Educator's Guide

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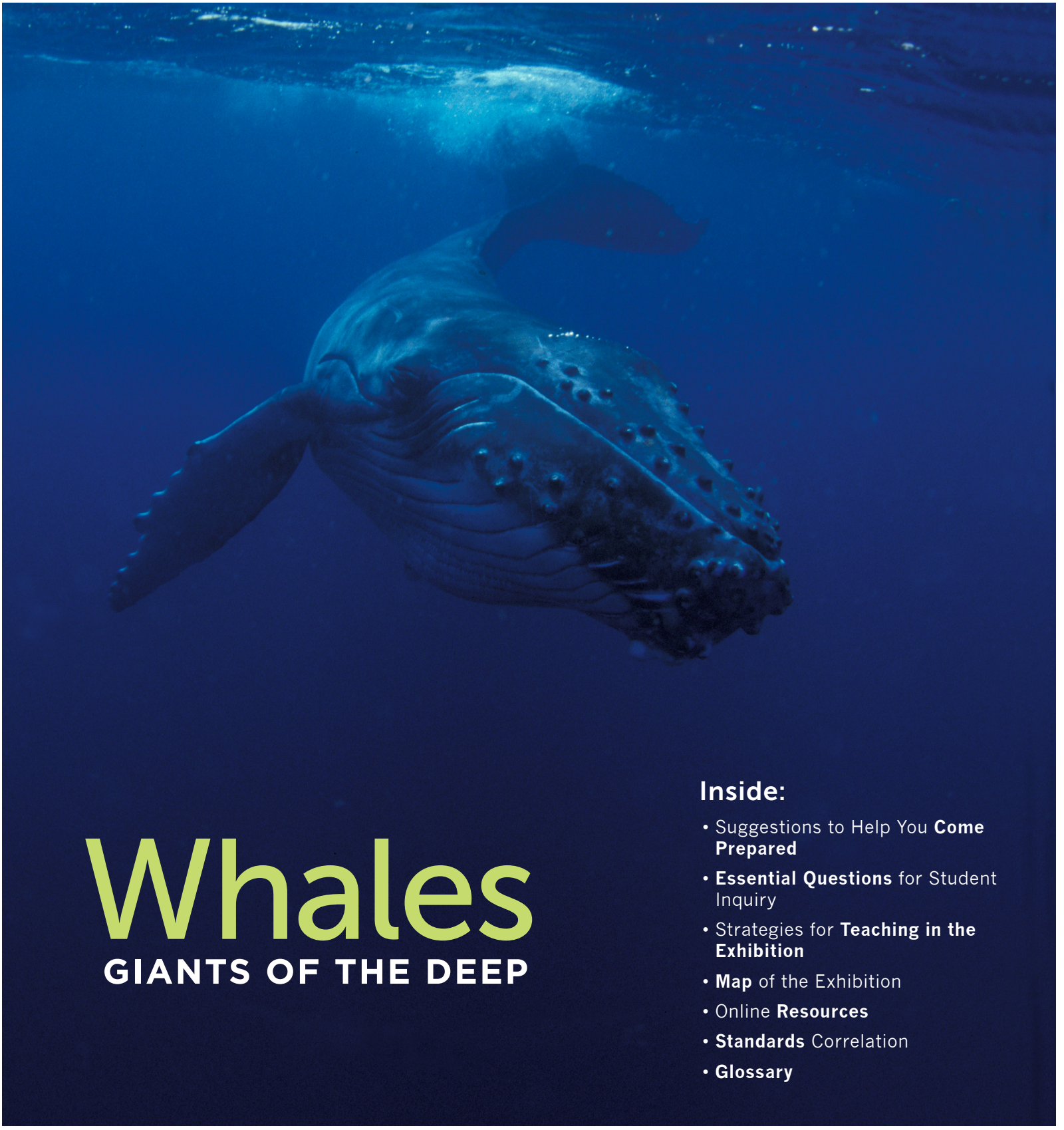
SAN DIEGO NATURAL HISTORY MUSEUM



Whales

GIANTS OF THE DEEP

Inside:

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- **Essential Questions** for Student Inquiry
- Strategies for **Teaching in the Exhibition**
- **Map** of the Exhibition
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sdnat.org/whales

The Museum gratefully acknowledges the County of San Diego and the City of San Diego Commission for Arts and Culture.

ESSENTIAL Questions

What is a whale?

Whales are **mammals**; they breathe air and live their whole lives in water. People often use the word "whale" to refer to large species like sperm and humpback whales, but dolphins and porpoises are also whales since they're all members of the order Cetacea. **Cetaceans** evolved from hoofed animals that walked on four legs, and their closest living relatives are hippos. Living whales are divided into two groups: baleen whales (Mysticeti, or filter feeders) and toothed whales (Odontoceti, which hunt larger prey). Whales inhabit all of the world's major oceans, and even some of its rivers. Some species are widespread, while others are localized. Many migrate long distances, with some species feeding in polar waters and mating in warmer ones during the winter months. All must come to the surface to breathe, but some dive to great depths to feed. Highly intelligent, whales have very strong social ties and often hunt and migrate together. To communicate they make sounds that range from a dolphin's series of clicks to the male humpback's complex song.

How are whales adapted to life in water?

Whales can be vastly larger than land mammals because water supports their weight. Other specialized features for living in water include:

- a streamlined shape, and layer of **blubber** that insulates against the cold
- plates of **baleen** that enable Mysticeti, like right and Bryde's whales, to filter huge amounts of **krill** and other small prey from seawater
- **echolocation** — most or all Odontoceti (toothed whales like killer whales and porpoises) use sound to navigate, communicate, and find prey
- nostrils, or blowholes, on the top of the skull so whales can breathe without raising their heads out of water

(See insert for more about specialized adaptations.)

How can people protect whales?

For millennia whales faced only dangers like disease and predators, but over the last few centuries, commercial hunting for oil, meat, baleen, **ambergris**, and bone drove some species to near-extinction. For example, 200,000 southern right whales were hunted down to fewer than 100 females. Chronic and acute noise pollution from engines, seismic surveys, and **sonar** can interfere with essential whale communication. Water pollution, coastal development, entanglement in fishing nets, collisions with ships, and climate change also put whales at risk.

Many populations remain endangered. National and intergovernmental organizations collaborate to establish and enforce regulations that protect whale populations, and some are showing recovery from whaling. The most effective whale protection programs involve the whole life cycle, from monitoring migration routes to conserving important breeding habitats and feeding grounds.

How do scientists study whales?

Many kinds of scientists — conservation biologists, paleontologists, taxonomists, anatomists, ecologists, geneticists — work together to learn more about these magnificent creatures. Fossil specimens provide a glimpse back some 50 million years, to whales' land-dwelling ancestors. New fossil whale species, and even new living ones, are still being discovered. Scientists use many methods to monitor these mysterious animals: beach, boat, and plane surveys to count and identify individual whales and monitor their life histories; tissue sampling for genetic analysis; and satellite tracking to understand habitat use and long-range migrations. Some living whale species are known only from **strandings**, which provide a unique opportunity to study the anatomy and genetics of these marine mammals. Scientists analyze both physical features and DNA (extracted from living animals and historic specimens) to resolve important issues such as conservation priorities and the placement of whales on the **tree of life**.

Photos help identify individual whales. Each humpback has its own individual tail fluke, like human fingerprints.

How are whales an important part of many cultures?

These massive and awe-inspiring creatures have played a vital role in the lives of coastal peoples around the world, as both a crucial natural resource and a source of ritual and legend. They are sacred to New Zealand's indigenous Mäori people, whose culture is rich with whale-riding stories and traditions. Whale imagery is incorporated into architecture and body art, and whale bone weapons and ornaments are prized. In the Americas, native people also have long utilized and honored whales, relying upon their meat for food, bone for tools and building material, and oil for fuel — and upon the majestic animals themselves as source of spiritual inspiration.

GLOSSARY

ambergris: a solid, waxy substance formed in the intestines of sperm whales that floats and occasionally washes ashore. Ambergris was once valued as an ingredient in perfume.

baleen: flexible plates that hang from the upper jaws of baleen whales with hairy fringes that strain small animals from sea-water. Although it's made of keratin, like your fingernails, baleen was once called "whalebone." It was used for many products that required strength and flexibility, like corset stays and buggy whips, until plastics were invented in the 20th century.

blubber: a thick layer of fat under the outermost part of the skin of marine mammals

cetaceans: a common name for members of the order to which all whales belong. The order Cetacea contains almost 80 species, and can be divided into Mysticeti (baleen whales) and Odontoceti (toothed whales, including dolphins and porpoises). Cetaceans are carnivorous, and except for four species of freshwater dolphins, all live in the ocean.

echolocation: the process of emitting sound waves and listening to the echoes to locate food and avoid obstacles. Sometimes referred to as "biosonar," echolocation evolved independently in bats, cetaceans (dolphins and other toothed whales), shrews and some other mammals.

krill: small, shrimp-like crustaceans that are the main food for hundreds of animals, from fish to birds to many baleen whales.

mammal: a member of the class Mammalia, vertebrate animals descended from the common ancestor of the living placentals, marsupials, and monotremes. Almost all mammals share certain physical characteristics: they have hair; they're warm-blooded; and they produce milk to nurse their young.

sonar: the use of sound waves to detect submerged objects or calculate distances underwater.

stranding: swimming or drifting onto land. Once stranded, whales suffer internal organ damage, overheat, rapidly deteriorate, and usually die.

tree of life: a branching diagram that shows how forms of life, both living and extinct, are related to each other.

COME PREPARED

Plan your visit. For information about reservations and transportation, visit sdnat.org/whales.

Read the Essential Questions in this guide to see how themes in *Whales: Giants of the Deep* connect to your curriculum. Identify the key points that you'd like your students to learn.

Review the Teaching in the Exhibition section of this guide for an advance look at the fossils, models, artifacts, and interactives that you and your class will be encountering.

Decide how your students will explore the *Whales: Giants of the Deep* exhibition.

- You and your chaperones can facilitate the visit using the **Teaching in the Exhibition** section of this guide.
- Students, individually or in groups, can use copies of the **map** to choose their own paths.

CORRELATIONS TO NATIONAL STANDARDS

Your visit to the *Whales: Giants of the Deep* exhibition can be correlated to the following standards.

A Framework for K-12 Science Education

Science Practices • Asking Questions and Defining Problems • Analyzing and Interpreting Data • Constructing Explanations and Designing Solutions • Engaging in Argument from Evidence
• Obtaining, Evaluating, and Communicating Information

Crosscutting Concepts • Patterns • Cause and Effect: Mechanism and Explanation • Scale, Proportion, and Quantity • Systems and System Models • Function • Stability and Change

Core Ideas • LS1.A: Structure and Function • LS1.B: Growth and Development of Organisms • LS1.C: Organization for Matter and Energy Flow in Organisms • LS1.D: Information Processing
• LS3.A: Inheritance of Traits • LS3.B: Variation of Traits • LS4.A: Evidence of Common Ancestry and Diversity • LS4.B: Natural Selection • LS4.C: Adaptation • LS4.D: Biodiversity and Humans

National Curriculum Standards for Social Studies

Thematic Strands • 1. Culture • 3. People, Places, and Environments • 8. Science, Technology, and Society
• 9. Global Connections

Teaching in the EXHIBITION

Whales have long captured the imaginations of people around the world, who have hunted, revered, and passionately protected them. This exhibition uses fossils, models, specimens, and artifacts to explore the cultural significance, evolutionary history, and amazing biological adaptations of these highly intelligent marine mammals. The Guided Explorations below are organized around five themes. **Refer to the map for locations.**

Carving of Whale Rider

Upon entering the exhibition you'll see the representation of a young man riding a whale. He is **Paikea**, an ancestral figure for New Zealand's Mäori people. Whales feature prominently in Mäori traditions and are carved on structures like this gateway.

Whale People

Students can watch perspectives on whale biology, whaling, conservation, research, and cultural tradition in **videos** throughout the exhibition.

1. EVOLUTION & DIVERSITY

OVERVIEW: The ancestors of whales lived on land. Once whales adapted to the water about 50 million years ago, they diversified and came to inhabit the world's oceans. Almost 80 species are alive today. Scientists study both living and fossil species, using anatomy and genetic evidence to understand how whales evolved and where they fit in the tree of life.

GUIDED EXPLORATIONS

a. **Casts of fossils:** These skeletons belong to early relatives of modern whales. Have students find out when they lived, then compare land-dwelling *Pakicetus* and *Ambulocetus* to the water-dwelling *Dorudon*. Ask: How do skeletons of the whales that lived on land compare to those that were fully aquatic? *(in aquatic whales, hind limbs are smaller or absent, nostrils move towards top of head, forelimbs evolve into flippers, vertebrae in tail flatten)*

b. **Diversity wall & beaked whale skulls:** There are two main living whale groups: baleen, or Mysticeti, and toothed or Odontoceti. At the diversity wall, have students identify them. Ask: What is the main difference between these two groups? *(Mysticeti have baleen, Odontoceti have teeth)* What other differences do they observe? *(Mysticeti tend to be larger, have two blowholes instead of one).* Have them explore the diversity wall to see where the beaked whales fit in, then examine the case on the left to see how scientists classify members of the beaked whale family using anatomical characters: things as simple as the shape and position of their tusk-like teeth. Also ask them to consider the differences between a dolphin and a porpoise. *(dolphin teeth are conical and porpoise teeth spade-shaped; porpoises have beaks)*

2. SOUND

OVERVIEW: In addition to sight, whales rely on the ability to produce and perceive different sounds in order to navigate, find food, and communicate.

GUIDED EXPLORATIONS

a. **"Search and Destroy" theater:** In this five-minute immersive experience students will explore hunting from a sperm whale's point of view. Ask: What is the whale hunting? *(giant squid)* How does the whale find its prey? *(echolocation)*

b. **Sound chamber:** Different whale species make a variety of sounds, ranging from throaty rumbles and melodious phrases to squeaks, whistles, clicks, and buzzes. Invite students to turn the dial to tune in to the voices of eight different whale species and to explore more via graphics and animations. They can also compare the low-frequency sounds of the baleen whales to the higher frequency ones produced by odontocetes.

3. ANATOMY

OVERVIEW: Whales share many anatomical features with land mammals, but also evolved unique adaptations that enabled them to become fully aquatic.

GUIDED EXPLORATIONS

a. **Blue whale's heart:** Invite students to crawl inside this life-size model of a blue whale's heart. Inside they can see colorful graphics about its enormous size and weight, and hear the heartbeat. Ask: Why does the whale heart need to be so big? *(to pump blood through a massive animal)*

Anatomy interactive & touchable bones: Students can use the interactive display to investigate and compare a dolphin's external features, internal organs, and skeletal structure to those of a sperm whale and a human. Then have students touch some of the bones they just explored, including a vertebra, rib, and tooth.

Flipper X-rays and bones: Even though a whale flipper and a human arm and hand look very different, they contain the same kinds and basic arrangement of bones. Ask students to look at the X-rays of the flippers of a dolphin and a humpback whale and compare them to the human arm and hand. How are they used differently? How do the skeletons reflect this? *(hands are highly flexible, have mobile joints; flippers are stiff paddles without movable joints)*

Models of dolphin mother and calf: Use the models and information on the text panels to guide an exploration of how whales mate, give birth, and care for their young.

Scale model case: Have students observe the models of different whale species, and compare their sizes relative to humans.

Sperm whale skeletons: Invite students to observe the male and female skeletons and compare them to images of the fleshed-out whale on the panel. Ask students to point out features such as the presence of teeth, fused neck vertebrae, bones in flippers, and the contrast between the shape of upper jawbone and the bulbous head.

Feeding: Have students observe the skulls and compare the feeding strategies of the two types of whale. Ask students to identify how the structure of each skull reflects that animal's feeding strategy. *(Mysticetes use baleen to efficiently filter large quantities of small animals from seawater; odontocetes have structures for echolocation, which allows them to seek larger prey, and some use teeth to grab it. Odontocetes without erupted teeth feed by creating suction.)*

4. STRANDINGS

OVERVIEW: Sometimes whales come ashore accidentally, alone or in groups. Strandings often mobilize communal rescue efforts. Whales that can't be saved present a rare opportunity to collect material for scientific or cultural purposes.

GUIDED EXPLORATION

a. **Strandings section:** Students can watch a video, sniff ambergris, and read about strandings. Ask: What are some causes of whale strandings? *(parasites, pollution, disease, disorientation, accidents with boats, entanglements with fishing gear. Weakened whales may swim into shallow water where it is easier to breathe.)* How have humans responded? *(tried to rescue whales, collected meat and bones, taken samples for scientific research)*

5. WHALE PEOPLE

OVERVIEW: The lives of many people around the world have been inextricably linked with whales.

GUIDED EXPLORATIONS

a. **Mäori storehouse, artifacts, and animation:** Have students watch the video about the varied role of whales in Mäori culture, then examine the ceremonial and everyday objects in the storehouse. Ask: Why are these objects so important to the Mäori? *(whales are central to Mäori traditions; the material these objects are made of is rare)*

b. **Whaling history wall and whaling artifacts:** Have students explore this timeline of the history of whaling in New Zealand and examine whaling traditions in America through artifacts such as a whale oil lamp, a log book from the New England whaling ship *William Rotch*, and an early edition of *Moby Dick*. Ask: How have behaviors and attitudes towards hunting whales changed over time? *(beached whales were passively gathered; development of commercial whaling reduced some populations to the brink of extinction; global whale conservation movement has emerged)*

c. **Whale Riders Theater:** Students can watch whale-riding stories from three different Mäori tribes of New Zealand.

d. **"A Global Vision: The Power of Whales":** Invite students to examine these sacred objects and everyday items from Alaska, Canada, and Peru, and consider how they represent the importance of whales to these Native peoples.

ONLINE Resources

Whales: Giants of the Deep
sdnat.org/whales
Learn about exhibition highlights, whale evolution and biology, whale people, and related Museum programs.

Whales | Tohora
collections.tepapa.govt.nz/exhibitions/whales
The *Whales* exhibition website of the Te Papa Museum in Wellington, New Zealand.

Cetaceans: Whales, Dolphins, and Porpoises
nmfs.noaa.gov/pr/species/mammals/cetaceans
Detailed information about every cetacean species from NOAA's National Marine Fisheries Service.

Whales: The Kids' Times
nmfs.noaa.gov/pr/education/whales.htm
Eight PDFs compiled by NOAA, each focused on a different species.

Discovery of Sound in the Sea
dosits.org
The physical science of how mammals (including humans) use underwater sound to navigate and communicate.

CONSERVATION
Information about whale conservation and management around the world, including conservation status and how humans can work to protect cetaceans.

WWF: Whales, Dolphins, and Porpoises
wwf.panda.org/what_we_do/endangered_species/cetaceans

Whale Research
whaleresearch.org

International Whaling Commission
iwc.int

International Union for Conservation of Nature and Natural Resources (IUCN)
iucnredlist.org

WHOPPING WHALE FACTS
Even the smallest whale — the finless porpoise, which weighs 30-45 kg (65-100 lbs) — is huge compared to the "average" land mammal, which weighs less than one pound.

Sperm whales were hunted for the oil found in the spermaceti chamber at the top of their heads. Their oil lit city streets and lubricated machines all over the world.

Gray whales migrate farther than any whale — or any mammal. Their 18,000-kilometer round trip (11,200 miles) takes them from the Bering Sea down the Pacific Coast of North America to Baja California, Mexico, and back to the Arctic.

CREDITS
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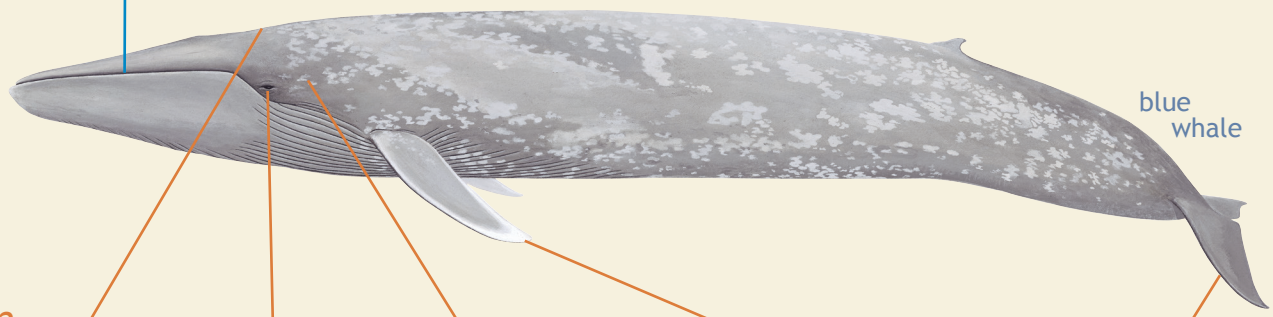
Glossary: Whale feeding case, © Museum of New Zealand Te Papa Tongarewa, 2008.
Come Prepared: Hunter's helmet, © AMNH/D.Finnin.
Whale Adaptations: blue whale and common dolphin illustrations, © Pieter Folkens.

Whale ADAPTATIONS

Adaptations Unique to Baleen Whales (Mysticeti)

Baleen
Instead of teeth, these whales have flexible plates that hang from their upper jaws, with hairy fringes that strain small animals like krill from seawater. Baleen is made of keratin, like your fingernails.



Common Adaptations

Blowhole
Whales breathe air like other mammals. They must come to the surface to take in air through their nasal openings, the blowholes on top of the head.

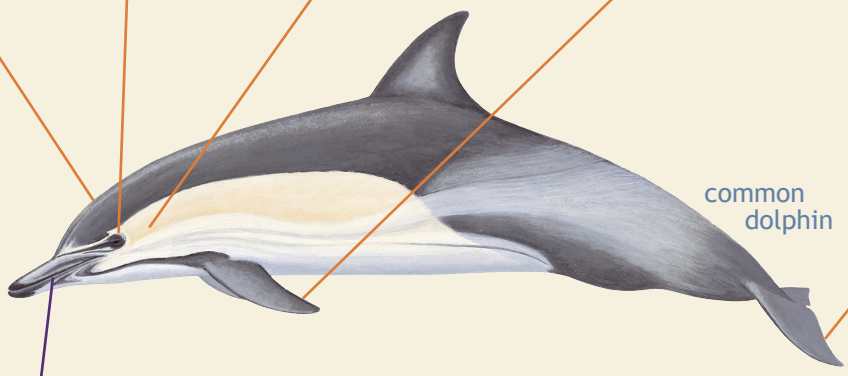
Eyes
Unlike humans, whales can see very well both in and out of water. But studies suggest that whales don't have color vision.

Hearing
A whale's external ear is the size of a pinhole and plays little role in hearing. Instead, whales hear through "acoustic" fat in their lower jaws, which transmits sound along a channel leading to the inner ear.

Flippers
A whale's front limbs, or flippers, have the same kinds and basic arrangement of bones as human arms. These rudder-like paddles provide both stability and great maneuverability in the water.

Flukes
Most of a whale's swimming power comes from moving its body and these horizontal lobes at the end of its tail up and down.

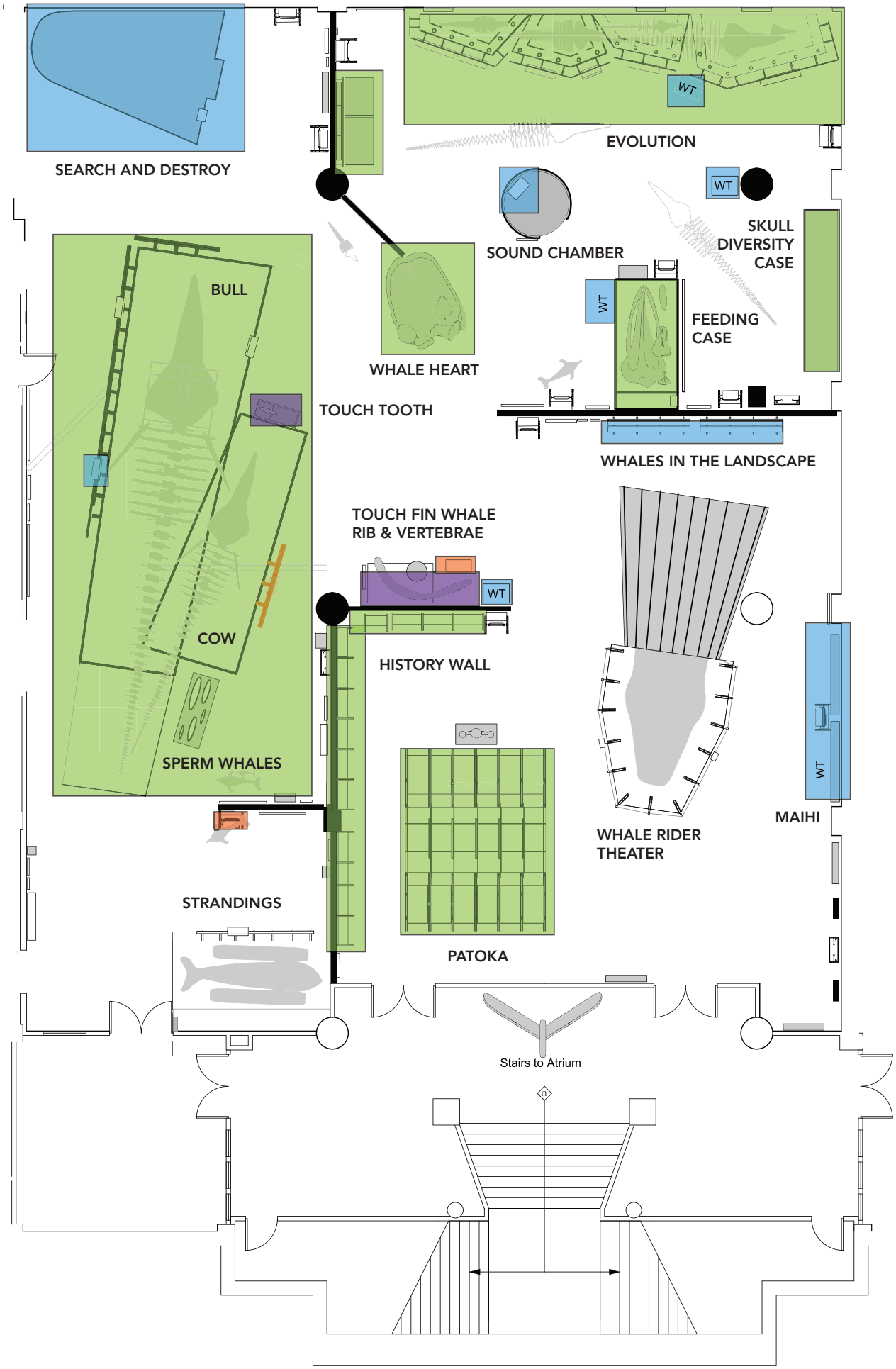
Streamlined Teardrop Shape
This reduces resistance, so whales can move through water faster.



Adaptations Unique to Toothed Whales (Odontoceti)

Teeth
Odontocetes retain the teeth of their mammal ancestors. But some are highly specialized, as in beaked whales and narwhals, while dolphins, for example, have lots of the same kinds of teeth. Toothed whales hunt their prey — fish, squid, and other whales and marine mammals — one by one. They either grab it with their teeth or suck the food directly into their mouths.

Echolocation
Toothed whales use this "biosonar" to locate prey and navigate with remarkable accuracy. They produce a series of sounds, and interpret the echoes for information about the seafloor, underwater obstacles, and the presence of other animals in the water.


SEARCH AND DESTROY
EVOLUTION
WT
SOUND CHAMBER
WT
SKULL DIVERSITY CASE
BULL
WHALE HEART
WT
FEEDING CASE
TOUCH TOOTH
WHALES IN THE LANDSCAPE
TOUCH FIN WHALE RIB & VERTEBRAE
WT
COW
HISTORY WALL
WHALE RIDER THEATER
WT
MAIHI
SPERM WHALES
STRANDINGS
PATOKA
Stairs to Atrium