Name:_____ Date:_____

A Whale Evolutionary Tale

Background: Whales are mammals that live in the ocean, but just how/when did they evolve to be suited to an aquatic ecosystem? While the answer of how will have to wait we can at least observe the progression of several transitional species, which are at the very least share a common ancestor with the modern whale.

The time is 65 million years ago, just after the dinosaurs went extinct and a new class of animals, the mammals; develop very rapidly in evolutionary terms over the next 10-15 million years. Some 130,000 species evolve and diverge from their shared common ancestors; many of which go extinct. However, after using both geologic and organic evolutionary evidence scientists have developed the "Tree of Life".

The evidence:

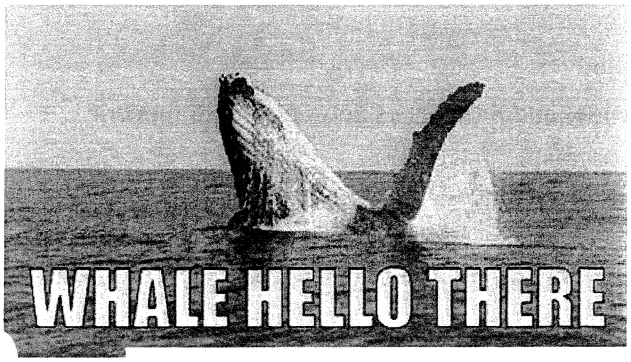
1. Whale transitional species fossils
2. Whale transitional species descriptions of discoveries from fossil sites.
3. DNA/molecular evidence from modern species
4. A cladogram showing the evolutionary history and when certain groups of mammals diverged from a common ancestor.

Your Task:

A. View and discuss the videos about whale fossil discoveries, radiometric dating, and the evidence of evolution.

B. Complete the "Whales in the making" graphic organizer using available resources.

C. As a group make a phylogenetic tree (with a timeline to scale) of the evolutionary history of the whale and its closest living relatives beginning ~65million years ago.



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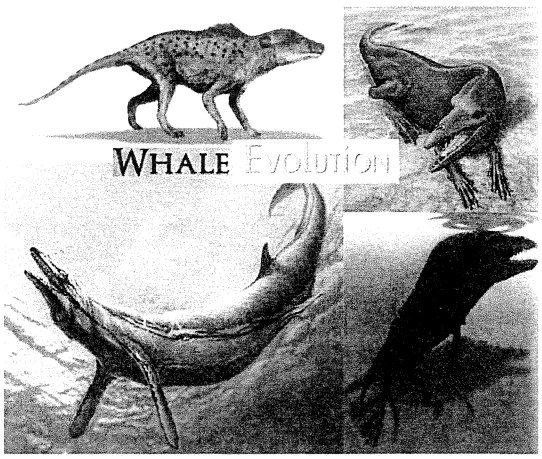

Task A. Complete these questions based on our class discussions and the video.

Part I Fossil Formation

Video #1 Becoming A fossil As you watch think about

1. How are fossils formed?

2. How do scientists determine the age of fossils?

Video #2 Radiometric Dating

1. What is radioactive element is used in radiometric dating?

2. How is this method of dating fossils different from relative dating?

Part 2: Evidence of the Evolutionary Process

Video #3 Early Tetrapod How the first Fish "walked"

1. Discuss the ways in which our current understanding of early tetrapod evolution differs from the traditional view, and explain why this is important.

Video #4 Evolving Ideas: How Do We Know Evolution Happened?

1. Using the words homolgous and analogous discuss the similarities and differences between whale filppers and fish fins.

Part B. Whale in the Making

Directions: Fill out the Whale in the Making Organizer based on the reading "The Evolution of the Whale" and "Whale in the Making" images of the transitional species of whale. Both are attached to the back of this lab.

****<u>None of these animals are necessarily a direct ancestor of the whales we know today; they may be side branches of the family tree.</u>** But the important thing is that each fossil whale shares new, whale-like features with the whales we know today, and in the fossil record, we can observe the gradual accumulation of these aquatic adaptations in the lineage that led to modern whales.

After completing the organizer answer these questions.

- What typical whale-like traits were apparently the earliest to appear? What apparently evolved much later?

_____

_____

_____

_____

- To find fossil evidence to fill the largest remaining gap in whale evolution, what age sediments would you search?

- What distinguishing traits would you expect to find in whale fossils of that age?

_____

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Part C. Now it is time to make a phylogenetic Tree of Whale Evolution.

Materials: meter stick, poster paper, colored pencils, species pictures and the Mammalian Cladogram (attached to lab).

Directions:

Making A Scale

1. Hold the paper vertically and draw a vertical line 4cm from the left side of the paper.
2. Label at the very bottom of the page just to the left of this line "65mya".
3. Using a meter stick mark off every 1cm on your vertical line till you get to 56cm.
4. Label the first line "55 mya" Note this scale jumps from 65mya to 55mya for the first centimeter only.
5. Complete the remainder of the scale by using the ration 1cm= 1mya.
6. Draw a horizontal line at time "0".

Completing the Cladogram

1. Use the Mammalian Cladogram to start making a phylogentic tree starting at 65 mya and the ancestral shrew at the 25cm point from the left side of the paper.

Your Phylogenetic Tree should:

- Be accurate in when species or groups of species diverged
- Show which organisms are extinct and which are still present today.
- Have color pictures (provided) of the organisms glued onto the poster
- Have DNA comparisons of modern species to the modern whale listed at the top of the page (use the cladogram provided to get info)
- A heading of "The Phylogenetic Tree of Whales"

******Answer the conclusion questions on the next page.

Concluding Questions: Answer in complete sentences.

1. **Predict why it took 2 million years of evolution to transition from ambulocetus to Rodhocetus, but took 9 million years to transition from Rodhocetus to Basilosaurus.**

2. **How do scientists use a combination of organic and geologic evolution to put together the phylogenetic tree of modern whales? Use absolute dating, relative dating, homologous structures and DNA in your answer. *bonus point if you use geologic time scale**

The evolution of the Whale

Background Reading

Call it an unfinished story, but with a plot that's a grabber. It's the tale of an ancient land mammal making its way back to the sea, becoming the forerunner of today's whales. In doing so, it lost its legs, and all of its vital systems became adapted to a marine existence -- the reverse of what happened millions of years previously, when the first animals crawled out of the sea onto land.

Some details remain fuzzy and under investigation. But we know for certain that this back-to-the-water evolution did occur, thanks to a profusion of intermediate fossils that have been uncovered over the past two decades.

Pakicetus,

In 1978, paleontologist Phil Gingerich discovered a 52-million-year-old skull in Pakistan that resembled fossils of creodonts -- wolf-sized carnivores that lived between 60 and 37 million years ago, in the early Eocene epoch. But the skull also had characteristics in common with the *Archaeocetes*, the oldest known whales. The new bones, dubbed ***Pakicetus,*** proved to have key features that were transitional between terrestrial mammals and the earliest true whales. One of the most interesting was the ear region of the skull. In whales, it is extensively modified for directional hearing underwater. In *Pakicetus*, the ear region is intermediate between that of terrestrial and fully aquatic animals.

Ambulocetus

Another, slightly more recent form, called *Ambulocetus*, was an amphibious animal. Its forelimbs were equipped with fingers and small hooves. The hind feet of *Ambulocetus*, however, were clearly adapted for swimming. Functional analysis of its skeleton shows that it could get around effectively on land and could swim by pushing back with its hind feet and undulating its tail, as otters do today.

Rhodocetus

shows evidence of an increasingly marine lifestyle. Its neck vertebrae are shorter, giving it a less flexible, more stable neck -- an adaptation for swimming also seen in other aquatic animals such as sea cows, and in an extreme form in modern whales. The ear region of its skull is more specialized for underwater hearing. And its legs are disengaged from its pelvis, symbolizing the severance of the connection to land locomotion.

Basilosaurus

By 40 million years ago, *Basilosaurus* -- clearly an animal fully adapted to an aquatic environment -- was swimming the ancient seas, propelled by its sturdy flippers and long, flexible body. Yet *Basilosaurus* still retained small, weak hind legs -- baggage from its evolutionary past -- even though it could not walk on land.

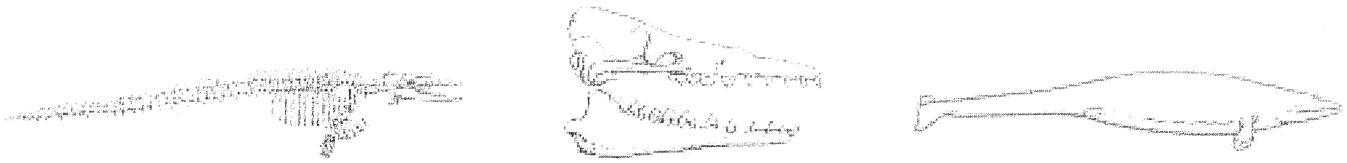
None of these animals is necessarily a direct ancestor of the whales we know today; they may be side branches of the family tree. But the important thing is that each fossil whale shares new, whale-like features with the whales we know today, and in the fossil record, we can observe the gradual accumulation of these aquatic adaptations in the lineage that led to modern whales.

As evolutionary biologist Neil Shubin points out, "In one sense, evolution didn't invent anything new with whales. It was just tinkering with land mammals. It's using the old to make the new."

evolution

Figure 1

Whales in the Making



a b c

1. *Zygorhiza*, *Prozeuglodon*, *Dorudon* ~ 36 mya (million years ago)

a b c

2. Mesonychids (extinct land mammals, with whale-like teeth, e.g. *Pachyaena*, *Dissacus, Haplodectes*) ~ 55 mya

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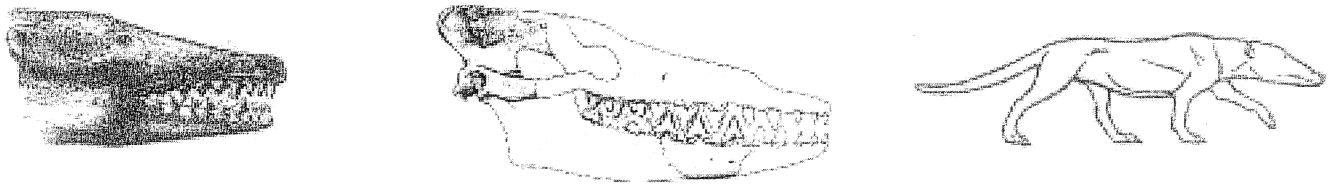

a b c

3. (1983) *Pakicetus inachus* (skull and teeth only) ~ 50 mya

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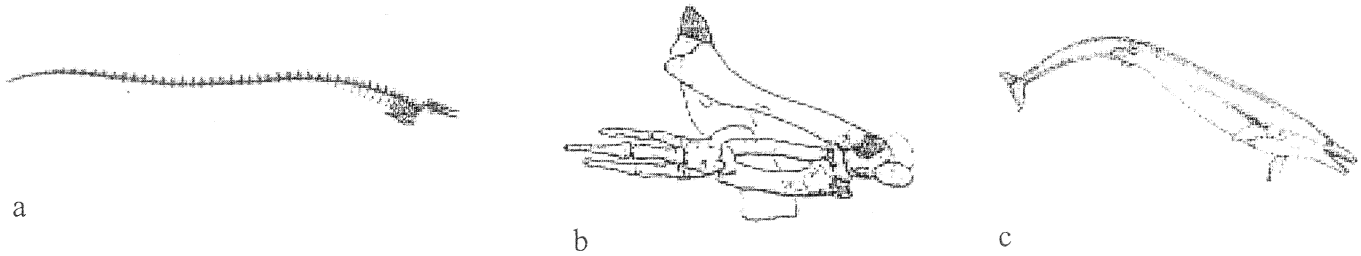
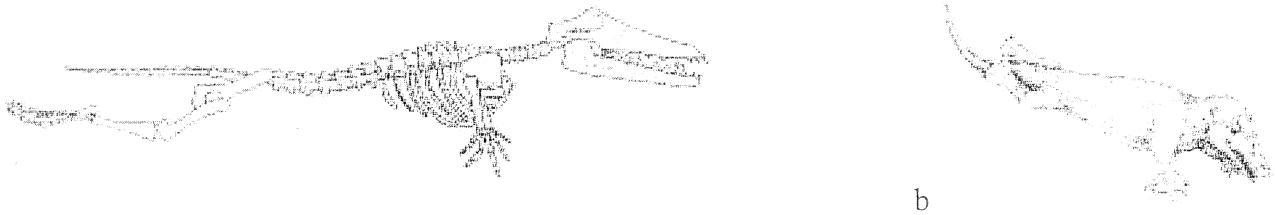


a b c

4. (1990) *Basilosaurus isis* (hind leg found) ~ 37 mya

a b

5. (1994) *Rodhocetus kasrani* ~ 46 mya



a b

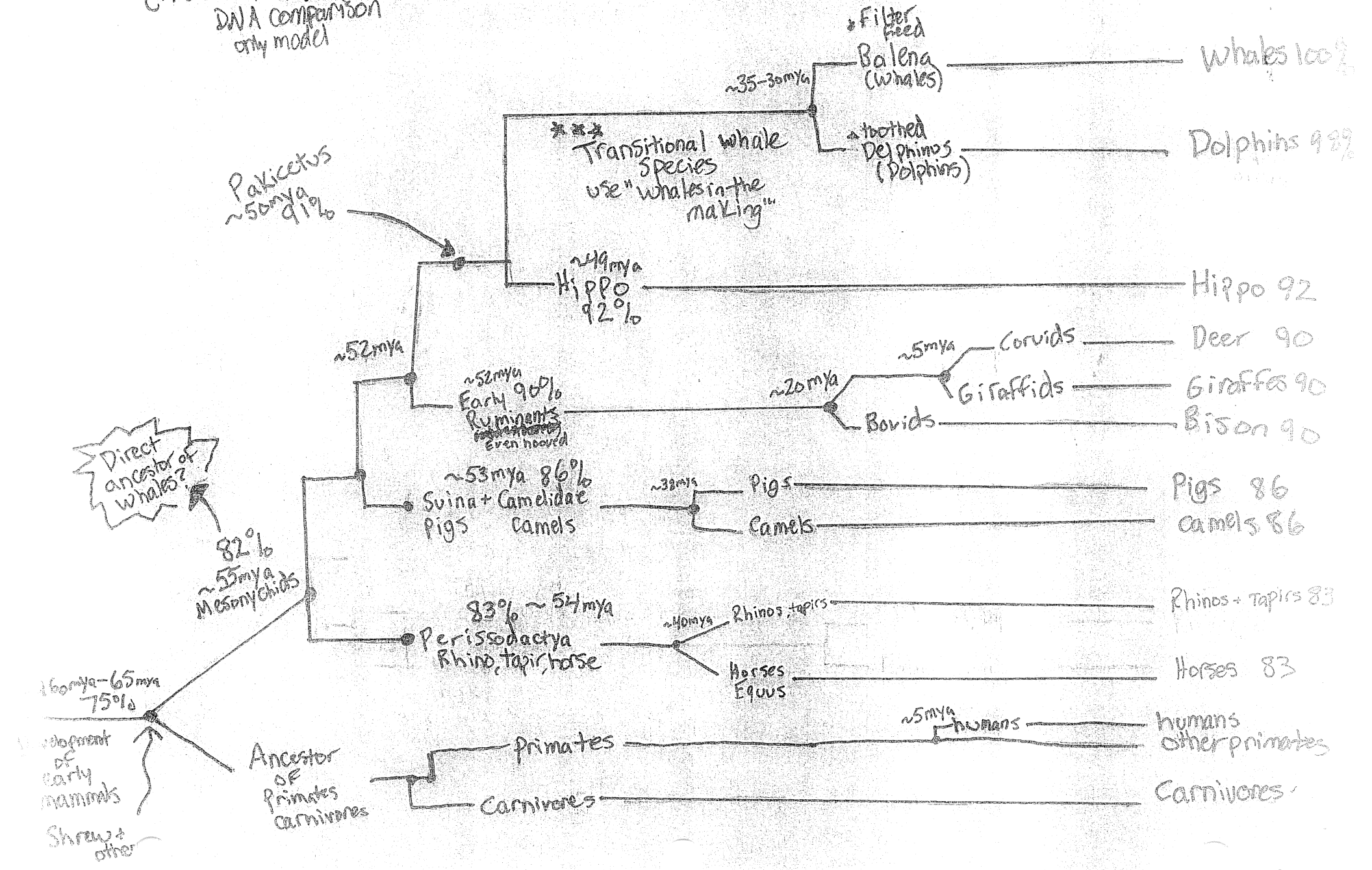
6. (1994) *Ambulocetus natans* ~ 48 mya

mya = million years ago

% = percent DNA shared with modern whales (* Note not actual DNA comparison only model)

Mammalian Cladogram or Phylogenetic Tree

Figure 2



Whale Evolution Data Table

Name	Mesonychids *e.g. Pachyaena*	*Pakicetus*	*Ambulocetus*	*Rodhocetus*	*Basilosaurus*	*Zygorhiza*
Year reported						
Country where found						
Geological age (mya)						
Habitat (land, fresh water, shallow sea, open ocean)						
Skull, teeth, ear structure types most like... whale or land mammal?						
Limbs and tail: Description; Did it swim? How?						