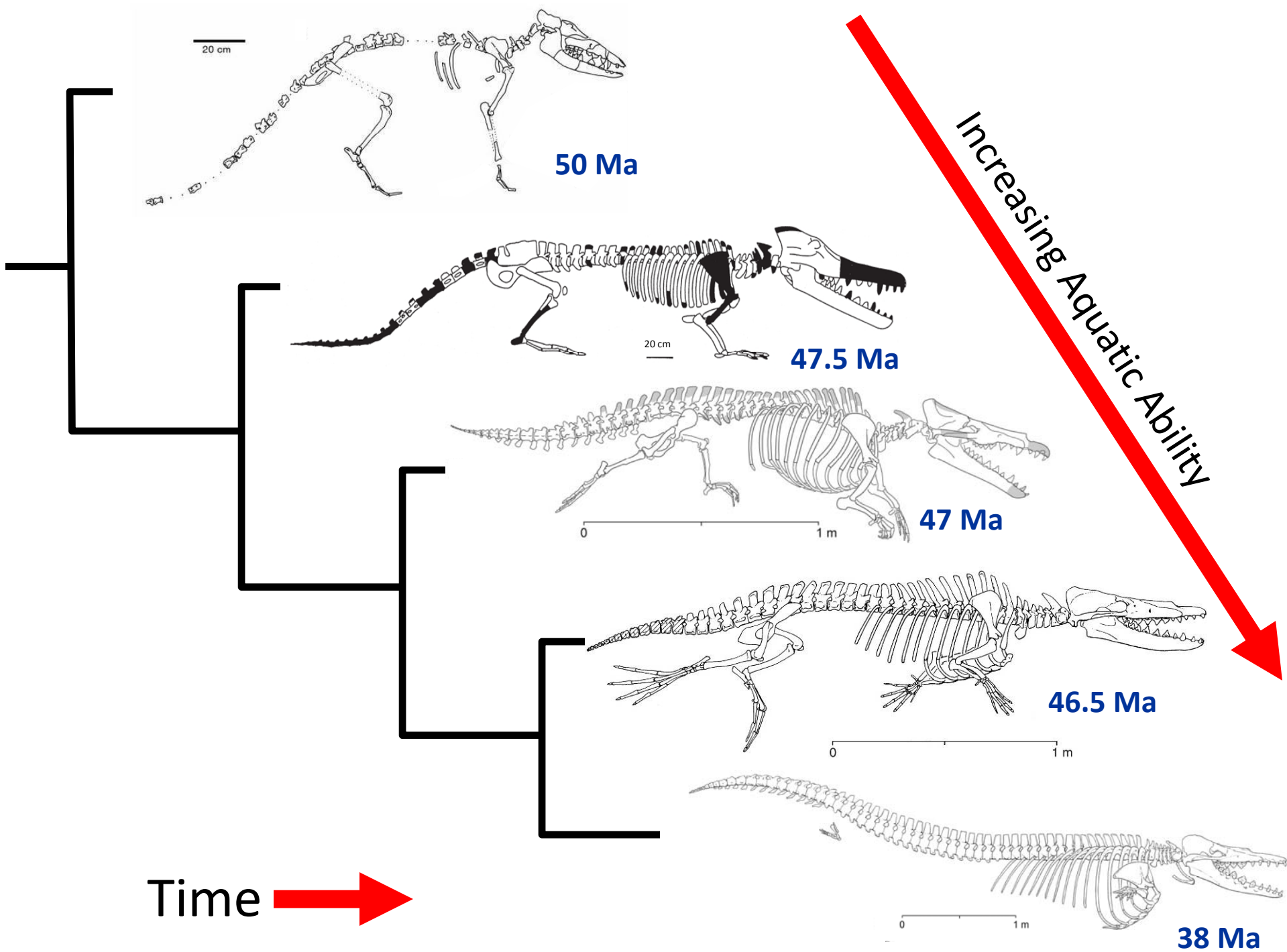
2009: *Maiacetus inuus*



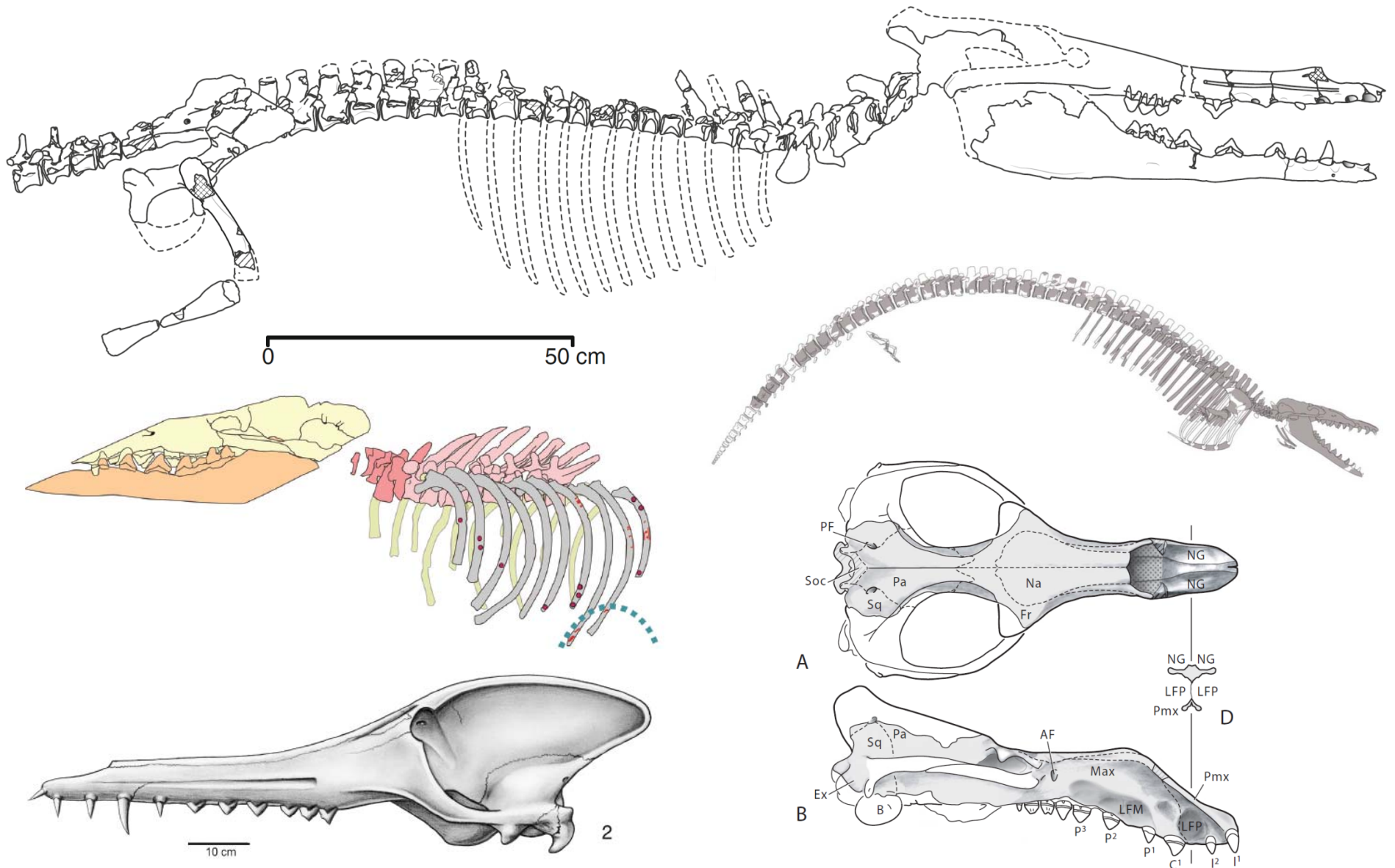
2009: *Maiacetus inuus*



A mother preserved with a fetus *in utero*!



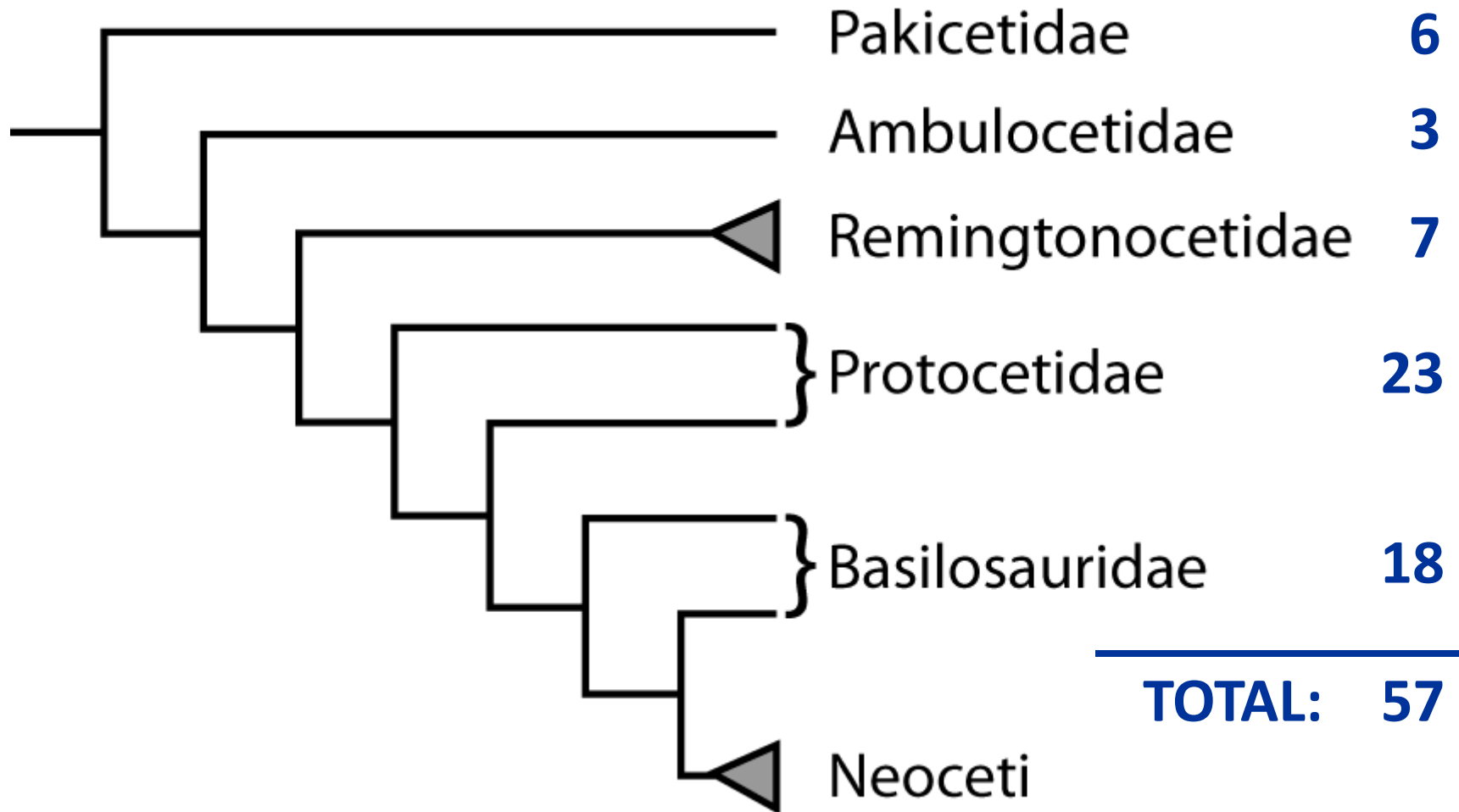
Eocene Cetaceans



Gingerich et al. 2005, Thewissen & Bajpai 2009, Bianucci & Gingerich 2011, Martínez-Cáceres & de Muizon 2011, Bebej et al. 2012

Eocene Cetaceans

*Number of
Species*



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Locomotor Evolution

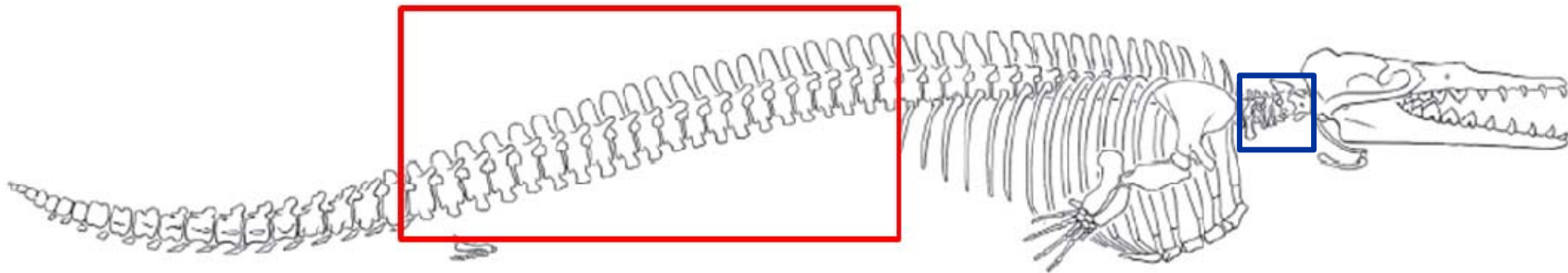
How does an animal go from swimming by paddling four limbs (how most mammals swim)...



...to losing its hind limbs and developing a specialized tail for propulsion?

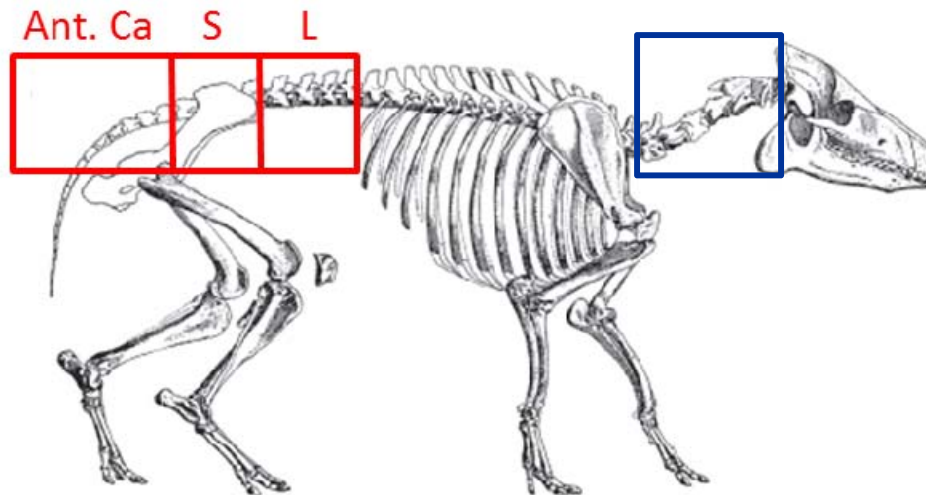
Evolution of the Vertebral Column

Dorudon atrox



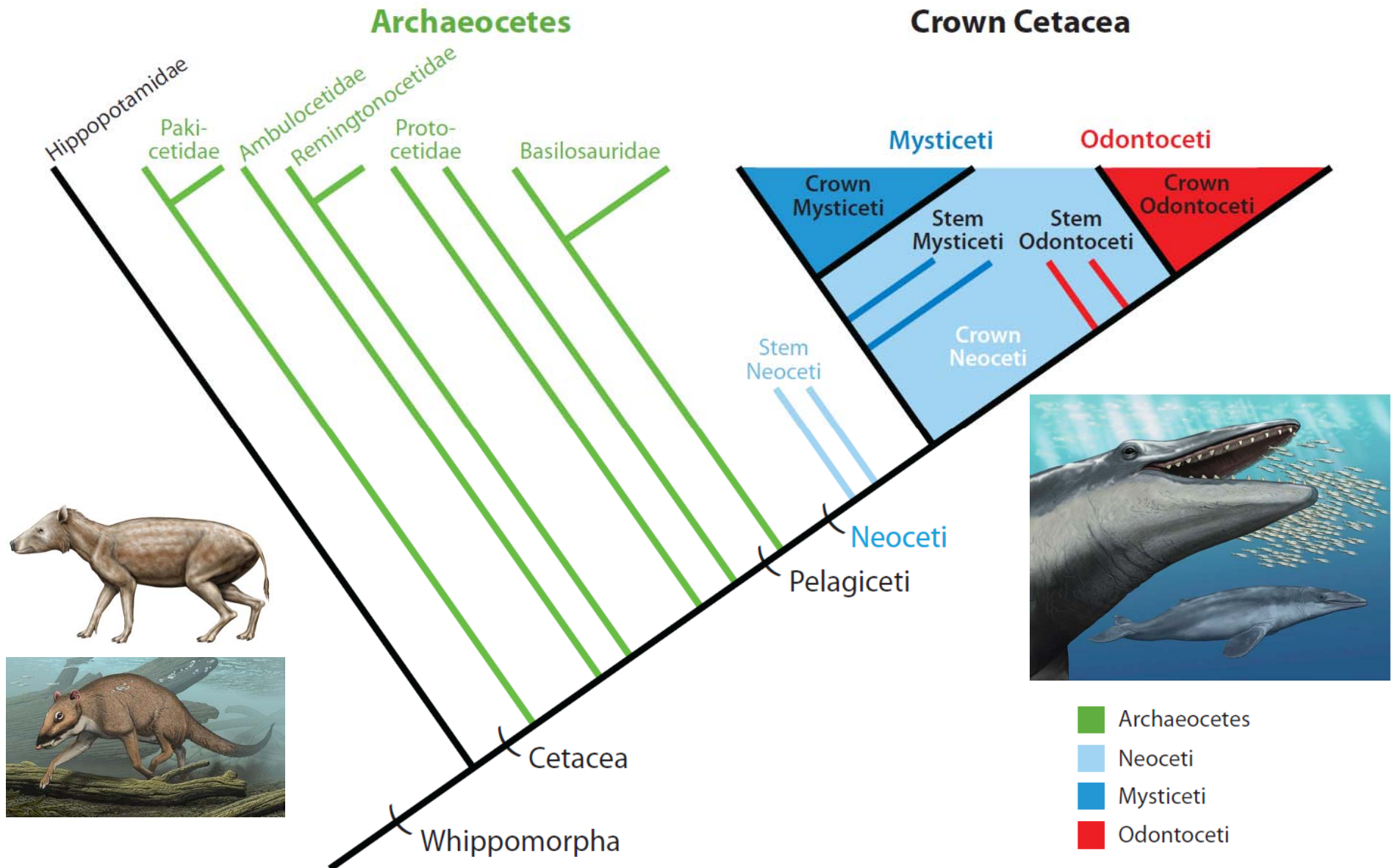
Lumbar, sacral, &
anterior caudal regions

Cervical region



Elomeryx armatus

Cetacean Phylogeny

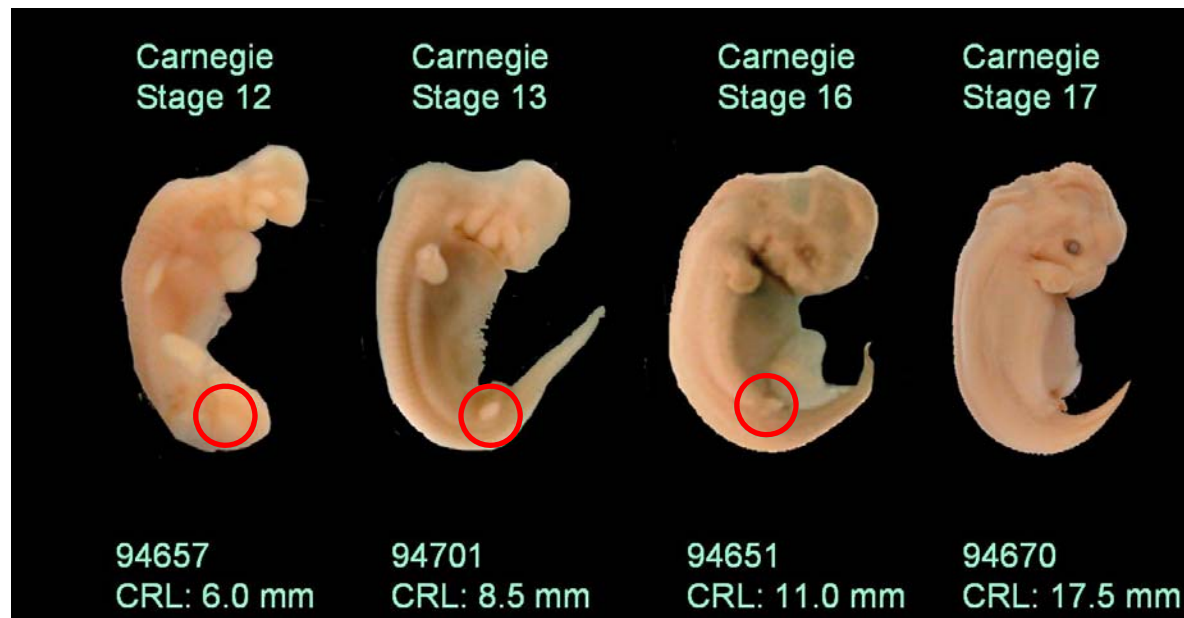


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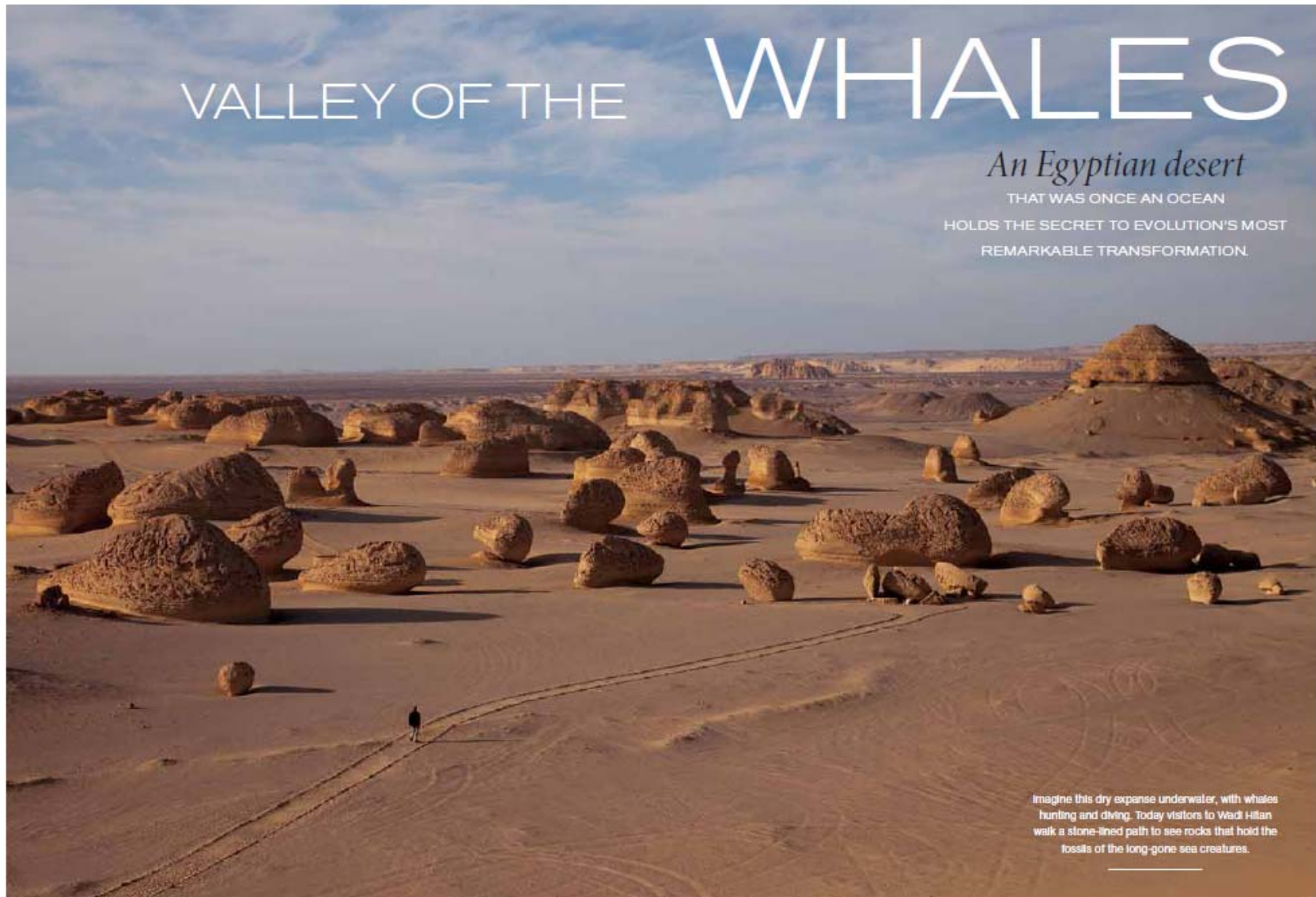
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Concluding Remarks

- Fossil cetaceans with intermediate anatomies appear during the time periods and in the paleoenvironments when and where we expect to find them
- Evidence from development, comparative anatomy, genetics, biogeography, and stable isotope analyses corroborate the scenario illustrated by the fossil record



Further Reading (bebej@calvin.edu)



Questions?

