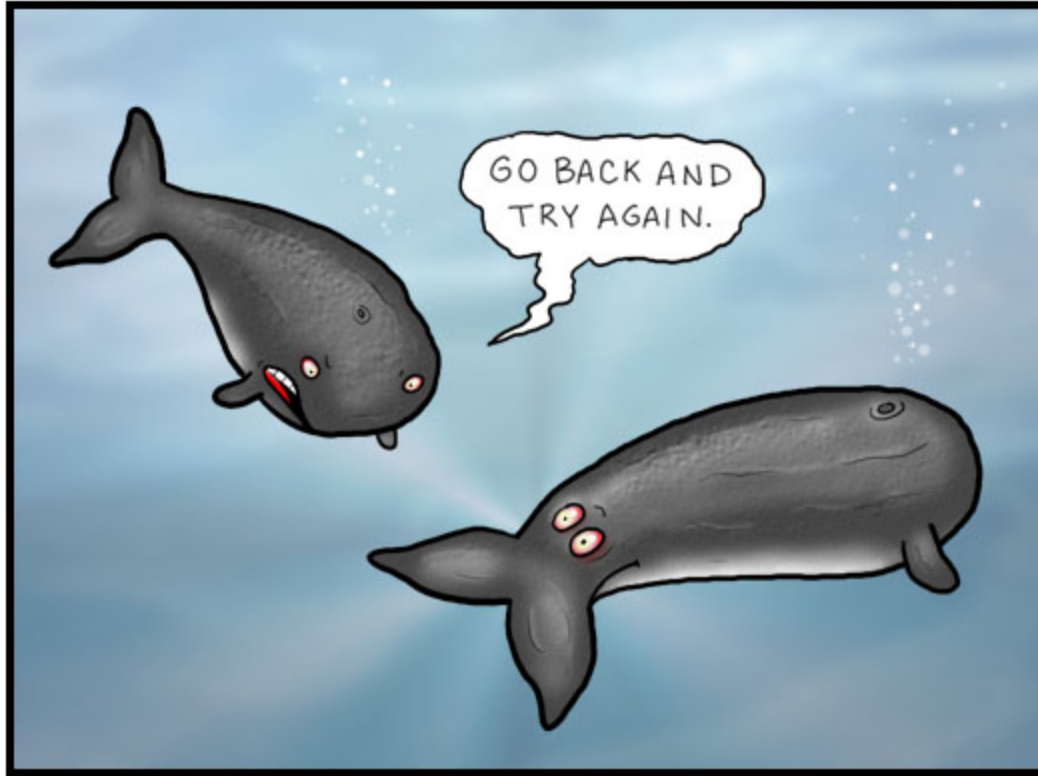


The Evolution of Whales

Geology 331

DOCTOR FUN

7 Feb 2006



The Mis-evolution of Whales

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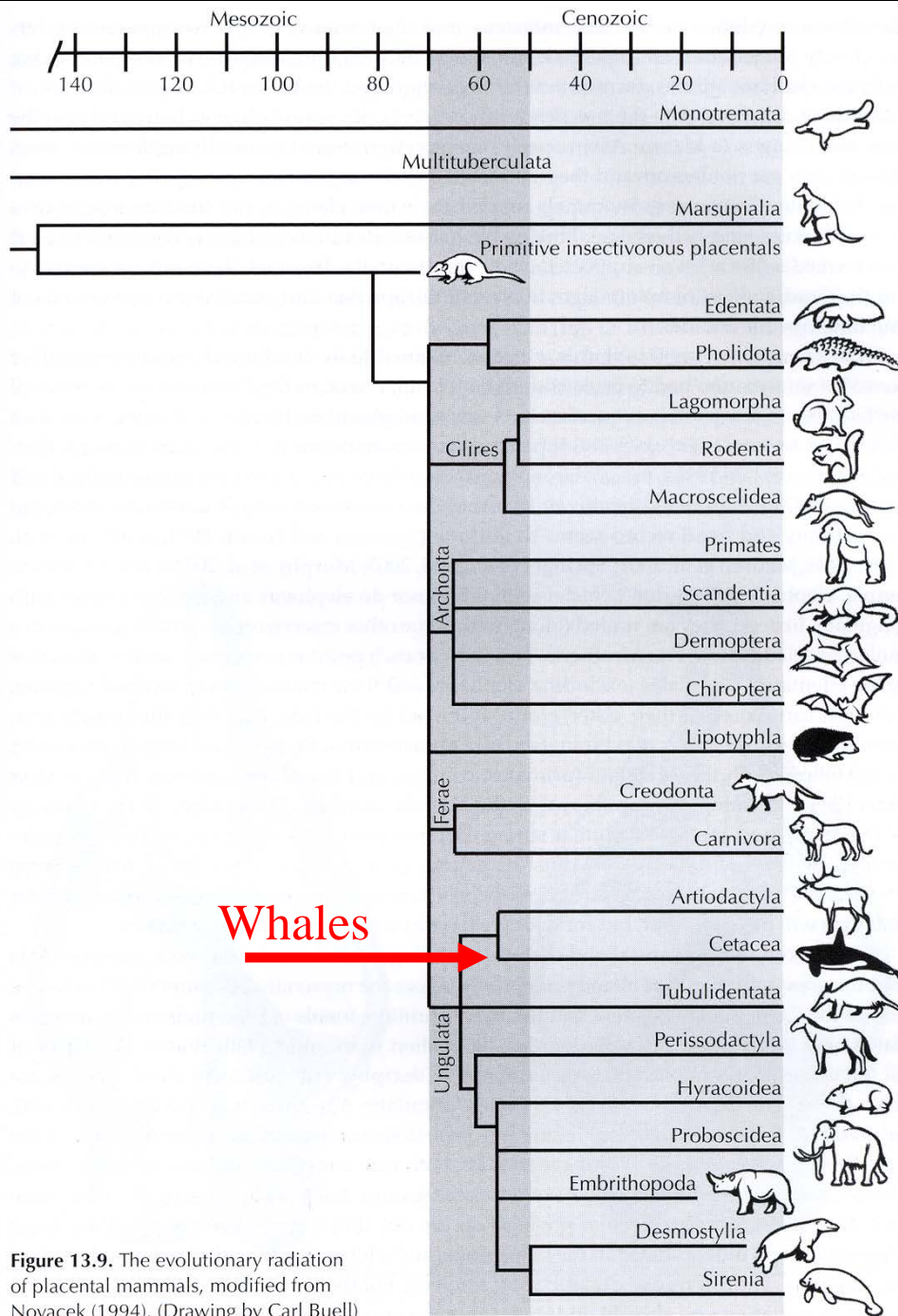
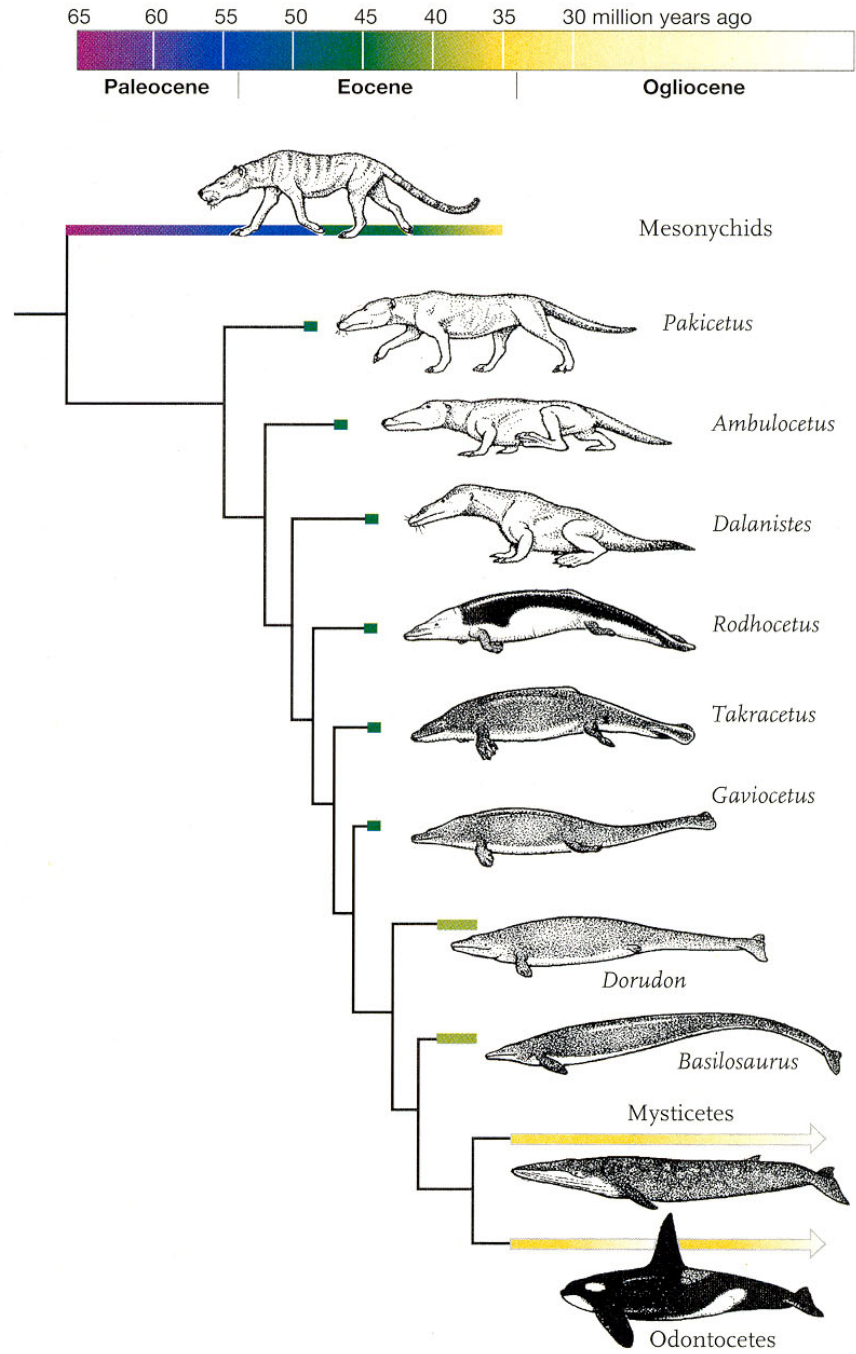


Figure 13.9. The evolutionary radiation of placental mammals, modified from Novacek (1994). (Drawing by Carl Buell)

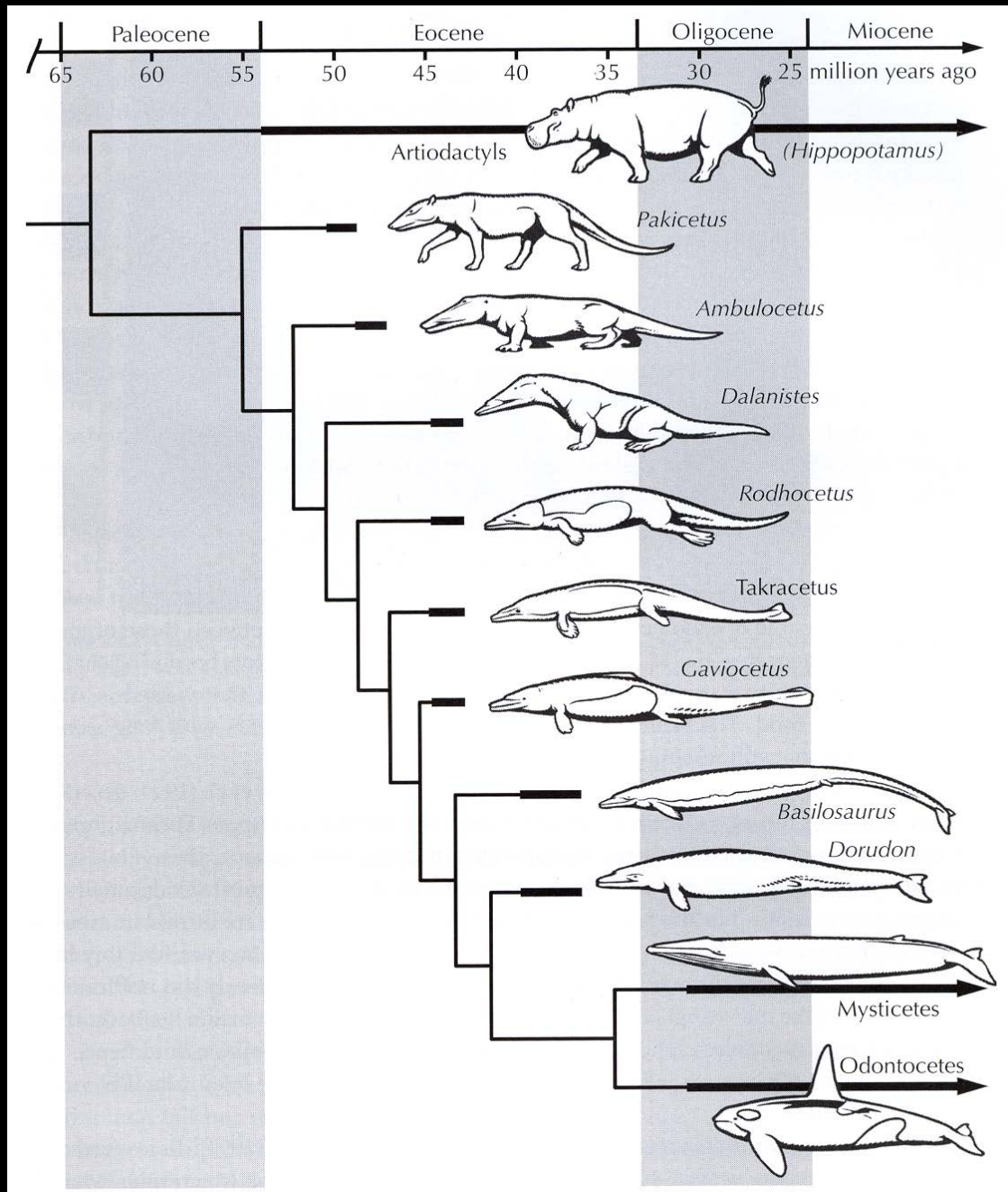
Evolution of Whales

1990s



Evolution of Whales

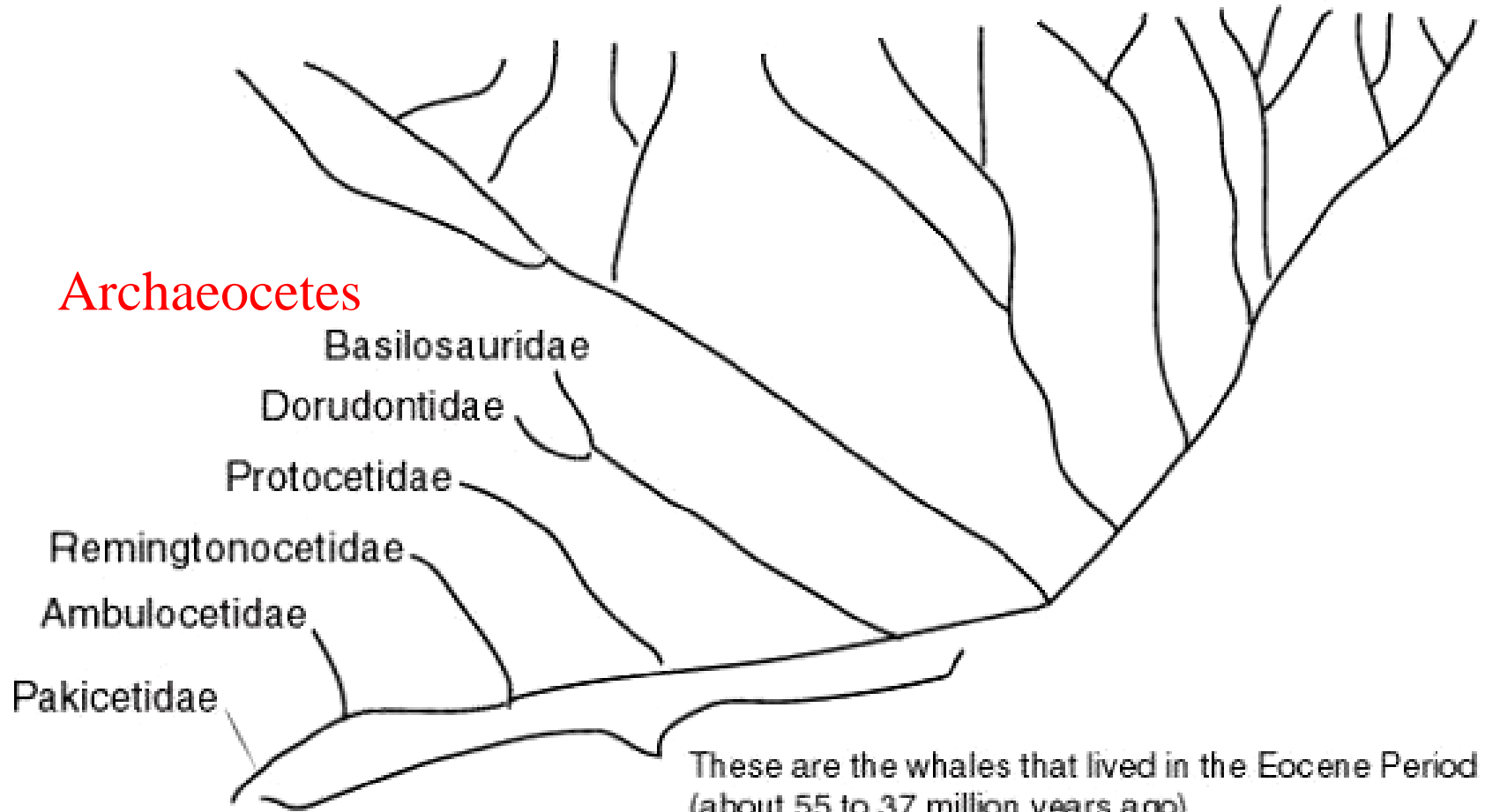
2000s



A family tree of Whales (CETACEA in Latin)

MYSTICETI
(or baleen whales)

ODONTOCETI (or toothed whales,
which includes dolphins and porpoises)



Archaeocetes

Basilosauridae

Dorudontidae

Protocetidae

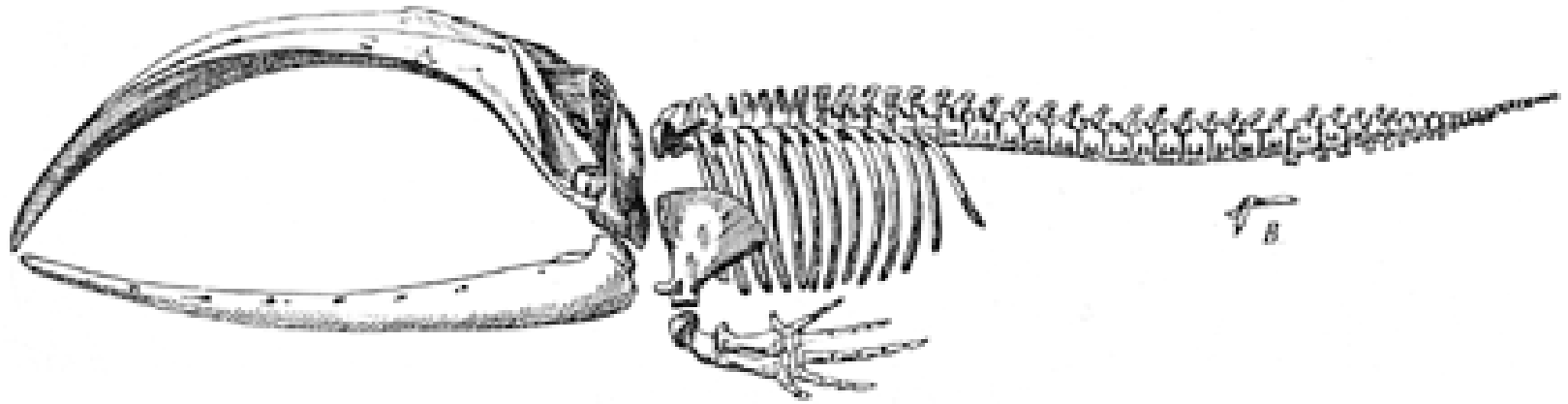
Remingtonocetidae

Ambulocetidae

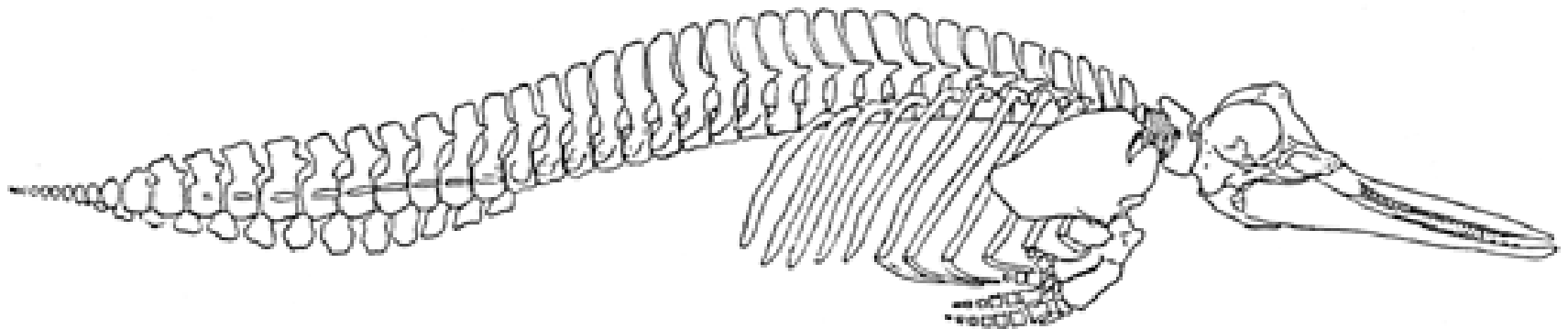
Pakicetidae

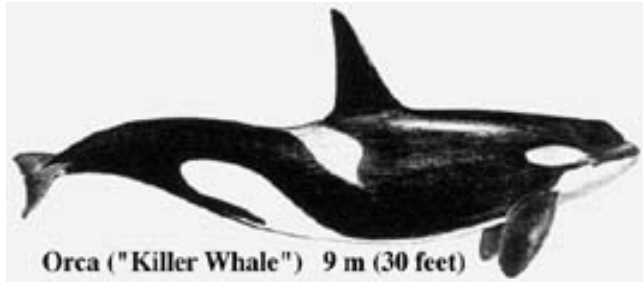
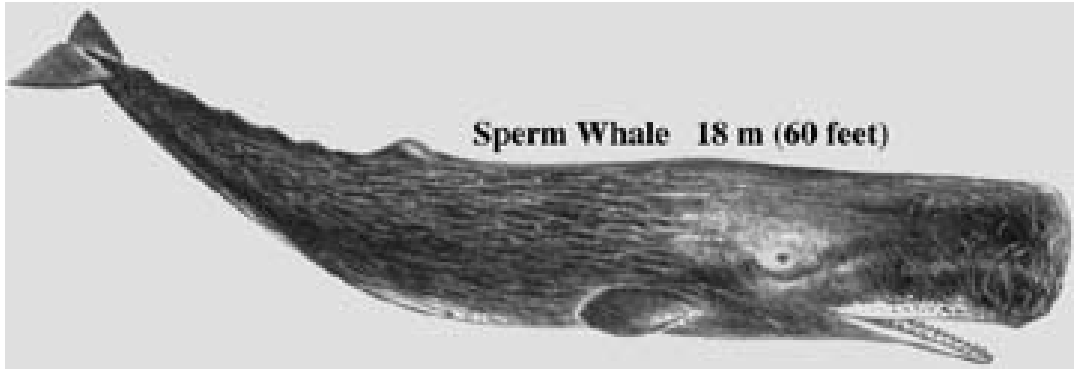
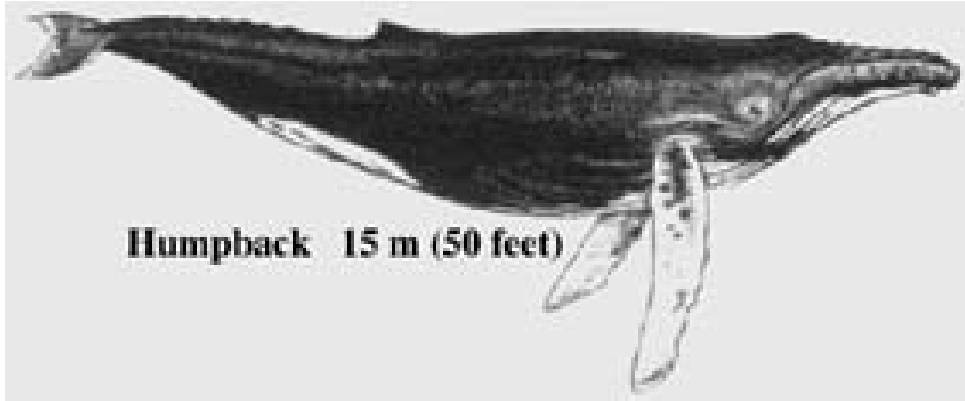
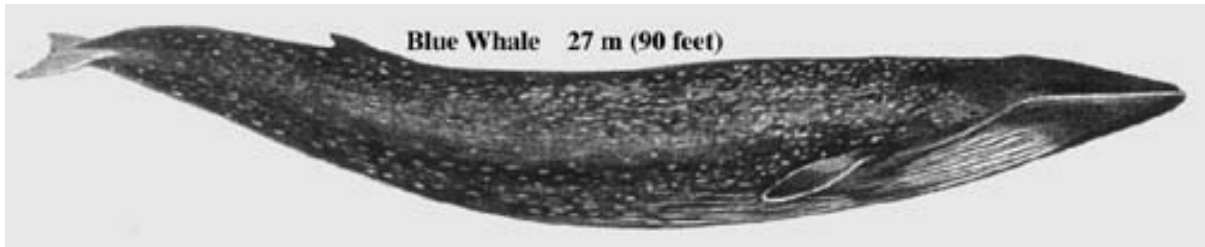
These are the whales that lived in the Eocene Period
(about 55 to 37 million years ago)

Collectively they are often referred to as archaeocetes



The two major groups of living whales: Mysticetes (baleen) and Odontocetes (toothed)





Blue
Whale,
Humpback
Whale,
Sperm
Whale,
and Killer
Whale

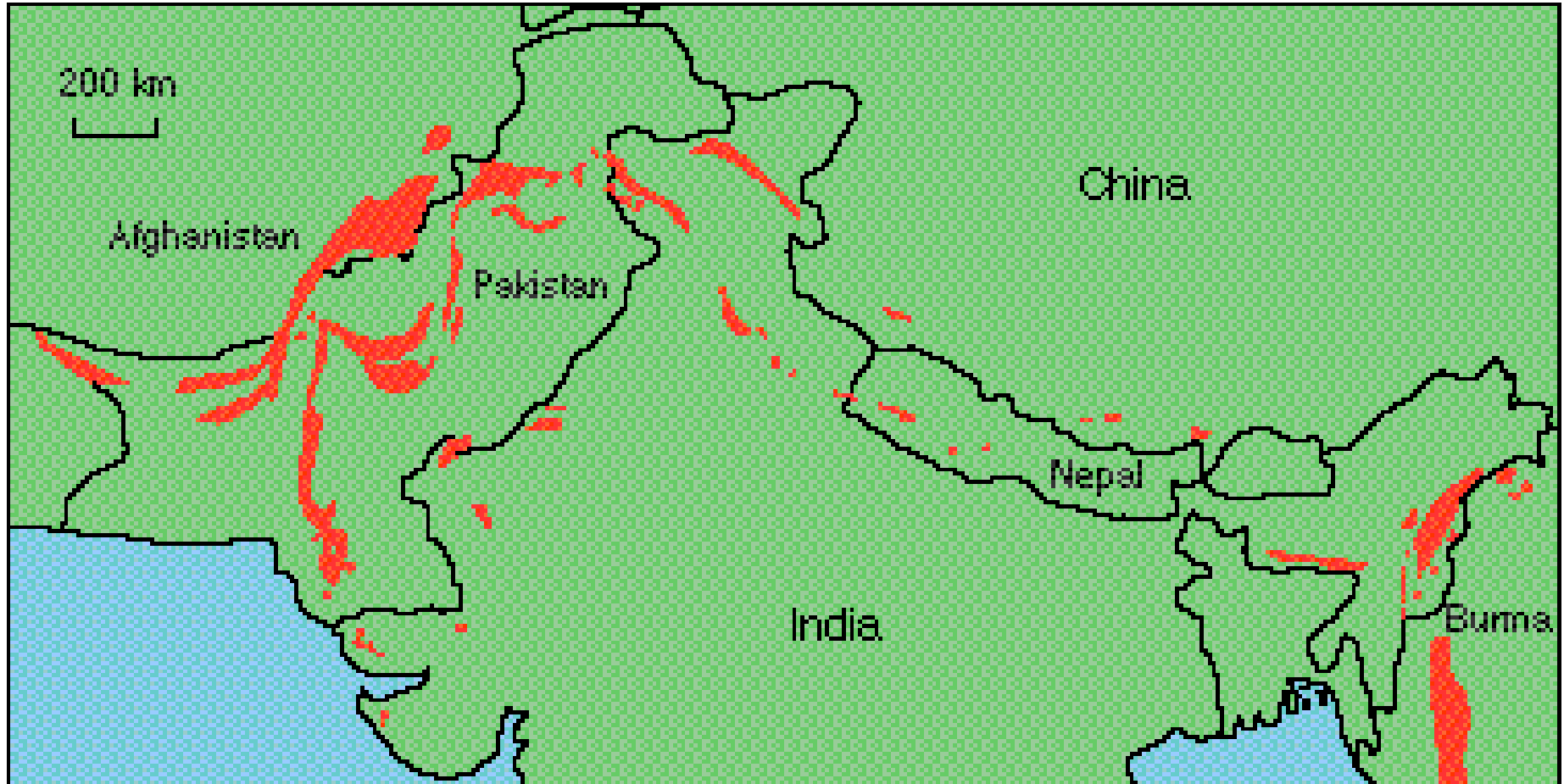


Whale
baleen

WEL

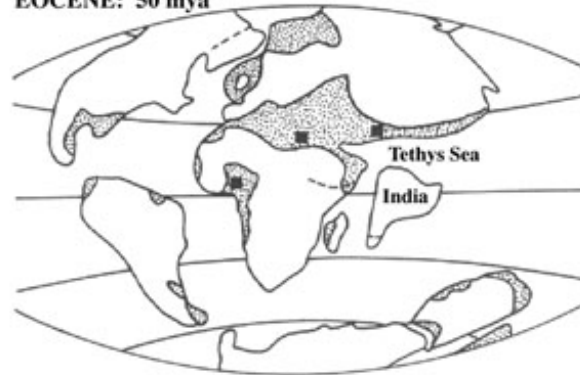


Tertiary Outcrops Yielding Fossil Whales in Asia



CONTINENTAL DRIFT CARRIES INDIA INTO ASIA
MAKING THE TETHYS SEA MORE SHALLOW

EOCENE: 50 mya



MIOCENE: 20 mya



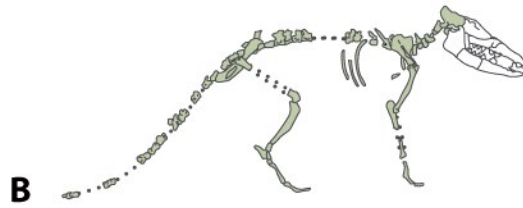
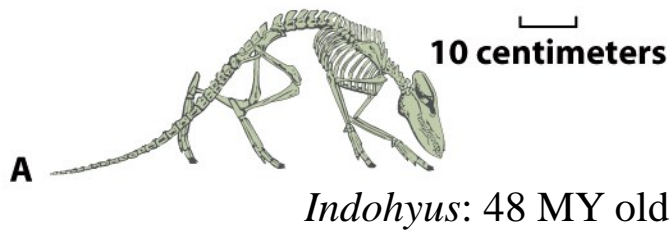
PRESENT



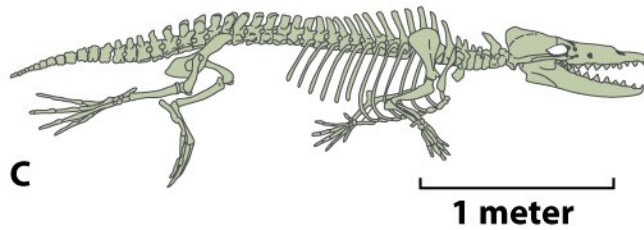
- shallow continental seas
- early archaeocete fossils
- early cetothere fossils

from Peter Evans, 1987
The Early History of Whales & Dolphins

Closing of the Tethys Sea during the Cenozoic



Pakicetus: 50 MY old



Ambulocetus: 49 MY old

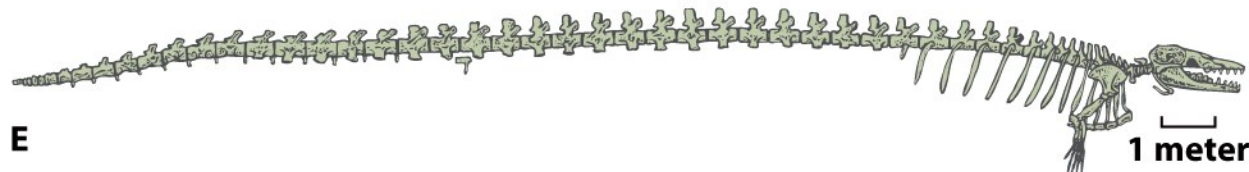
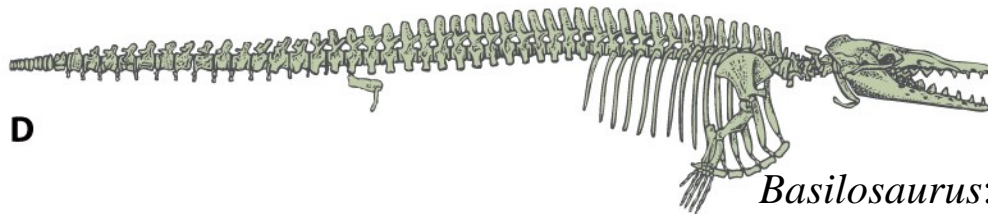
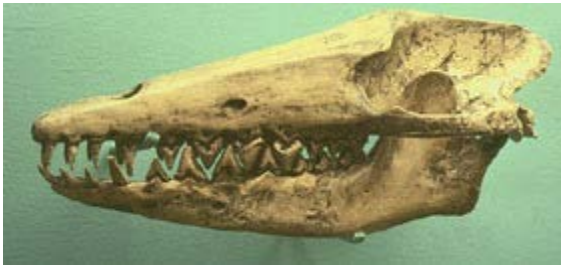
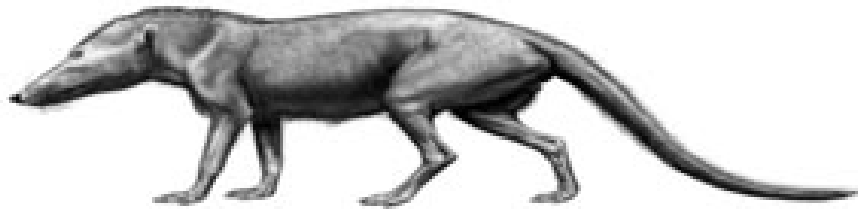


Figure 7-17
Earth System History, Third Edition
© 2009 W.H. Freeman and Company



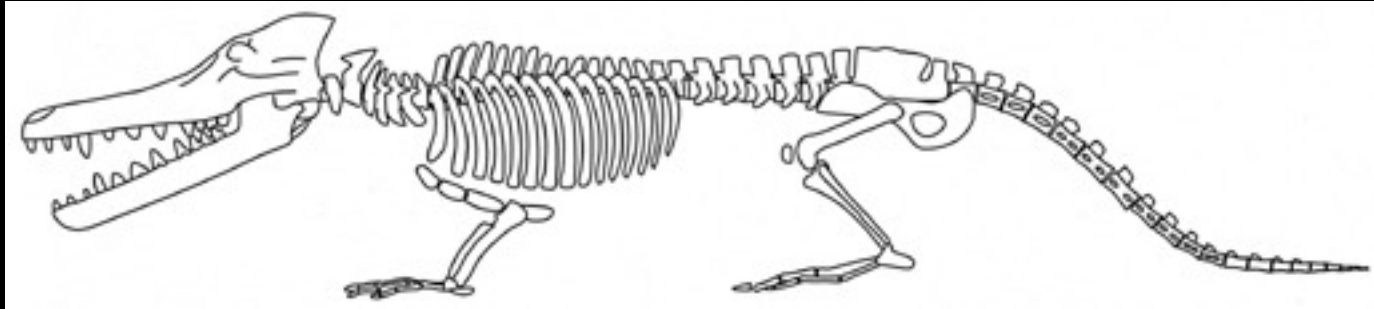
Pakicetus:
50 MY old



Size comparison with
a modern coyote skull



Ambulocetus: 49 MY old

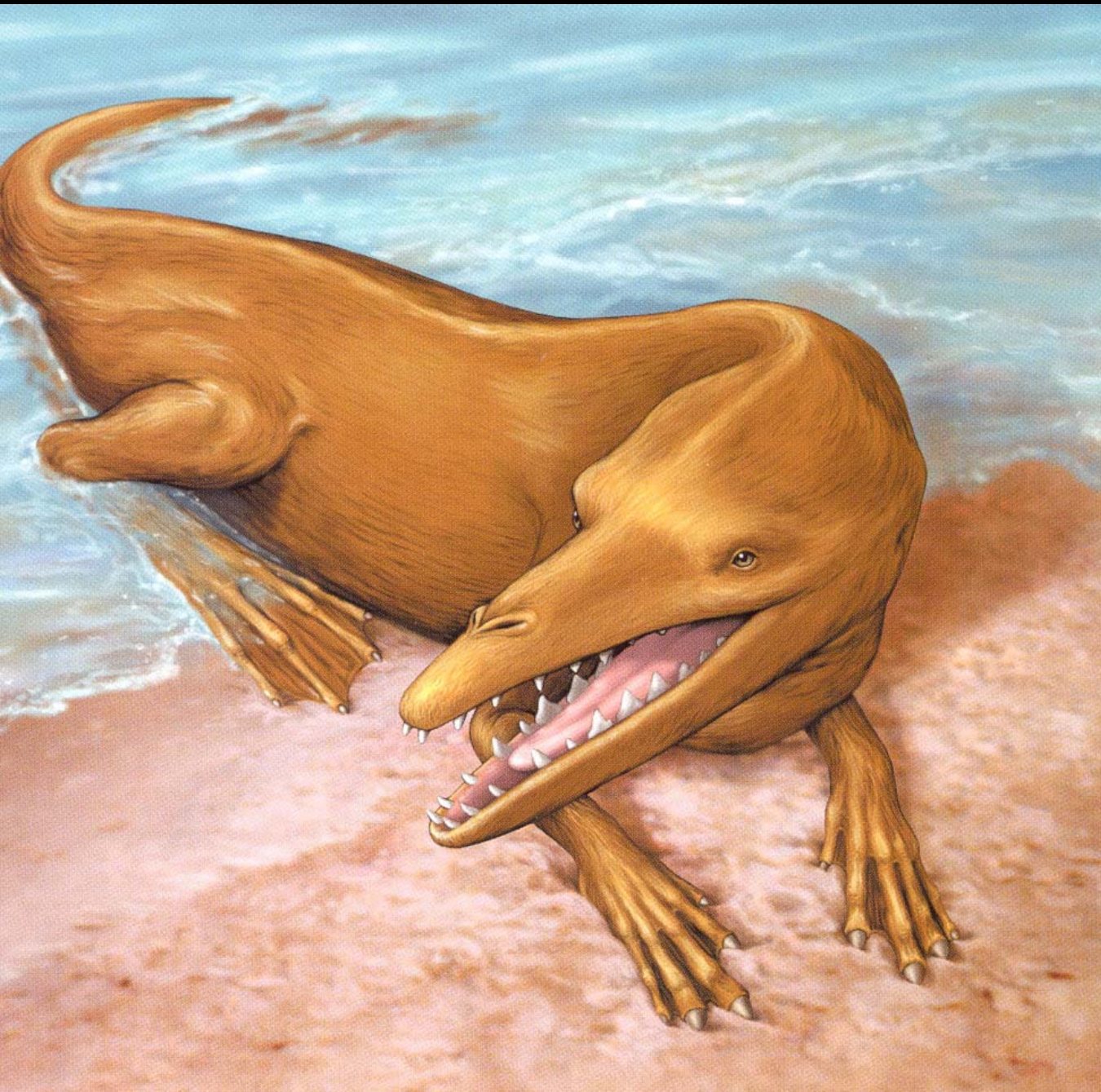


Ambulocetus in action

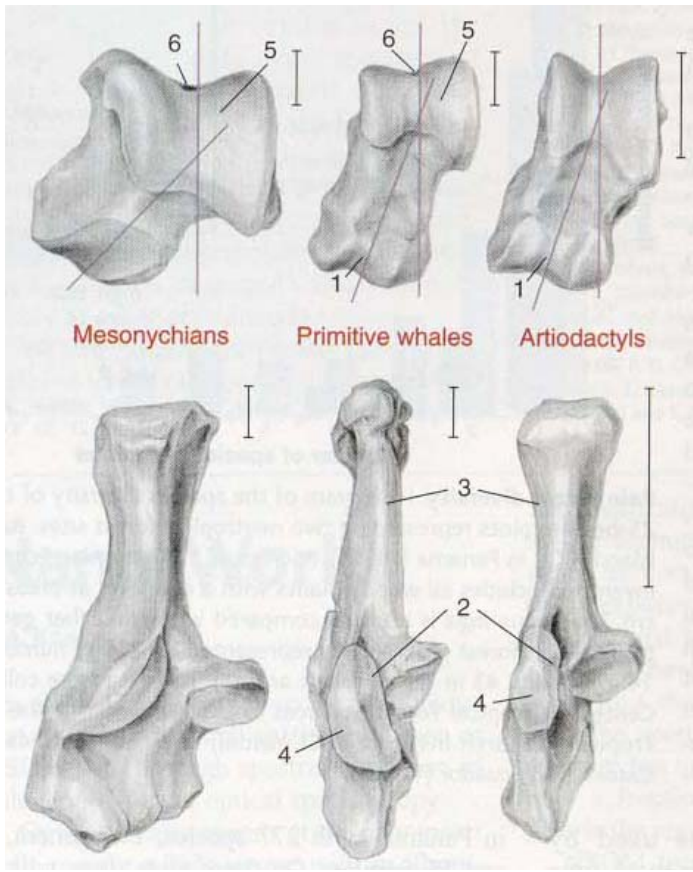




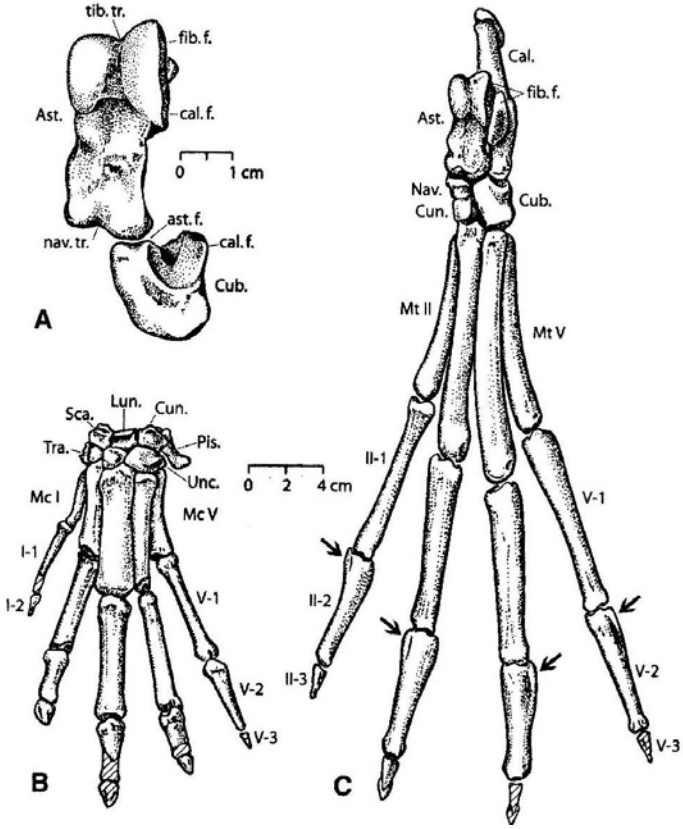
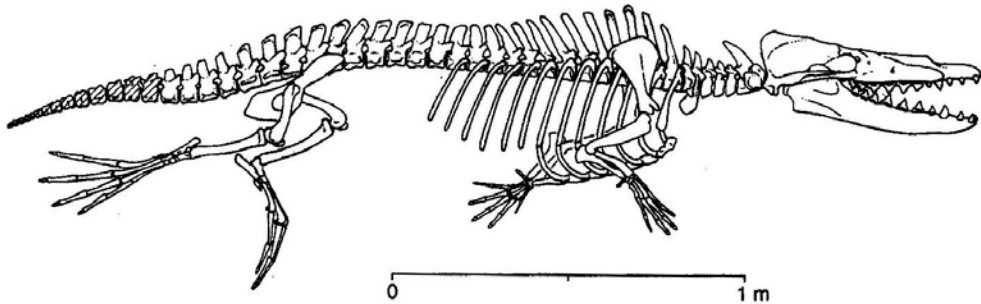
Reconstruction of the fossil whale *Ambulocetus* from the Eocene of Pakistan (~ 49 million years ago). *Ambulocetus* was discovered in 1994. In this artist's reconstruction, *Ambulocetus* is shown living like a crocodile, hunting land mammals near the shore.



Rodhocetus:
46 MY old



The ankle bones of *Rodhocetus* are more similar to artiodactyls (even-toed ungulates) than the traditional mesonychian ancestor.



Ocean Hall, Smithsonian Institution

Link to Land Mammals



Odocoileus virginianus Astragalus
Deer Right Ankle Bone

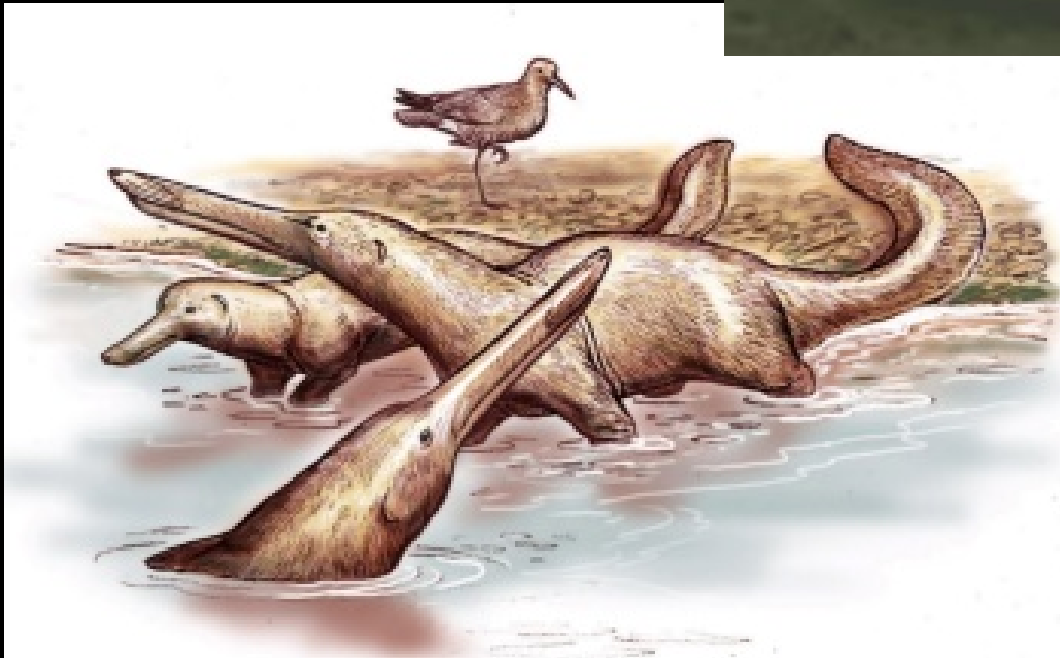
MODERN

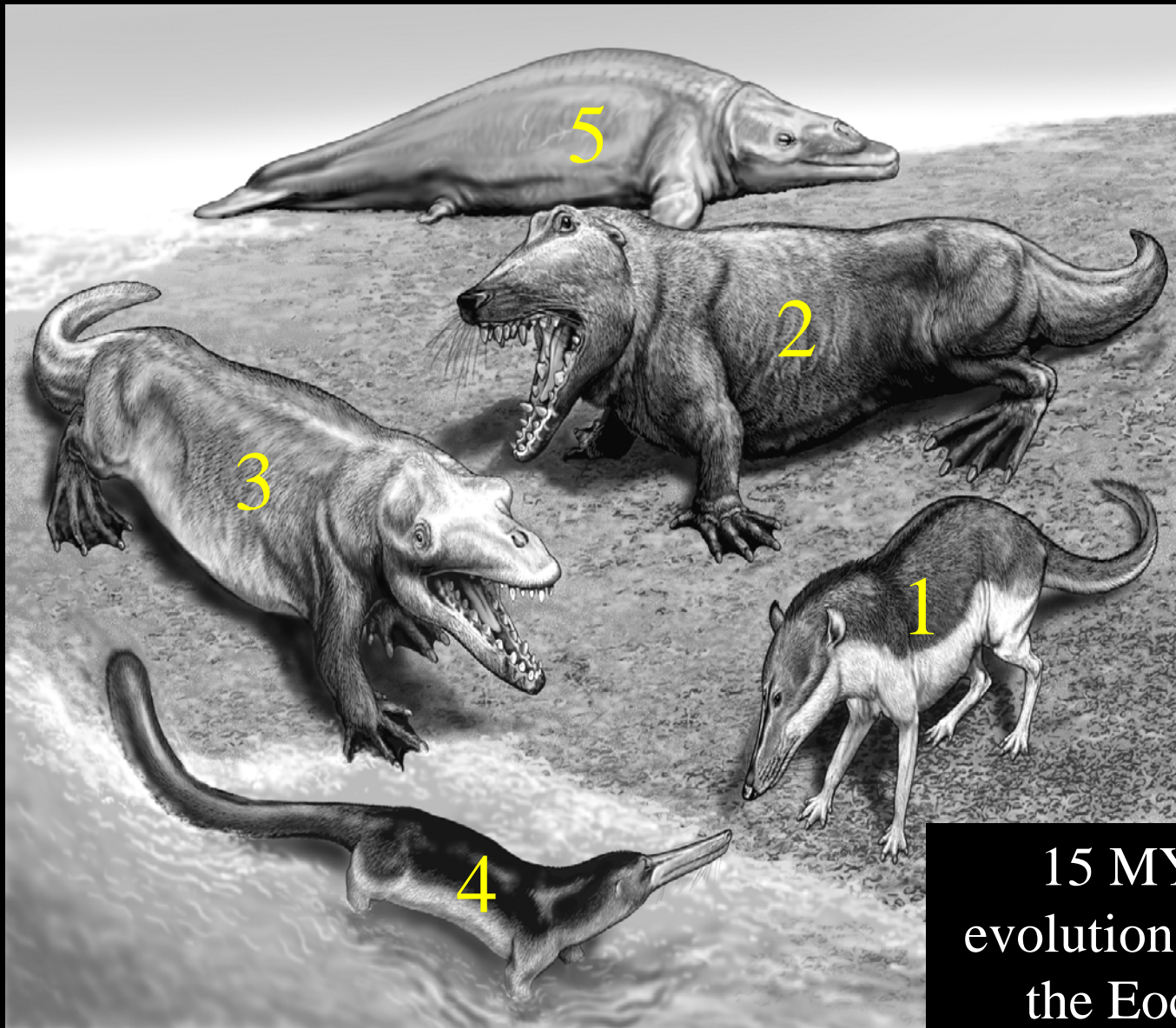
Rodhocetus balochistanensis Astragalus
Fossil Whale Ankle Bone (cast)

EARLY EOCENE

Similar ankle bone assemblies in this deer and in early whales strongly indicate their ancestral relationship.

Kutchicetus: 45 MY old

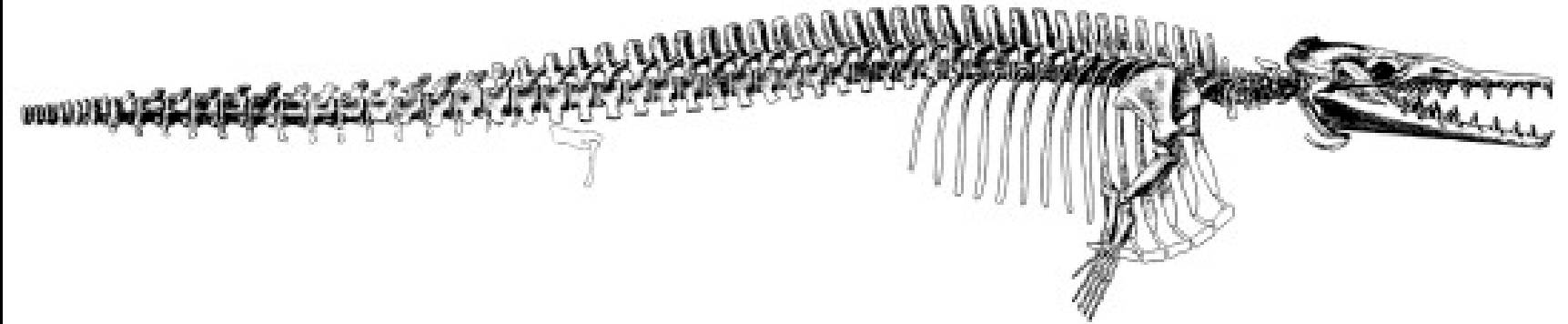




15 MY of
evolution during
the Eocene

Evolutionary Order: 1, *Pakicetus*; 2, *Ambulocetus*;
3, *Rodhocetus*; 4, *Kutchicetus*; 5, *Dorudon*

Basilosaurus: 37 MY old



Ankle, foot, and toes of *Basilosaurus* excavated in Wadi Hitan, Egypt. The foot as shown is approximately 12 cm long. Photograph ©1991 Philip Gingerich.

Phil Gingerich's work on fossil whales

<http://www.youtube.com/watch?v=I2C-3PjNGok>



Dr. B. Holly Smith working at the base of the tail at a *Basilosaurus* excavation in Wadi Hitan, Egypt. We are particularly interested in this part of the skeleton because this is where the reduced hind limbs, feet, and toes are found. Photograph ©1991 Philip Gingerich.

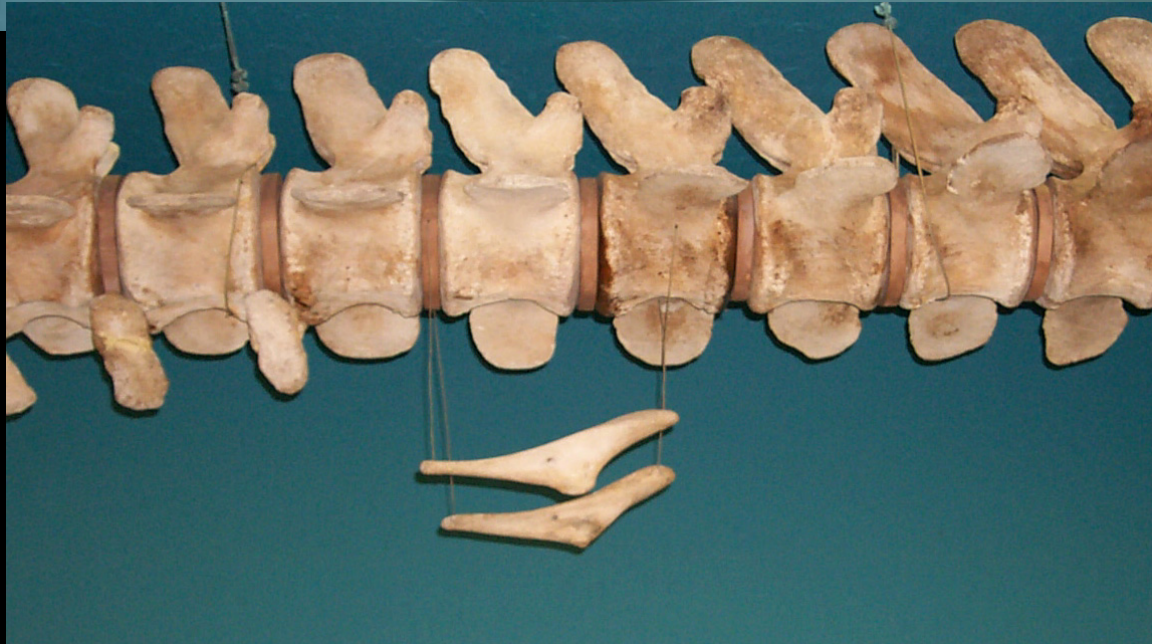


Virtually complete skeleton of *Dorudon* excavated in Wadi Hitan, Egypt. Note the retention of hind limbs, feet, and toes like those found in *Basilosaurus*. The skeleton is approximately 5 m long. Photograph ©1998 Philip Gingerich.



Dorudon from the
late Eocene of Egypt



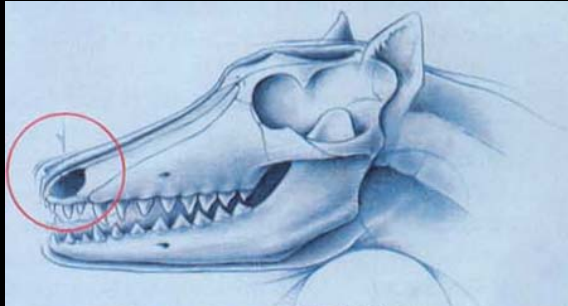


vestigial
whale
hips

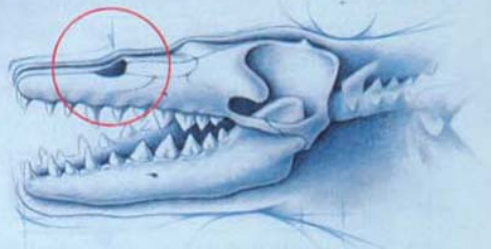


Dolphin with
extra fins in
position of
rear legs,
Japan 2006

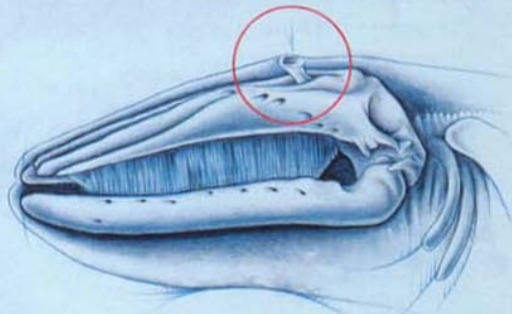
Evolution of nasal opening in whales



The ancient, amphibious whale *Pakicetus* had a land mammal's nostrils at the end of the snout.

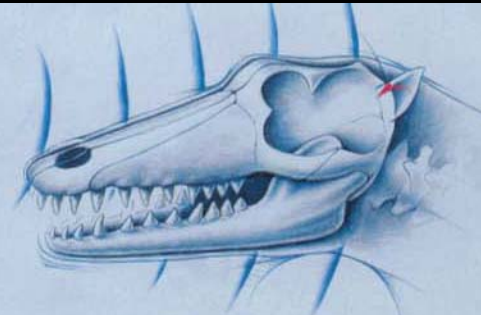


Rodhocetus swam the seas; its nostrils were higher on the skull, intermediate to those of its ancestors and modern whales.



A modern gray whale's blowhole allows it to break the surface, inhale, and resubmerge without having to stop or tilt the snout up.

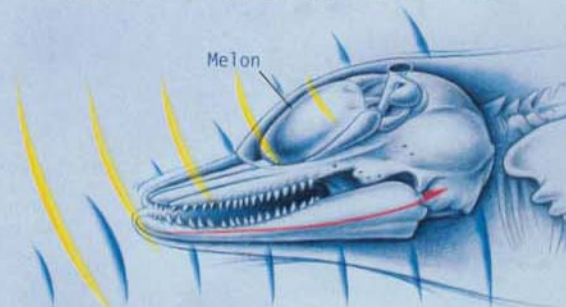
Hearing in whales



Though more aquatic than *Pakicetus*, *Ambulocetus* still heard directly through its ears.



Sounds were transmitted to the middle ears of *Basilosaurus* as vibrations from the lower jaw.



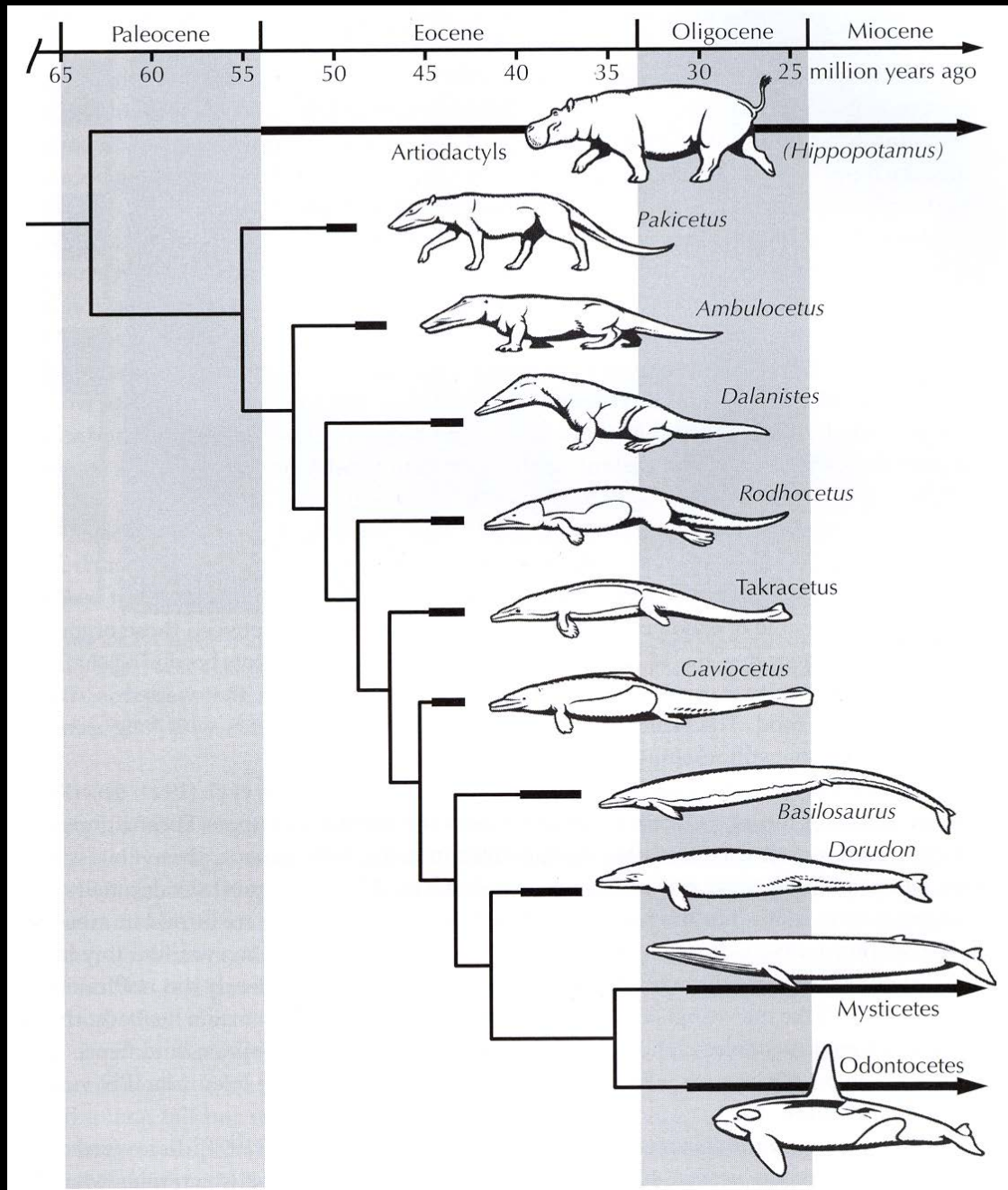
Modern toothed whales echolocate: The melon directs sound at an object, and the lower jaw receives the echoing reply.

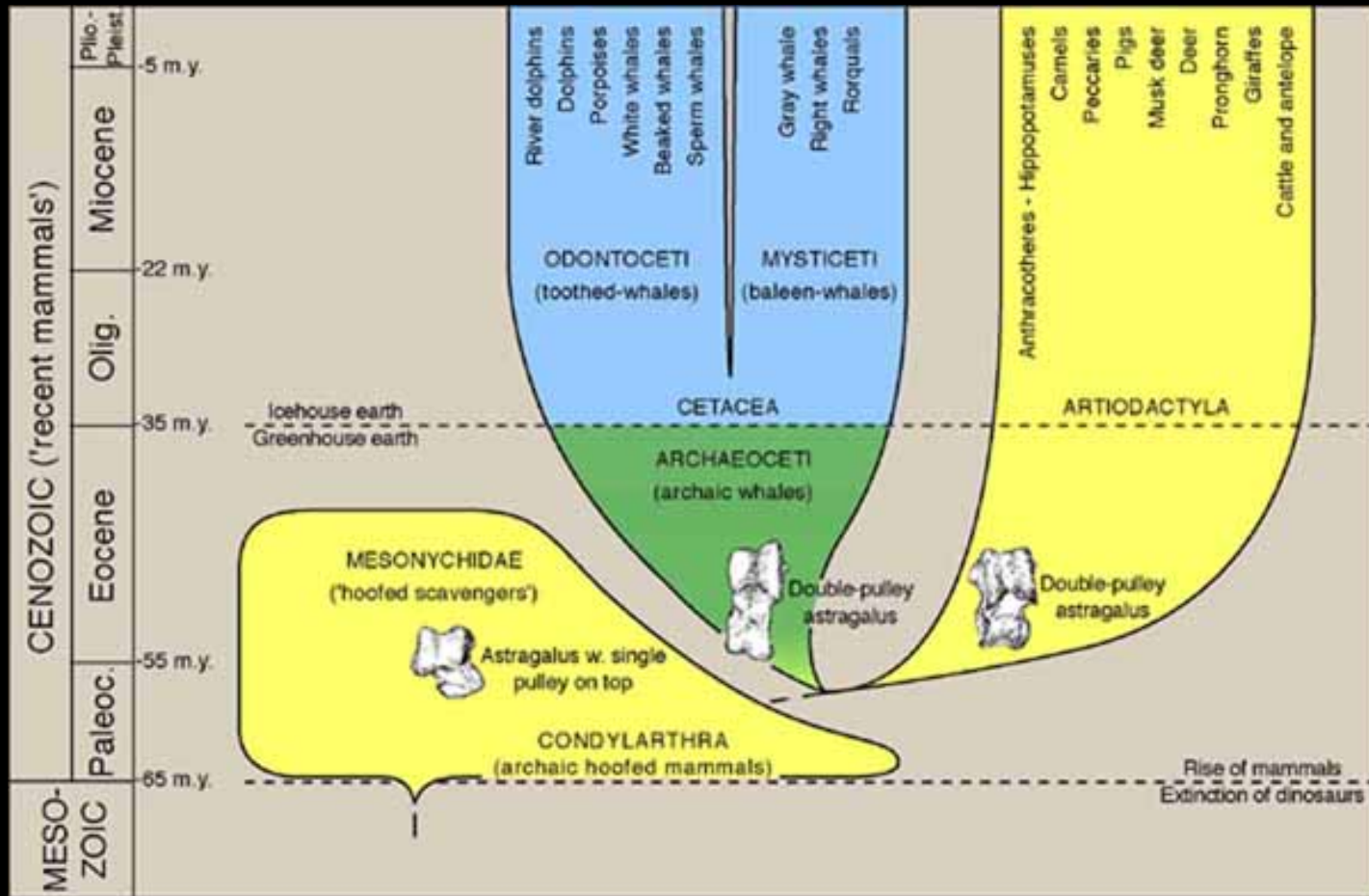
Genetic evidence suggests that hippos (artiodactyls) are the closest living relatives of whales.



Evolution of Whales

2000s





Phylogeny of Cetacea showing a common ancestry shared with Artiodactyla, and the hypothesized evolutionary origin of both from older Paleocene age Condylarthra. Horizontal axis is arbitrary, while the vertical axis is geological time. Our 2000 discovery of distinctively artiodactyl-like double-pulley astragalus bones in articulated skeletons of early archaeocetes is the principal evidence linking whales and artiodactyls as shown here (see Gingerich et al., 2001). The evolutionary origin of both whales and artiodactyls is closely tied to the Paleocene-Eocene boundary, and the transition from archaeocetes to modern whales is related to climatic and ocean circulation changes at the Eocene-Oligocene boundary. Source: University of Michigan Museum of Paleontology.

Evidence for
the
evolutionary
link between
cetaceans
and
artiodactyls

