Evolution of Marine Mammals

Multiple Independent Origins

- Cetaceans
- Sirenians
- Desmostylids
- Edentates
  - Marine sloth

- Carnivora
  - Ursidae
  - Pinnipididae
  - Mustelidae
    - Sea otter
    - Marine otter
    - Marine mink
Cladistics

• Phylogeny
  – Hypothesis about evolutionary relationships
  – Can never be proven, just supported

• Clades
  – Groups of related taxa and their descendants

Cladistics

• Character
  – Diverse, heritable attributes
  – Any feature that is useful in phylogenetic analysis

• Character state
  – Condition expressed in the individual
    • Limb number (0,2,4,6,8)
    • DNA sequence (GGGAATT)
    • Burrowing vs. Nesting
Origin of Features

- Homologous structures - Similar features resulting from common ancestry
  - Bones of a flipper & hand
  - **Not** tail fluke & hind limbs

Origin of Features

- Analogous structures - structures with similar function that evolved separately
  - Convergent evolution
  - Wings of a bat & bird

- Parsimony - fewest evolutionary steps/changes is accepted as the best
Tools used to study evolution

Bones (especially teeth)
- saved in fossil record
- structure used to infer diet (ecology)
- hind limbs, pelvis - shows how animal moved

Tools used to study evolution

Immunology
- similar response shows relatedness
- used with extant species

Biochemistry & Molecular tools
- DNA sequencing
- DNA recombinations – more connections shows relatedness
Cetacean Evolution

Major Trends in Evolution

- Changes in skull morphology:
  - Telescoping
    • Extension of premaxilla & maxillae
    • Shift of nares to top of head
Major Trends in Evolution

- Changes in skull morphology:
  - Mysticetes: increase in size
  - Odontocetes: asymmetry, isolation of auditory system, air sacs, fatty canal to auditory bulla

Major Trends in Evolution

- Changes in Teeth:
  - From Heterodont to homodont, piscivorous dentition
Major Trends in Evolution

- Changes in Teeth:
  - From Heterodont to homodont, piscivorous dentition
  - Normal mammalian dentition is max of 44 heterodont teeth
  - Polydont dentition = increased # of teeth
  - Or marked reduction in teeth to 0

Evolutionary Trends

- Reduction in neck function
  - Cervical vertebrae fusion
  - Results in short, rigid neck, adds to streamlining
Evolutionary Trends

• Small cetaceans give rise to large ones
  – Large cetaceans are very specialized
  – Evolutionary dead-end

• Changes in body form
  – Flukes, loss of hind limbs
  – Fusiform - elongation, streamlining
  – Thermoregulation, blubber blanket
Eocene:
- homogenous environment
- Tethys sea region

Oligocene/Miocene:
- Reduction of Tethys sea (40 mya)
- Antarctic separates (25 mya)
- new currents cause upwelling
Stable Isotopes Provides Insight Into Climates Trends

Ecological trends in cetacean evolution
Early Cetaceans

Requirements to move into the water:

- Warm, shallow water
- Plenty of food
- Little competition

Early Cetaceans

- 1st appeared in Eocene
- 55-60 mya
- Tethys sea: warm, shallow
- Large habitat, lots of food
Early Cetaceans

Disappearance of the Ichthyosaurs

- marine reptile
- morphologically resembled cetaceans
- CONVERGENT EVOLUTION

Cetacean Evolution

Order Condylarthra

- Ancestor to modern ungulates (cows, camel, sheep)
Phylogeny of Cetaceans

Ancestors of the ungulates (hoofed mammals) gave rise to:

(1) Order *Perissodactyla* (horses, rhinos & tapirs)

(2) Order *Cetartiodactyla* (pigs, camels, cows & hippos) (whales, dolphins & porpoises)
Cetacean Evolution

Earliest forms from the Eocene (~50 mya)

Early forms in Sub-order Archaeoceti
“Sub Order Archaeoceti”
Ancient whales, Early Eocene

5 Families:
- Pakicetidae- Early Eocene
- Ambulocetidae- E-M Eocene
- Protocetidae- Middle Eocene
- Remingtonocetidae- Middle Eocene
- Basilosauridae- M-L Eocene
Cetacean evolution

http://www.youtube.com/watch?v=l2C-3PjNGok&feature=related
http://www.youtube.com/watch?v=O_lKPSavQ4Y&feature=related

http://www.youtube.com/watch?feature=endscreen&NR=1&v=runQf6m9G4
“Sub Order Archaeoceti”

**Pakicetus:**
- Skeletons found near water
- Early Eocene
- Capable of walking on land
- Amphibious

**Ambulocetus:**
- “walking whale”
- Skeleton: paddling type of locomotion with undulation
- Early-Mid Eocene
Sub Order Archaeoceti

*Ambulocetus:*

Strong vertebral column suggests less paddling & more undulation

*Ambulocetus natans.* (From Thewissen *et al.*, 1996.)

Skeleton of *Rodhocetus kasrami*. Dashed lines and crosshatching show reconstructed parts. Original 2 m in length. (From Gingerich *et al.*, 1994.)
Sub Order Archaeoceti

*Protocetus & Rodhocetus:*
- First transitional archeocetes
- Initially described as terrestrial later recognized as aquatic

*FIGURE 7.39* Reconstructions, based on skeletal anatomy, of stages in the evolution of the Cetacea. (A) *Mesonychid; (B) Ambulocetus; (C) Rodhocetus; (D) Basilosaurus.* (From Futuyma 1995.)
Sub Order Archaeoceti

Family Basilosauridae

- ‘King of the Reptiles’
- *Basilosaurus* & *Dorudon*
- First Archaeoceti discovered
- Mid to late Eocene

Basilosaurus

Reconstruction of Basilosaurus from the Eocene: this giant 20-m-long whale had a very small head and must have fed on small fish and squid.

Skeletons of two late Eocene archaeocetes from the Atlantic coast of USA. Top: Basilosaurus (length 20m) and above Zygopterus (length 15m).
Early Odontocetes

Family Agorophiidae

Cranial asymmetry
Moderate degree of skull telescoping
Heterodont dentition
Proto-odontocetes (35-30mya)

F. Agorophiidae
  • Short beaked whales

  ↓

F. Squalodontidae
  • leads to modern delphinids (?)
  • fully developed
  • telescoping
  • heterodont dentition
Early Mysticetes

Family Aetiocetidae

Diverged from Odontocete line ~ 35 mya
Cranial symmetry
Primitive cranial telescoping
Early forms had heterodont dentition
Baleen appears ~ 30 mya

Proto-mysticetes (35-30mya)

F. Aetiocetidae
- Articulated lower jaw
- Teeth present
- Vasculature indicates baleen

F. Cetotheridae
- Earliest true mysticete
- 1st toothless whale
Pinniped Evolution

Diphyly: Fossil & morphological support
Monophyly: molecular & revised morphological support
Pinniped Evolution

Diphyly: Fossil & morphological support
Monophyly: molecular & revised morphological support

When & where?
- Arctoid ancestors (mustelid, bear, dog)
- 27-25 mya (late Oligocene)
- N. Pacific along Oregon coast
  - *Enaliarctos spp*
- Canadian Arctic-
  - *Puijila darwini*
Geographic location of *Puijila darwini* fossil site.


Early Fresh Water Carnivore that was a Proto Pinniped

*Puijila darwini* - derived from-

*Puijila* (Inuktitut): young sea mammal, often referring to a seal

darwini: for Charles Darwin, who wrote “A strictly terrestrial animal, by occasionally hunting for food in shallow water, then in streams or lakes, might at last be converted into an animal so thoroughly aquatic as to brave the open ocean”.

Pinnipedia

- *Enaliarctos* spp.
  - (very derived early pinniped)
  - Late Oligocene, eastern N. Pacific
  - small animal, terrestrial dentition
  - size of harbor seal
Divergence of Early Otariids

- *Pithanotaria* spp.
  - 11 mya (late Miocene), CA
- *Thalassoleon* spp.
  - 8-6 mya, CA, Mexico, & Japan
- *Callorhinus*
  - 5-4 mya, extant
Present day Otariids

Precursor to Phocids

- Desmatophocidae – 21-20 mya
  - derived from *Enaliarctos*
  - not true phocid but possible evolutionary link
  - N. Pacific coastal (CA, OR, Japan)
  - Large, sexually dimorphic
  - *Allodesmus & Desmatophoca*
Allodesmus:

Early Phocids

- *Monotherium* spp. & *Callophoca* spp.
- 15-14 mya
- Appeared in N. Atlantic
Monotherium & Leptophoca moved through Central American Seaway or down from Arctic

**Early Phocids**

- *Monotherium* spp. & *Leptophoca* spp.
  - 15-14 mya
  - Appeared in N. Atlantic
  - Split into many lineages
Present day Phocids

- Relationship to Otariids & Phocids unclear
- Very diverse group (3 suborders)
- *Proneotherium* & *Neotherium* spp.
  - Ancestral walrus 16 mya & 14 mya
  - Eastern N. Pacific
  - Fish eaters
Modern Odobenids

• Evolved in N. Atlantic
• *Prorosmarus*, early Pliocene
• Re-invaded Pacific through Bering Strait ( < 1mya)
• *Odobenus rosmarus*
Order Sirenia

- Family Dugongidae
- Family Trichechidae – Manatees

A cladogram depicting the relationship of sirens and their close relatives. Numbers refer to sirenian synapomorphies, several of which are illustrated in Fig. 5.3. +=extinct taxa.
Sirenia Evolution

Earliest Ancestors:

- herbivorous mammals
- 50 mya, Caribbean region
First Sirenians

- *Prorastomus & Pezosiren*:
  - Moved out of Caribbean region to Tethys & Western Pacific
  - Partially aquatic
- Appearance of Trichechidae & Dugongidae - late Eocene
Order Desmostylii

- Only extinct order of marine mammal
- N. Pacific, Late Oligocene (33-10 mya)
- 10 species
- hippopotamus-like
- *Paleoparadoxia & Desmostylis*

Unique Teeth Structure:
This restoration of Deinosuchus attempts to give an idea of what the animal looked like when grazing for submarine food, but the type of food involved is perfectly obscure since there is no fossil evidence for whether the beast ate plants or seafood. Indeed, some would suggest that Deinosuchus came ashore to forage for plants, rather than to feed on the sea bottom.
Figure 7: Reorganization of continents, ocean basins, and palaeoecology in the (A) early Mesozoic (203 Ma) (1) early records of arctite, planorbid, heterostegids, and hemicyathids) and (B) middle Miocene (12 Ma), with (2) well-documented phocids, (3) dispersal of “monachini” and related alopoids to Atlantic; (4) dispersal of phoebetrians to South Pacific. 4-5 isolation of phoebetrians in remains of Panthalassa Sea and in North Atlantic. (From Bonn et al., 2006; base map from Ishida et al., 1994.)