

Topic 10: Origin of Cetaceans: A Macroevolutionary Case Study

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I. Cetaceans

A. What

1. Fully aquatic, mostly marine mammals
Colloquially called dolphins, porpoises, & whales



Harbor Porpoise

Photo by E.Christensen

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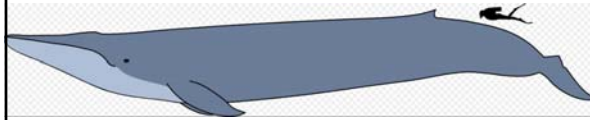
Bottlenose Dolphin

Photo by Pelican

I. Cetaceans

A. What

- 1. Fully aquatic, mostly marine mammals
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Blue Whale
Illustration by Kurzon

I. Cetaceans

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- 2. Generally called "whales" or "cetaceans" and classified into two main groups:

- a. **Ondontocetes** (toothed whales)

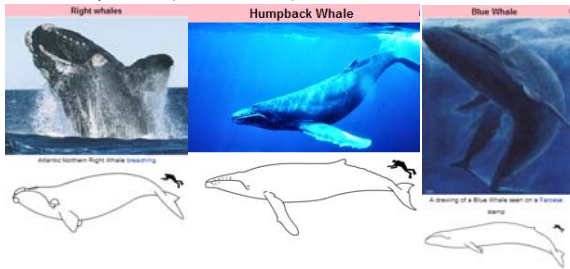


I. Cetaceans

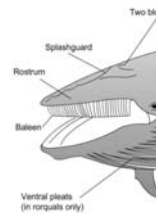
A. What

- 2. Generally called "whales" or "cetaceans" and classified into two main groups:

- a. **Ondontocetes** (toothed whales)
- b. **Mysticetes** (baleen whales)



I. Cetaceans



From upper jaw: fine-comb-like epidermal protrusion of Keratin (stiff, elastic) & hydroxyapatite (bony)

I. Cetaceans



A. What

B. Mammalian Heritage

- Warm-blooded
- Live young*
- Mammary glands

nipples concealed in abdominal mammary slits



I. Cetaceans



A. What

B. Mammalian Heritage

- Warm-blooded
- Live young*
- Mammary glands
- Hair (snout, chin, behind blow hole)
- Up-down spinal motility



Fluke, humpback whale



Tail fin, yellow-tail snapper

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- Warm-blooded
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- Lungs




Above: Sperm whales: 40 min down, 10 min up, starts to exhale just below surface.
Left: minke whale

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Blowhole (nostrils) in a blue whale.

II. Evolutionary Origins

A. Phylogenetic Evidence

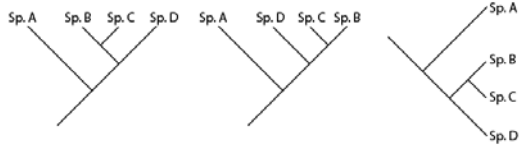
II. Evolutionary Origins



A. Phylogenetic Evidence

1. "Phylogeny" is the evolutionary history of a group
2. Cladograms used to depict phylogeny

Relative recency of common ancestry read from tips.



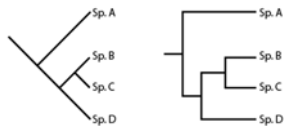
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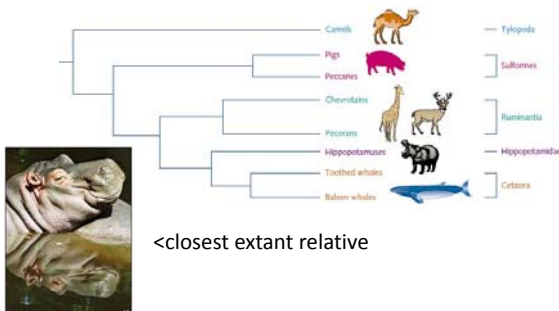


II. Evolutionary Origins



A. Phylogenetic Evidence

3. DNA-based cladograms point to terrestrial origin among ungulate mammals

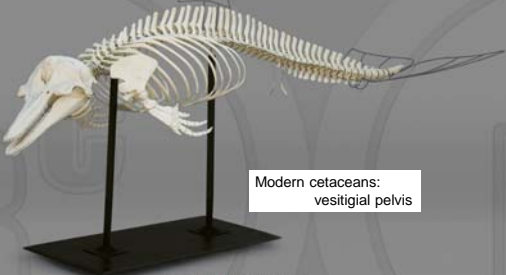


II. Evolutionary Origins

A. Phylogenetic Evidence

B. Anatomical Evidence

1. Front legs evolved into flippers
2. Hind legs lost



Modern cetaceans:
vestigial pelvis

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II. Evolutionary Origins

A. Phylogenetic Evidence

B. Anatomical Evidence

C. Paleontological Evidence

1. Front legs evolved into flippers
2. Hind legs lost



Valley of the Whales
(150 km S of Cairo)

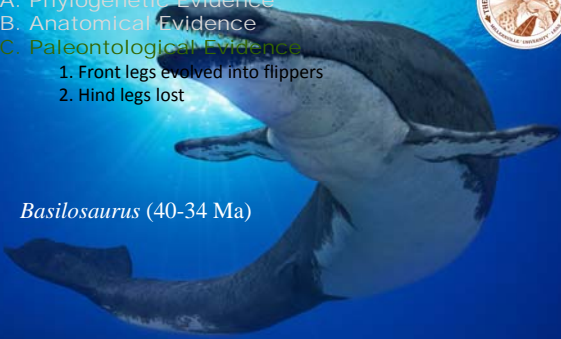
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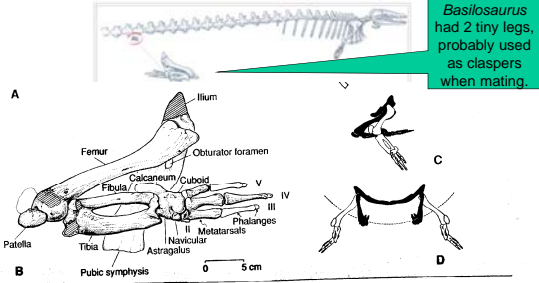


Basilosaurus (40-34 Ma)

II. Evolutionary Origins

- A. Phylogenetic Evidence
- B. Anatomical Evidence
- C. Paleontological Evidence

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2. Hind legs lost



II. Evolutionary Origins

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- B. Anatomical Evidence
- C. Paleontological Evidence

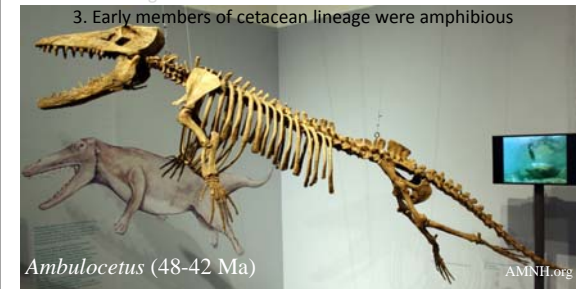
1. Front legs evolved into flippers
2. Hind legs lost
3. Early members of cetacean lineage were amphibious



II. Evolutionary Origins

- A. Phylogenetic Evidence
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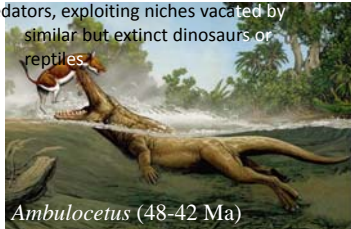
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II. Evolutionary Origins

- A. Phylogenetic Evidence
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1. Front legs evolved into flippers
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3. Early members of cetacean lineage were amphibious ambush predators, exploiting niches vacated by similar but extinct dinosaurs or reptiles.



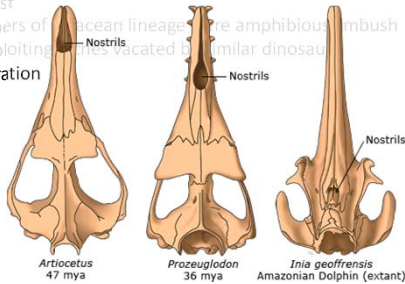
Ambulocetus natans in action. A reconstruction of an early close cousin of whales. Shown here with the kind permission of artist Carl Buell.



II. Evolutionary Origins

- A. Phylogenetic Evidence
- B. Anatomical Evidence
- C. Paleontological Evidence

1. Front legs evolved into flippers
2. Hind legs lost
3. Early members of cetacean lineage were amphibious ambush predators, exploiting niches vacated by similar dinosaurs or reptiles.
4. Nostril migration



III. Analagous Transformations



III. Analagous Transformations



A. Sirenians

- Diverged from protoungulates, related to elephants, aardvarks
- 40 Ma
- Manatees (Caribbean, Amazon, W Africa) & Dugongs (Indo-Pacific)



Photo by San Diego Zoo

Manatees can remain underwater for up to 20 minutes, but like all mammals, they need to breathe air.

III. Analagous Transformations



A. Sirenians

- Diverged from protoungulates, related to elephants, aardvarks
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- Manatees (Caribbean, Amazon, W Africa) & Dugongs (Indo-Pacific)



Photo by est-nord

III. Analagous Transformations



A. Sirenians

- Diverged from protoungulates, related to elephants, aardvarks
- 40 Ma
- Manatees

- Foreflippers dextrous for maneuvering in shallow coastal waters & rivers. 3-4 nails each.



Photo by San Diego Zoo

The bones in manatee flippers are similar to a human hand, with jointed finger bones.

III. Analagous Transformations



A. Sirenians

- Diverged from protoungulates, related to elephants, aardvarks, and sloths
- 40 Ma
- Manatees (Caribbean, Amazon, West Africa) & Dugongs (Indo-Pacific)
- Foreflippers dextrous for maneuvering in shallow coastal waters & rivers. 3-4 nails each.
- Hind legs lost



Dugong skeleton
Photo by M. Pugliano, Smithsonian

III. Analagous Transformations



A. Sirenians

B. Pinnipeds

- Diverged from "bear-like" carnivores 30 Ma
- Seals, Sea lions and Walruses



Bull elephant seals, CA, USA

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III. Analagous Transformations



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- Forelegs dextrous, function as flippers when in water, legs on land



III. Analagous Transformations

- A. Sirenians
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- Diverged from "bear-like" carnivores 30 Ma
- Seals, Sea lions and Walruses
- Forelegs dextrous, function as flippers when in water, legs on land
- Hindlegs dextrous but highly reduced, toes webbed, claws reduced



III. Analagous Transformations

- A. Sirenians
- B. Pinnipeds
- C. Otters

- Diverged from badgers, weasels, polecat carnivores 5-7 Ma.
- Amphibious
- Least streamlined of marine/aquatic mammals
- Limbs are those of a terrestrial carnivore but with webbed toes.



Pacific sea otter



III. Analagous Transformations

- A. Sirenians
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- Diverged from badgers, weasels, polecat carnivores 5-7 Ma.
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Northern river otter



III. Analagous Transformations

- A. Sirenians
- B. Pinnipeds
- C. Otters
- D. Demonstrate Convergent Evolution
Similar adaptations arisen independently.



IV. Summary

- A. Terrestrial origin for cetaceans
Whales evolved from a terrestrial, mammalian ancestor via an amphibious ancestor.
- B. Analogous modifications have occurred or are occurring in a variety of lineages.
Sirenians, Pinnipeds, & Otters

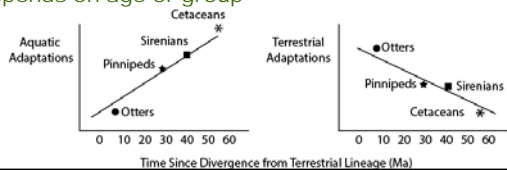


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Whales evolved from a terrestrial, mammalian ancestor via an amphibious ancestor.
- B. Analogous modifications have occurred or are occurring in a variety of lineages.
Sirenians, Pinnipeds, & Otters



C. Degree of modification in various structures depends on age of group



Hairiness

Sea Otter Sea Lion

Manatee Whale calf

More Less
Terrestrial Aquatic

Nostril Position

Sea Otter Sea Lion

Manatee Duogong Orca

Low (Front of head) High (Top of head)
Terrestrial Aquatic

Forelimbs

Otter Pinniped

Sirenian Cetacean

Large (digits & dextrous) Flipper-like (streamlined, not dextrous)
Terrestrial Aquatic

Hindlimbs & Pelvis

The diagram illustrates the evolutionary divergence of hindlimbs and pelvis in aquatic mammals. It is divided into two horizontal sections: the top section for 'Hindlimbs' and the bottom section for 'Pelvis'. Each section compares a terrestrial-like form (Otter and Sirenian) with an aquatic form (Pinniped and Cetacean). The Otter and Sirenian are labeled as 'Well-developed (good for walking)' and 'Terrestrial', while the Pinniped and Cetacean are labeled as 'Poorly developed (out of the way for swimming)' and 'Aquatic'. A green arrow points from the terrestrial forms to the aquatic forms, indicating the direction of evolution. A circular logo for 'THE JAMES CLARK PAPER LIBRARY' is located in the top right corner of the diagram area.

Well-developed (good for walking) / Poorly developed (out of the way for swimming)
Terrestrial / Aquatic
Hindlimbs

Well-developed (good anchor for legs) / Poorly developed (poor anchor for legs)
Terrestrial / Aquatic
Pelvis

Otter, Pinniped, Sirenian, Cetacean
