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Marine Mammals of the World

A Comprehensive Guide to their Identification

Illustrations by Brett Jarrett

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Preface and Acknowledgments

This book represents the latest stage in an ongoing attempt to produce materials that will allow people to more easily identify marine mammals that they may come across during dives or just while walking on the beach, or when visiting a museum or other research collection. It is fair to say that this effort grew out of a passion and talent for preparing useful marine mammal identification guides by Dr. Ida Boulton Leatherwood, a colleague and good friend to all three of us. Steve (along with co-authors Randy Reeves, Bill Perrin, Bill Evans, Brent Stewart, and several others) had already prepared a number of well-received regional and global field guides on cetacean and marine mammal identification by the time that we first became involved in the effort.

Around 1990, Steve pulled Tom and Mark into a project to produce the world's first guide to identification of all marine mammals of the world, the FAO guide *Marine Mammals of the World* (pronounced as Jefferson et al. 1993). Although we were not entirely happy with how that guide turned out, many of our colleagues told us the book was very helpful to them, and we continued to get requests for copies for some years after it went out-of-print. It was even used as a text book for some university classes on marine mammal biology.

As the FAO guide neared its ten-year anniversary we began to realize that it was badly out of date, and that there was a great need to prepare a replacement that both updated the cetacean taxonomic classification system of the FAO guide, and expanded upon those features that others found useful in that guide. Sadly, one fallout of this entire effort, Steve Leatherwood, had passed away of lymphoma in early 1997. Although we felt reluctant to do another field guide without Steve, some of our colleagues were urging us to update the FAO guide. Eventually we decided not just to update the FAO guide but to produce a much more useful and complete guide to identify marine mammals of the world. To help us in the effort to produce a better marine mammal identification guide, we asked Bob to come onboard. Once Academic Press agreed to publish the book, we talked about the task of writing and brought in Brent Jarrett to join the publishers.

It is important to realize that we do not see this book as an end product. We hope to periodically produce new editions of the book, each one updated and improved over the last version. This is necessary as marine mammal taxonomy is constantly evolving (and doing so very fast in the last few years as we move from a 'century of 'lumping' back towards 'splitting'), and we are always learning more about the species represented. Further to this effort, we would ask readers and users of the book to contact us with any suggestions for changes in the next edition, including any suggestions for better photos. We especially welcome anyone pointing out any errors, inconsistencies, or incomplete sections that we may have made. Rest assured that your criticisms will not fall on deaf ears, but will help us to improve any future versions.

A book like this cannot be completed without the assistance of a large number of people. First we would like to thank our editors and colleagues at Academic Press—Kevin Carpenter, Dave Cella, Chuck Crumly, Claire Hutchins, Kelly Sonnack, Andy Richford, and Rogue Shindler, for their patience and guidance over the years during this long process. We are also extremely grateful to Emma Power, who helped us in editing and proofing the pages.

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1. Introduction

The Need for This Guide

[illegible] in the world in general, and marine mammals in particular, has increased significantly in recent years, both in the general public and in the scientific and management communities. More people than ever are including wildlife watching in their activities, and this includes naturalists and adventure expeditions to see wild marine mammals up close. At the same time, there is increasing awareness of the integral importance of marine mammals to healthy aquatic ecosystems, and of the growing threats that a variety of human activities pose to these animals and their environments. Research and education programs are seeking to better understand, and more clearly communicate the nature of these threats and appropriate steps to reduce or eliminate their impacts.

Good identification guides are integral to all these activities. Although there are many guides to limited geographic areas and some subsets of the world's marine mammal fauna, there are few comprehensive guides that cover all the world's whales, dolphins, porpoises, seals, sea lions, walruses, manatees, dugongs, sea otters, and polar bears. Additionally, few of the existing guides provide special aids to identifying live animals, in-hand specimens, and skulls. This identification guide, compiled after several years of work by the authors and illustrators, is intended as a significant step toward filling that need.

We have attempted to make this volume as complete, comprehensive, and up to date as possible. However, we are aware that it is limited by the differences in the amount and quality of information available on the various groups, as well as by the inadequacies of our approach towards representing what is available. Therefore, we prefer to think of this as somewhat of a starting point, to be improved by input from those who [illegible] in the field and lab. In this edition, assuming that there will be future editions, which is mainly determined by how well it is received, it is our intention to correct errors and deficiencies revealed by extensive use in the meantime. We hope this book helps both amateurs and professionals with the sometimes-difficult task of positively identifying species of marine mammals they sight alive or encounter dead.

Most biologists and the term "marine mammal" to include members of five different mammalian groups: cetaceans (whales, dolphins, and porpoises), pinnipeds (seals, sea lions, and walruses), sirenians (manatees, dugongs, and Steller's sea cow), marine and sea otters, and the polar bear. These diverse groups are currently thought to represent five or six different modern descendants of land-dwelling ancestors. The term "marine mammal" therefore implies no systematic or taxonomic relationship. In fact, the cetaceans are more closely related to camels and hippos than they are to other marine mammals; the pinnipeds have more in common with bears and weasels, and the sirenians are more closely allied to elephants and hyraxes. These differences not withstanding, however, all marine mammals have one thing in common—they derive all or most of their food from marine or some other aquatic [illegible] water.

All marine mammals have undergone major adaptations, which permit them to live in the water. The cetaceans and sirenians spend their entire lives in the water, while other marine mammals come ashore for various reasons, at particular times in their life cycle (most commonly to reproduce, molt, or rest). Major structural modifications to the bodies of cetaceans, sirenians, and pinnipeds involve the loss of hind limbs (only vestigial in cetaceans and sirenians), the adaptation of limbs for propulsion through water (flippers and flukes), and the general streamlining of the body for hydrodynamic efficiency (all three groups). Structural modifications to the marine and sea

orders and the adaptations to marine existence are less apparent in body form; these animals in most ways are closely related to their terrestrial counterparts.

Like its predecessor (Jefferson et al. 1993), since this is an identification guide, we include mainly information useful for identifying marine mammal species. For good introductions to the biology of mammals in general, see Gould and McKay (1998) and Macdonald (1984). More detail specifically on the biology of marine mammals can be found for cetaceans in Leatherwood and Reeves (1983), Evans (1987), Harrison and Bryden (1988), and Martin (1990); for pinnipeds in King (1983), Bonner (1990), Riedman (1990a), and Reeves et al. (1992); for sirenians in Reynolds and Odell (1991), and Reeves et al. (1992); for marine and river otters in Riedman (1990b); and Reeves et al. (1992); and for polar bears in Stirling (1988), and Reeves et al. (1992). The best sources for basic information on the biology and phylogeny of marine mammals are Ridgway and Harrison (1999), Twiss and Reeves (1999), Berta et al. (2006), Hoelzel (2002), and Perrin et al. (2002).

Marine Mammal Identification and How to Use This Guide

Most available marine mammal identification guides do not provide the most appropriate information for accurate identification, have limited geographic or taxonomic scope, or are badly out-of-date. Two very good recent ones are Reeves et al. (2002) and Shirihai (2006). Marine mammals can be difficult to identify at sea, even under ideal conditions. An observer often gets little more than a brief view of a splash, blow, dorsal fin, or back, and this is often at a great distance. Rough weather, glare, fog, or other poor sighting conditions only compound the problem. The efforts of lighting, in particular, must be kept in mind. Many diagnostic characters may only be visible under good lighting or at close range. One must always acknowledge the limitations of the particular set of conditions under which they are exposed to when making a marine mammal identification.

Sexual dimorphism is common in many pinnipeds and cetaceans. Northern elephant seals show an extreme form, which involves both size and body shape differences. The large individual in the background is an adult male, and the smaller one in the foreground is a fully-grown adult female. (John Ternullo)

Many species appear similar to another, especially in the brief glimpses typical at sea. Animals of some poorly known groups (most notably, beaked whales and Southern Hemisphere fur seals) are especially difficult to identify to species, even with a good look at a live animal or an "in hand" specimen (and even to most marine mammal specialists). For all these reasons, even experts often must log a sighting as "unidentified." In all cases, the designation, accompanied by a detailed description is preferable to assuming an incorrect identification. This point cannot be overemphasized!

In addition to the diagnostic variation among species, marine mammals often exhibit other types of variation in morphology and coloration. These are important to keep in mind when making identifications, as such variation can mask diagnostic species characters and cause confusion and even misidentifications. The most common types of such variation in external appearance are discussed briefly below.

Intraspecific geographic variation Marine mammal species generally occur in populations that are (more or less) reproductively isolated from each other. If these populations have been separated for a long enough period of time, they may have evolved noticeable differences in their external morphology. Virtually every marine mammal species (with the possible exception of those that only occur as a single population, like the vaquita and possibly the baiji) shows some geographic variation. Much of this variation is subtle and not very noticeable, and therefore will not significantly affect field identification, but sometimes distinct geographic forms may have evolved. These may differ quite strongly in overall size, body shape, coloration, etc. Some such variants have been formally described as subspecies (which, in many cases, are incipient species), and have been given binomials (subspecific names), but most have not been formally recognized. This book attempts to provide descriptions and illustrations of geographic forms that are well-described and may be recognizable in the field, regardless of whether they have been described as subspecies.

Sexual dimorphism Most marine mammal species show some sexual dimorphism, with one sex being somewhat larger than the other. In addition, many toothed whales and pinnipeds have males and females showing distinct differences in body shape and coloration. These differences usually remain insignificant until near the age of sexual maturity, but can become quite

pronounced in adults. One must keep this dimorphism in mind when making identifications, especially in areas where only a single individual is known for the species' population. We make every attempt to describe significant sexual dimorphism as it is known for marine mammal species identification.

Developmental variation Obviously, young marine mammals do not look exactly like adults. Clearly they are smaller than adults, but they may also have very different body proportions and color patterns. The head and appendages of most newborn marine mammals are typically proportionately longer than they are in adults. It is not uncommon for cetacean calves and pinniped pups to show very different pigmentation than adults. For instance, most dolphins have a muted version of the adult color pattern when first born. Size and other external differences of young animals are described in this book, when adequately documented.

Seasonal variation Seasonal variation in external appearance is not nearly as important in marine mammals as it is in fishes, birds, and other animals that are out of water for long periods. However, there are some species in which seasonal differences are important. An example of this is the northern elephant seal, which has a seasonal molt occurring at different times for different age classes. During the molting period, some animals look ragged and have a quite different appearance than the more typical beige of the rest of the year. We attempt to identify seasonal variants in this guide.

Uncommon color morphs Some marine mammal species are characterized by the existence of uncommon, rarely-occurring color morphs. This is the case for some species of dolphins (e.g., short-beaked common dolphins, Pacific white-sided dolphins, northern and southern right whale dolphins), porpoises (e.g., Dall's porpoise), and seals (e.g., sea otters) for seals for instance. In addition, melanistic (all black) individuals, albinos, and other anomalously-white color morphs occasionally occur, and are a possibility for any marine mammal species. Where one or more uncommon color morphs are well-known, we attempt to describe and illustrate them in this book.

Hybrids and intergrades Sometimes animals of different species mate with each other and produce offspring. Hybrids are the result of such interspecific matings. One must always be cautious about the possibility of a hybrid when making marine mammal identifications. Hybrids between certain whale species (e.g., between minke and Bryde's), between dolphin species, between porpoise species, and between muted species have been documented. In fact, in the southern

A group of short-beaked common dolphins leap at the bow of a research vessel in the eastern North Pacific, showing some of the individual variation in coloration and body shape that is common in marine mammals. (©Robert L. Pitman)

Hemisphere, the species Arctocephalus gazella and A. tropicalis are very similar in appearance and behavior and there is much overlap in ranges. As a result, hybridization is very common, and can be a major complicating factor in making species identifications. Although not documented in dolphins among the many similar species of the beaked whale genus Mesoplodon should also be considered a possibility. Finally, intermediates may appear (these are the equivalent of hybrids, but result from a cross between subspecies, not full species). Intergrades are known to be very common in common dolphins, for instance, where a "geographic form" of the species in the eastern tropical Pacific (the white-bellied spotted form) is now known to be an intergrade swarm. We generally do not describe hybrids and intergrades in this guide, except in those few cases where they appear very commonly. However, one must always be on the lookout for them.

Individual variation Beyond all of the types of variation mentioned above, there is individual variation in every species. No two individuals are exactly alike—this variation is usually the raw material of natural selection. There will naturally be some range in all of the species' diagnostic characters. Some species are more variable than others, and certain features (such as body length and body mass) tend to show great amounts of individual variation in most species. This should always be kept in mind when making identifications. We attempt to document and illustrate some of the individual variation present within any species in this book, but it should be recognized that we can only present a small fraction of what naturally occurs.

Scarring, injuries and deformities One must always remember that, in the course of evading predators, finding and obtaining food, interacting with conspecifics, and avoiding impacts or human activities, marine mammals

These Antarctic fur seals of South Georgia show the basic body shape that is typical of all eared seals (otariids). Their ability to turn their hindflippers forward under their body and walk on land reminds one of their terrestrial ancestry. [illegible]

become scarred and injured. In short, they may develop deformities, either as a result of congenital defects or disease. These may cause an animal to appear quite different than the usual individuals during the diagnostic characters. Most such defects will have little or no impact on the ability to identify marine mammals to species, but some may cause problems. For the most part, we are unable to describe and illustrate the effects of injuries and deformities in this book, but we caution the reader to keep these factors in mind.

Finally, although it is not really a type of variation, the effects of lighting must also be considered. This is especially true when making identifications of living animals in the field, and when examining photographs. Some subtle color pattern components may only be visible in the right lighting, and glare on an animal's body can sometimes look like light-colored patches. This is especially a problem when making an identification from still photographs.

Notes on the Format of the Species Accounts

The species accounts in this guide are the "meat and potatoes" of the book and are designed to be the primary tool used in identifying marine mammals observed at sea. We toyed with the idea of producing a dichotomous key to marine mammals observed at sea, but the paucity of useful clues for most species and the variability of many mammal behaviors would make such a key difficult to use. Marine mammal identification is something that must be learned through doing. Experienced marine mammal observers, the birders, often will be able to make an identification based on a composite of many subtle features and personal knowledge of the local marine mammal fauna. This ability will come with experience, guided by working with seasoned observers and the use of a proper field guide (this guide, or any of the future regional ones).

The species accounts are presented in taxonomic order, with closely-related species grouped together, even though in some cases the main species that may cause confusion are only distantly related. The following describes how the species accounts are set up:

Original description This is given immediately after the scientific name, and is the person (or persons) who originally described the species, and the year in which the description was published. Note that international taxonomic rules require that there always be a comma after the author(s), and that the parentheses that occur around some of the dates are important: they indicate that the species was originally described in a different genus.

Recently-used synonyms This is a list of synonyms of the scientific name that have been widely used in the past 50 years or so. The list is not intended to be comprehensive. Older, and more obscure, names are not listed here.

Common names For each species, the standard common names in English, Spanish, and French are given here. Note that other common names are used in these languages in some areas, and that there are a wide variety of common names used in other languages as well. However, we have made no attempt to compile a list of all the common names that the species goes by.

Taxonomic information After a brief list of the higher-level taxonomic groupings that the species belongs to, this section contains a very brief summary of any recent taxonomic controversies and taxonomic revisions, and mentions subspecies where widely recognized.

Species characteristics This section includes the main characteristics of the species used in field identification of whole specimens, including body shape, color pattern, size, and such things as tooth or baleen counts. For some of the better-known species, there is also a listing of age/sex classes that animals may be divided into, along with descriptions of how to recognize them. However, the latter is only attempted for those situations where such age/sex classes have been well-described.

Recognizable geographic forms There is significant geographic variation in virtually every species of marine mammal. However, beyond this for some species, distinct geographic forms have been described and

possess external characteristics that allow them to be identified in the field. When this is the case, we present a short description of such geographic forms in this section. If 'none' is listed, this does not mean that geographic forms do not exist, but rather that we do not feel that they have been adequately described or that they are not possible to reliably recognize in the field.

Can be confused with Those species that are most commonly confused with the species of interest are listed here, along with tips on how they can be separated. We cannot list every detail of the characteristics of the other species here, but simply list the types of features that should be given attention to. The reader must generally consult the species account for those species to get details.

Distribution This section includes a short description of the species' range, to be used along with the distribution maps provided for each species. We must emphasize that, although we have put considerable effort into providing the most useful range maps possible, the distribution areas should be considered approximate. The range limits shown, especially in offshore areas, are sometimes little more than educated guesses, based on incomplete data from cruise reports considered in light of available information on the species' distribution and habitat preferences discovered, in some cases, only in the past few years. Indicated are probably more a reflection of search effort than of real distribution limits. Therefore, the absence of sightings in a certain area does not necessarily mean that the species is not found there. This is especially true for many of the beaked whales, which are still known mostly from strandings. Just tell us little about the species' true distribution and habitat preferences).

Ecology and behavior The basic ecology of the species is very briefly summarized here. Although it is often of little use in identification, their morphological characteristics, behavior can rarely be used under favorable conditions to help in identification. Group sizes, in particular, are often useful. However, it should be remembered that the behavior of highly complex social mammals is highly variable, and group composition and morphology should always be given as the primary features for identification.

Feeding and prey This section contains a brief list of the types of prey items that the species feeds upon.

Threats and status The history of human exploitation of the species is briefly reviewed, and current conservation issues identified. Available population estimates are of variable accuracy, and should thus be taken cautiously. Techniques for estimating sizes of marine

Fishing nets, in particular various forms of gillnets and drift nets, kill hundreds of thousands of marine mammals every year—in this case a Dall's porpoise. Fishing net entanglement is now widely recognized as the single largest threat to the continued existence of many marine mammal populations and even some species. [illegible]

Discarded and lost fishing line, rope and net fragments are a hazardous type of marine pollution that injures and kills pinnipeds of many species such as this adult female Juan Fernandez fur seal. [illegible]

populations at sea are still evolving and are far from standardized, and available tools have been used unevenly, often with violations of underlying assumptions. For these reasons, the density of sightings on the distribution maps is intended to show only known or postulated range, and not population density.

IUCN status The legal status of each species is also given in the accounts. "Endangered Species Lists" are maintained by both the United States Fish and Wildlife Service (USFWS) (U.S. List of Threatened and Endangered Species) and the International Union for the Conservation of Nature and Natural Resources, now the World Conservation Union (IUCN Red List), among other agencies. In this guide, we present only IUCN designations.

"Endangered" status is assigned to those species considered to be in immediate danger of extinction. Species at risk of soon becoming endangered are generally listed as "Vulnerable" or some similar designation. Because of incomplete information, political considerations, and the time lag in completing requirements for listing, these status designations do not always accurately reflect the true status of a species (for instance, some species listed as endangered are at no immediate risk; others not listed may be on the verge of extinction). Nonetheless, they are helpful as warning flags that plans to exploit a given species must proceed only with great caution, and will give some idea of the degree of concern for the species' future.

References For each species, we provide about 4–6 references to which the reader can turn for more information. We have tried to include mostly recent review papers and more easily obtained publications that might be available at larger university libraries. The full references are listed at the end of the book.

Notes on the Dichotomous Keys

Marine mammals specimens "in hand" can best be identified by using the dichotomous keys to external features, provided as appendices at the end of the book. With such identification, it may be possible to view the entire body and to measure relative proportions of features. Various features of coloration and morphology are of particular help in such considerations. We have used geographical information as much as possible to separate the species. This will help to avoid biasing observers toward making an identification based on what they think it "should" be out there.

Marine mammal skulls can be keyed-out using the keys provided in the appendices. We have assumed that some geographical information is available, so the key can be used to identify an unlabeled skull of unknown origin in a museum, for instance. It is clear from our own work and discussions with colleagues that is not yet possible to prepare a completely reliable and effective skull key for the non-specialist. Published keys and reference literature are marred with errors and incomplete studies. Skulls of many species are so "county similar" that it will be necessary to examine a full series of each to define reliable diagnostic features. Until that exercise is completed for each species, the skull keys must be considered to be works in progress.

It can sometimes be very difficult or impossible to identify marine mammals to species, whether based on at-sea sightings, "in hand" whole specimens, or an unlabeled skull. Great variability in behavior, coloration, body morphology, and bone structure can occur. Sometimes it may only be possible to label an animal or group as "unidentified long-snouted dolphin," "unidentified beaked whale," or "unidentified minke," for instance. If this guide helps lead to a specific identification in some cases and to narrow down the choices in others, then it will have served an important function. We are happy to share our experience with others in this endeavor.

Request For Feedback from Users

We are hopeful that there will be future editions of this book (although that decision is up to the publisher, based mainly on how well the book sells). Assuming that there will be future editions, we would like to encourage all of the users of this book to provide us with feedback on the accuracy of the information contained therein and leads on better photos. Mistakes and inaccuracies are inevitable when reviewing so much information, and if users of the book contact the authors with suggestions for changes in future editions we promise to give those serious consideration.

2. Basic Marine Mammal Biology

In this chapter, we will introduce those readers who are unfamiliar with marine mammals to the subjects of this guide. We will not attempt to give a detailed summary of the biology of marine mammals, as that is not the purpose of this book. Besides, it has already been done much better than we could do elsewhere (e.g., see Berta et al. 2006; Ridgway 2002; Perrin et al. 2002; Reeves and Stewart 2003). Instead, we will simply provide a brief summary of the basic biology of the group of animals that we call marine mammals, primarily intended for use by those readers who are new to these animals.

What is a Marine Mammal?

It is important to recognize that marine mammals do not form a natural biological grouping. Many people do not realize this, but the term "marine mammal" is something of a "catch-all" phrase used for those groups of mammals that have returned to life in the sea." The most important criterion is that they must get all or most of their food from the aquatic environment. It is not essential that they actually live in the sea. In fact, many species of marine mammals never encounter marine waters, living instead in various land-locked lakes and rivers. However, all of them are thought to have come from marine ancestors.

Marine mammals are not necessarily completely dependent on an aquatic existence. For instance, pinnipeds do not generally mate or give birth in the water and polar bears may spend great amounts of time walking on land long distances away from the nearest marine waters. But, these mammals, along with the cetaceans and sirenians, do obtain most or all of their sustenance from the water, and this makes them marine mammals. Only two species of otters (the sea otter and marine otter) and the polar bear are ecologically bound to be marine mammals.

In reality, there is no hard-and-fast rule of what is a marine mammal. Some people consider other mammals also to be in this group, but the scheme most commonly followed, by far, is the most conservative. It originated with the list of "marine mammals" produced when the U.S. Congress passed the Marine Mammal Protection Act of 1972, and has been widely followed ever since.

Types of Marine Mammals

There are several different types of marine mammals. The two most commonly seen and best-known groups of marine mammals are the cetaceans (whales, dolphins, and porpoises) and the pinnipeds (seals, sea lions, and walruses). Most people are very familiar with these animals from seeing them in zoos and aquariums, or on television and in movies. They are both well-adapted to living in the oceans although the pinnipeds must return to land for some life history stages (e.g., mating, breeding, and molting). Cetaceans are fully adapted to live their entire lives in the water and never return to land for any significant period of time. The body plans of cetaceans and pinnipeds are radically modified from those of more familiar terrestrial mammals.

The sirenians are much less often encountered by people, because there are only a few species (four today) and they occur only in certain parts of the world, mainly in the tropical zones. They are also well-adapted to a wholly-aquatic life, although they are rarely more than a few kilometers from the coastline and many even inhabit lakes and rivers. Sirenians are unique in being the only vegetarians among the marine mammals. They also have radically modified morphology.

Finally, there are several species of fissipeds (the group of carnivores that have separate digits) that qualify as marine mammals, even though the other members of their taxonomic families are not considered among the marine mammals. These include the polar bear, the sea otter, and two others (the marine otters). In general, it can be said that these animals are much less completely adapted to living in the water than are the cetaceans,

Table 1 Recent Marine Mammals of the World—130 species

Order Cetacea (whales, dolphins, and porpoises)	
Suborder Mysticeti (baleen whales)	**Family Balaenidae** (right and bowhead whales)
	North Atlantic right whale—*Eubalaena glacialis*
	North Pacific right whale—*Eubalaena japonica*
	Southern right whale—*Eubalaena australis*
	Bowhead whale—*Balaena mysticetus*
	Family Neobalaenidae (pygmy right whale)
	Pygmy right whale—*Caperea marginata*
	Family Balaenopteridae (rorquals)
	Blue whale—*Balaenoptera musculus*
	Fin whale—*Balaenoptera physalus*
	Sei whale—*Balaenoptera borealis*
	Bryde's whale—*Balaenoptera brydei* and/or *edeni*
	Omura's whale—*Balaenoptera omurai*
	Common minke whale—*Balaenoptera acutorostrata*
	Antarctic minke whale—*Balaenoptera bonaerensis*
	Humpback whale—*Megaptera novaeangliae*
	Family Eschrichtiidae (gray whale)
	Gray whale—*Eschrichtius robustus*
Suborder Odontoceti (toothed whales)	**Family Physeteridae** (sperm whale)
	Sperm whale—*Physeter macrocephalus*
	Family Kogiidae (pygmy and dwarf sperm whales)
	Pygmy sperm whale—*Kogia breviceps*
	Dwarf sperm whale—*Kogia sima*
	Family Monodontidae (narwhal and beluga)
	Narwhal—*Monodon monoceros*
	White whale or beluga—*Delphinapterus leucas*
	Family Ziphiidae (beaked whales)
	Baird's beaked whale—*Berardius bairdii*
	Arnoux's beaked whale—*Berardius arnuxii*
	Cuvier's beaked whale—*Ziphius cavirostris*
	Northern bottlenose whale—*Hyperoodon ampullatus*
	Southern bottlenose whale—*Hyperoodon planifrons*
	Shepherd's beaked whale—*Tasmacetus shepherdi*
	Blainville's beaked whale—*Mesoplodon densirostris*
	Gray's beaked whale—*Mesoplodon grayi*
	Ginkgo-toothed beaked whale—*Mesoplodon ginkgodens*
	Hector's beaked whale—*Mesoplodon hectori*
	Perrin's beaked whale—*Mesoplodon perrini*
	Hubbs' beaked whale—*Mesoplodon carlhubbsi*
	Pygmy beaked whale—*Mesoplodon peruvianus*
	Sowerby's beaked whale—*Mesoplodon bidens*
	Gervais' beaked whale—*Mesoplodon europaeus*
	True's beaked whale—*Mesoplodon mirus*
	Strap-toothed beaked whale—*Mesoplodon layardii*
	Andrews' beaked whale—*Mesoplodon bowdoini*
	Stejneger's beaked whale—*Mesoplodon stejnegeri*
	Spade-toothed beaked whale—*Mesoplodon traversii*
	Longman's beaked whale—*Indopacetus pacificus*

Table 1 (continued)

Family Delphinidae (ocean dolphins)
Irrawaddy dolphin—*Orcaella brevirostris*
Australian snubfin dolphin—*Orcaella heinsohni*
Killer whale—*Orcinus orca*
Short-finned pilot whale—*Globicephala macrorhynchus*
Long-finned pilot whale—*Globicephala melas*
False killer whale—*Pseudorca crassidens*
Pygmy killer whale—*Feresa attenuata*
Melon-headed whale—*Peponocephala electra*
Tucuxi—*Sotalia fluviatilis*
Costero—*Sotalia guianensis*
Indo-Pacific humpback dolphin—*Sousa chinensis*
Atlantic humpback dolphin—*Sousa teuszii*
Rough-toothed dolphin—*Steno bredanensis*
Pacific white-sided dolphin—*Lagenorhynchus obliquidens*
Dusky dolphin—*Lagenorhynchus obscurus*
White-beaked dolphin—*Lagenorhynchus albirostris*
Atlantic white-sided dolphin—*Lagenorhynchus acutus*
Hourglass dolphin—*Lagenorhynchus cruciger*
Peale's dolphin—*Lagenorhynchus australis*
Risso's dolphin—*Grampus griseus*
Common bottlenose dolphin—*Tursiops truncatus*
Indo-Pacific bottlenose dolphin—*Tursiops aduncus*
Pantropical spotted dolphin—*Stenella attenuata*
Atlantic spotted dolphin—*Stenella frontalis*
Spinner dolphin—*Stenella longirostris*
Clymene dolphin—*Stenella clymene*
Striped dolphin—*Stenella coeruleoalba*
Short-beaked common dolphin—*Delphinus delphis*
Long-beaked common dolphin—*Delphinus capensis*
Fraser's dolphin—*Lagenodelphis hosei*
Northern right whale dolphin—*Lissodelphis borealis*
Southern right whale dolphin—*Lissodelphis peronii*
Commerson's dolphin—*Cephalorhynchus commersonii*
Heaviside's dolphin—*Cephalorhynchus heavisidii*
Hector's dolphin—*Cephalorhynchus hectori*
Chilean dolphin—*Cephalorhynchus eutropia*

Family Phocoenidae (porpoises)
Dall's porpoise—*Phocoenoides dalli*
Harbor porpoise—*Phocoena phocoena*
Spectacled porpoise—*Phocoena dioptrica*
Burmeister's porpoise—*Phocoena spinipinnis*
Vaquita or Gulf of California harbor porpoise—*Phocoena sinus*
Finless porpoise—*Neophocaena phocaenoides*

Family Platanistidae (South Asian river dolphin)
South Asian river dolphin—*Platanista gangetica*

Family Iniidae (boto)
Boto or Amazon River dolphin—*Inia geoffrensis*

Family Lipotidae (baiji)
Baiji or Yangtze River dolphin—*Lipotes vexillifer* (probably extinct)

Family Pontoporiidae (franciscana)
Franciscana—*Pontoporia blainvillei*

Table 1 (continued)

Order Sirenia (sea cows)	**Family Trichechidae** (manatees)
	West Indian manatee—*Trichechus manatus*
	West African manatee—*Trichechus senegalensis*
	Amazonian manatee—*Trichechus inunguis*
	Family Dugongidae (dugongs)
	Dugong—*Dugong dugon*
	Steller's sea cow—*Hydrodamalis gigas* (extinct)
Order Carnivora (carnivores)	**Family Mustelidae** (otters)
	Sea otter—*Enhydra lutris*
	Marine otter—*Lontra felina*
	Family Ursidae (bears)
	Polar bear—*Ursus maritimus*
Suborder Pinnipedia (sea lions, walrus, seals)	**Family Otariidae** (fur seals and sea lions)
	Steller sea lion—*Eumetopias jubatus*
	California sea lion—*Zalophus californianus*
	Japanese sea lion—*Zalophus japonicus* (probably extinct)
	Galapagos sea lion—*Zalophus wollebaeki*
	South American sea lion—*Otaria flavescens*
	Australian sea lion—*Neophoca cinerea*
	Hooker's sea lion—*Phocarctos hookeri*
	Northern fur seal—*Callorhinus ursinus*
	Guadalupe fur seal—*Arctocephalus townsendi*
	Juan Fernandez fur seal—*Arctocephalus philippii*
	Galapagos fur seal—*Arctocephalus galapagoensis*
	South American fur seal—*Arctocephalus australis*
	New Zealand fur seal—*Arctocephalus forsteri*
	Subantarctic fur seal—*Arctocephalus tropicalis*
	Antarctic fur seal—*Arctocephalus gazella*
	Cape and Australian fur seals—*Arctocephalus pusillus*
	Family Odobenidae (walrus)
	Walrus—*Odobenus rosmarus*
	Family Phocidae (true seals)
	Harbor seal—*Phoca vitulina*
	Spotted seal—*Phoca largha*
	Ringed seal—*Phoca hispida*
	Baikal seal—*Phoca sibirica*
	Caspian seal—*Phoca caspica*
	Harp seal—*Pagophilus groenlandicus*
	Ribbon seal—*Histriophoca fasciata*
	Gray seal—*Halichoerus grypus*
	Bearded seal—*Erignathus barbatus*
	Hooded seal—*Cystophora cristata*
	Mediterranean monk seal—*Monachus monachus*
	West Indian monk seal—*Monachus tropicalis* (extinct)
	Hawaiian monk seal—*Monachus schauinslandi*
	Northern elephant seal—*Mirounga angustirostris*
	Southern elephant seal—*Mirounga leonina*
	Crabeater seal—*Lobodon carcinophagus*
	Ross seal—*Ommatophoca rossi*
	Leopard seal—*Hydrurga leptonyx*
	Weddell seal—*Leptonychotes weddelli*

pinnipeds, and sirenians. They vary only slightly divergent from their closest terrestrial relatives. However, that does not mean that they are not at home at sea. Quite to the contrary, especially the sea otter and polar bear, are well-adapted to living in the harsh conditions of the sea.

Evolutionary History

The major groups of marine mammals have separate evolutionary origins, from different groups of terrestrial mammals. The cetaceans arose 50 mya, and they are now universally thought to be monophyletic (or arising from the same ancestor), but there has been other controversy about their origins. The terrestrial mammal ancestors of cetaceans were previously thought to be a group of primitive, wolf-like, hoofed animals called mesonychid condylarths. However, recent fossil and molecular evidence suggests that cetaceans are most closely related to the artiodactyls (a group of even-toed, hoofed mammals that includes ruminants such as cattle, camels, and hippos). In addition, hippos have been shown with molecular data (but not fossils) to be the closest modern mammal relative of the whales, and this has shown doubt on the mesonychid hypothesis. However, some recent evidence for the mesonychids may actually have been primitive artiodactyls, which would support the traditional arrangement.

There were three major phases of cetacean radiation. The first occurred about 45–50 mya (Eocene) in the shallow, warm, tropical waters of the ancient Tethys Sea. It involved the initial radiation of the now-extinct archaeocetes, the archaeocetes (now extinct). It included the appearance of *Ambulocetus*, a 4-meter walking proto-cetacean, which has been seen as a "missing link" in cetacean evolution. The second major phase resulted in the initial radiation of the odontocetes (toothed whales) and mysticetes (baleen whales), about 25–35 mya (Oligocene). These two modern suborders included, at this time, a large array of unusual species, that would later become extinct. The development of important modern adaptations, such as echolocation in the toothed whales, and filter-feeding in the baleen whales, occurred during this period. The final radiation, in the Miocene about 12–15 mya, involved the appearance of modern cetaceans, especially the dolphinids and ziphorhynchids.

Pinniped evolution has also been plagued with controversy. Traditionally a diphyletic origin of the pinnipeds was proposed, with walruses and eared seals evolving from ursid (bear-like) ancestors, and true seals originating from mustelid (otter-like) ancestors. However, current thinking favors a monophyletic origin of the pinnipeds from an aquatic carnivore (most probably an ursid) ancestor in the North Pacific about 30–35 mya. The fossil record goes back to at least 26–27 mya. There is still some controversy, most of it involving whether pinnipeds is most closely related to the procyonids or the otariids.

The head of a surfacing fin whale clearly shows the posterior movement of the nasal openings (blowholes) to the top of the head, an element of the evolutionary 'telescoping' of the skull that is characteristic of all living cetaceans. Photo: Jim Stamates

There are five major lineages of pinnipeds, the three extant ones (walruses, eared seals, and true seals), as well as two extinct ones (the Desmatophocidae and Enaliarctidae). These latter two groups did not survive to modern times and played no multitude of roles in evolutionary experiments that did not work out, resulting in the evolutionary dead end of extinction.

The sirenians have a long evolutionary history, with a fossil record extending back to 50 mya. They evolved from proboscideans (represented by modern elephants and mastodons), and have no connection with pinnipeds or cetaceans. The earliest sirenians were pig-like, quadrupedal, amphibious mammals. The manatees originated in South America, and the dugongids began in the North Pacific, attaining a wide diversity in the fossil record there. Sirenians attained their maximum diversity in the Oligocene and Miocene but, due largely to the cooling of ocean waters, have since been reduced to the five extant species.

Compared to these ancient groups of marine mammals, the otters and bears are relative newcomers to the oceans. Not other evolutionary history is still somewhat unclear, but it is thought that they evolved only a few million years ago, and are closely related to other otters. The polar bear originated from brown and grizzly bears in Alaska less than one million years ago, and is still so closely related to them that hybridization in zoos is common. The oldest known fossils are less than 100,000 years old.

Zoogeography, Distribution, and Migration

Marine mammals are not randomly distributed in the world's oceans. It has long been known, for example, that certain species are found exclusively or primarily in waters of a particular depth, horizontal range, or

ocean regions, and not in areas lacking one or all of these characteristics. For most species, however, little is known of the particular reasons that cause them to be found in one area and not in another that appears, qualitatively at least, the same.

One major factor affecting productivity, and thus indirectly influencing the distribution of marine mammals, is the pattern of major ocean currents. These currents are driven largely by prevailing winds and are modified in their effects by the "Coriolis Force." Simply stated, the rotation of the earth causes major surface currents to move clockwise in the Northern Hemisphere and counterclockwise in the Southern Hemisphere. This has different implications for animals on east and west sides of ocean basins. In the Northern Hemisphere, warm tropical waters move further north along the east coasts of continental land masses, and warm-water species are often found unexpectedly far north. In the Southern Hemisphere, by contrast, cold polar waters move northward along the west coasts of continents, allowing cold-water marine animals to range closer to the equator.

The interplay of these surface currents and subsurface movements of major water masses moves nutrients around by upwelling (the vertical turning over of bottom and surface waters) and horizontal currents. As these nutrients and sunlight are the basic ingredients of productivity, areas of light mixing often are more productive than still areas of little or no mixing. Thus, the presence of marine mammals, and other high order predators and consumers in an area is related primarily to prey and only secondarily to the water conditions supporting that productivity. Wherever oceanic conditions are such, it is likely that some species of marine mammal will be present to exploit that richness.

Each species of marine mammal has its particular habitat preferences, which may comprise deep or shallow waters, tropical or polar regions, marine or estuarine regions, or any variation in between. Most species occur only in a distinct part of the world, although some are more cosmopolitan (found throughout the globe). The only species that can truly be said to be cosmopolitan, however, is probably the killer whale. It has been recorded in all oceans and seas, in many bays and channels and even some rivers from the equator to the pack ice in both hemispheres. It has habitat preferences to be sure, but there is almost nowhere in the world's oceans and seas where a killer whale sighting would be considered out of the question.

Although seasonal movements are known for most species of marine mammals, not all undergo what could be called true migrations. The baleen whales, sperm whales, and some other large toothed whales, many pinnipeds, and a few other species of marine mammals do have distinct, predictable seasonal movements of large portions of segments of populations. The timing and approximate reasons for these vary widely, but they are usually related to allowing maximum exploitation of food resources and meeting the needs of mating and breeding. Recently, the importance of predator pressure (especially from killer whales) has also become more appreciated.

Anatomy and Physiology

Although they are all clearly mammals, and thus share the basic mammalian characteristics with others in the class, marine mammals have undergone various evolutionary changes in their body shape and function in order to adapt to their lives in the oceans and freshwaters of the world. All species of marine mammals are streamlined to varying degrees. The cetaceans and some of the pinnipeds show very strong streamlining and are consequently fast swimmers. Manatees (along with sea otters and possibly some of the pinnipeds) have taken their hydrodynamic changes to a much lesser extent, but even these species have reduced appendages and smooth bodies for decreasing drag and turbulence. Most species can move fairly fast underwater, at least for short bursts.

All cetaceans and sirenians have lost their hind limbs (although bony vestiges buried in the abdominal muscles may still be present), and the hind limbs have been radically modified into flippers in pinnipeds. Polar bears and sea otters have only slightly modified hind limbs and can still walk reasonably well on land. The fore limbs have been modified into flippers in the three major groups of marine mammals, and additionally a dorsal fin has evolved for stability (and thermoregulation) in the cetaceans. Further, the cetaceans and sirenians have lost their mammalian hair, and only retain a small scattering of hairs on the body surface. Cetaceans, sirenians and some pinnipeds also have internal testes.

The head shape of some marine mammals, primarily cetaceans and sirenians, has also been drastically modified from their terrestrial ancestors. The nostrils have moved to the top of the head to allow ease of breathing in water (not requiring the head to be lifted fully out of the water), and the jaws and teeth have been modified to assist in feeding, and in cetaceans, echolocation and baleen filtering. The substitution of baleen plates made of keratin for teeth in modern mysticete whales is probably the most radical modification of all.

There are many internal adaptations to a marine existence that are difficult to see, unless a woodman is dissected. These include the development of a subcutaneous layer of fat (or oil in pinnipeds) for various functions in energy storage, insulation, and streamlining; varied modifications of the respiratory system to assist in rapid breath-taking and large pressure changes; modifications to the skull for breathing at sea, housing

the baleen plates in mysticetes, and the production of echolocation sounds in odontocetes.

Only fossils can reveal the cetaceans and sirenians for their evolutionary modifications from the traditional mammalian body plan. It seems that life in a medium different from living on land has required a large number of changes, and this explains why for many centuries odontocetes were thought to be fish, rather than mammals. It wasn't until naturalists began to look past "fish body" that they discovered the unmistakable similarities with other mammals.

Life History and Reproduction

Some types of marine mammals are very long lived and are among the mammal species reaching the greatest ages. This includes the baleen whales, the right whales, some dolphins, a few pinnipeds, and the sirenians. It is thought that some large toothed whales, like the killer whale, may routinely live to be as old as humans (perhaps nearing 80–90 years in some cases). On the other hand, other species, such as the porpoises, appear to have short life spans, rarely reaching the age of 20 years.

The reproductive patterns of marine mammals are not radically different from those of their terrestrial relatives in many ways. However, there are obviously some major adaptations that have been necessary to allow marine mammals to reproduce in the water. Cetaceans and sirenians are the only groups of marine mammals that undertake all of their reproductive activities in the water. Pinnipeds and the marine otters and polar bear all mate and give birth on land (with a few minor exceptions).

All marine mammal young are precocial, meaning that they are well-developed when they are born. They must be, to live in or close to the water very early in life. In fact, cetacean and sirenian neonates are capable of swimming as soon as they exit the womb. Seals and other marine mammals generally experience a bit of learning before they are ready to tackle the marine environment.

The gestation period of most marine mammal species is around one year, and in pinnipeds, there is a period of delayed implantation of the embryo, which allows for annual reproduction when the natural gestation period may only be 8–9 months. The length of lactation is highly variable, lasting from only a few days in some seals, to many years in some toothed whales.

While seasonal breeding is the norm in all temperate and high-latitude species, some marine mammals, mainly those in the tropics, have a protracted breeding period with at least some births scattered throughout the year. Only a single neonate is born in most marine mammal species under normal circumstances, and twinning is quite unusual.

Some of the marine species are unusual among mammals in having a post-reproductive period of

Unlike most other marine mammals, manatees have teats that are located in the axillary region—in most others they are more posterior. Thus, the manatee calf needs to nurse from a site near the breast, and this is considered to have led to the mermaid myth. Crystal Springs, Florida. ©2001 T. Flynn

of reproductive senescence, in females. Generally, this occurs in some of the longer lived toothed cetaceans. Other species may reproduce until they die.

Feeding Ecology

Different groups of marine mammals have different feeding ecologies. Mysticetes (baleen whales), which are the largest species, feed on shoaling fishes and small invertebrates, some of the smallest. Baleen whales are batch feeders, taking in large amounts of prey and straining them from the water with the fringes on the inside of their baleen plates. Most balaenopterids are "gulpers," which means they lunge through a prey patch, taking in huge amounts of sea water with the aid of their expandable throats. Then they close the mouth and use muscular actions to force the water out between the baleen plates, leaving the tiny prey trapped on the inside, which they then swallow.

Right and bowhead whales are much less active in their feeding. They are "skimmers," which swim slowly through patches of prey and filter out the prey mostly passively as the water flows through the baleen plates. This prey-filtering grows out a different feeding strategy. It is a "skimmer." Gray whales use another method to suck in a batch of amphipods or other invertebrates as they roll on their sides (usually near the bottom).

The toothed whales, dolphins and porpoises take individual prey items, generally one at a time. They feed mostly on fishes and squids, which are located and captured with the aid of echolocation, or sonar. Unlike most (but not all) species of baleen whales, toothed whales may use cooperative hunting techniques, sometimes involving dozens to thousands of individuals to corral and herd prey. Killer whales (commonly known as

species that regularly feeds on other marine mammals, and almost all marine mammal predators occasionally take prey, at one time or another. They will even hunt whales much larger than themselves, often working in cooperative groups, reminiscent of those of wolves and other pack-hunting carnivores.

The pinnipeds generally feed on fishes and squids, although some take primarily invertebrates such as krill. Seals and sea lions take their prey items individually and almost always feed solitarily. Individuals generally do not cooperate in feeding aggregations. There are few special adaptations for effective feeding in pinnipeds, with the possible exception of their incredible deep, repeated diving abilities of some species. For instance, elephant seals can dive for 20 minutes and surface for 3 minutes, 24 hours a day, day after day, for weeks on end!

The sirenians are all herbivores, and therefore do not need to be particularly fast or maneuverable to catch prey. Manatees feed mostly on water hyacinths and other aquatic plants that may be submergent or emergent. Dugongs feed mainly on seagrasses, and leave feeding trails in seagrass beds where they have been active. The extinct Steller's sea cow ate mostly kelp.

The sea otter feeds mostly on invertebrates, such as crabs, clams, mussels, and sea urchins. It can only dive to relatively shallow depths to obtain such items, which are then brought to the surface and eaten as the animal lies on its back at the surface. Sea otters often use rocks as tools to break open the hard shells of their prey. Polar bears feed mostly on seals, although they can also take beluga whales and even large fish. A common hunting technique for a polar bear is to wait by a breathing hole and then ambush a seal from the hole as it comes up to breathe.

A large group of humpback whales corrals a herring school in southeast Alaska. While such cooperation during feeding is common in toothed whales and dolphins, it is relatively rarely seen in baleen whales. (© Flip Nicklin/Minden Pictures)

Predation/Parasites/Disease

Many of marine mammal species suffer from predation, with the killer whale being the only possible exception. Sharks are the major predators for many types of marine mammals, although killer whales (and even false killer whales) may be important predators for others. Predation by killer whales has been considered to have been a major factor affecting the evolution of the migratory patterns of some of the baleen whales. Recently, killer whale predation has been suggested to be a primary pressure controlling the populations (and even causing declines) of sea otters and Steller sea lions in the North Pacific. More work needs to be done to confirm or deny these hypotheses.

Disease affects all marine mammal species, although certainly some more than others. A large number of afflictions can affect marine mammals, both in captivity and in the wild. In recent years, morbilliviruses and related distemper viruses have been identified as the causes of some mass die-offs of marine mammals (primarily of cetaceans and pinnipeds). As a result, these diseases have received a great deal of attention from marine mammal biologists and veterinarians.

Although parasites may be present in marine mammals that are considered healthy and functioning normally in their society, parasites may also cause disease that can result in death (either directly, or indirectly, by causing the animals to strand or be otherwise vulnerable to accidents). A large number of parasite species (mostly internal, but some external) have been identified from marine mammals. Parasites may be present in many organ systems in the body, but are generally found in the respiratory, digestive, circulatory, and reproductive systems.

Behavior and Social Organization

The majority of cetacean species live in social groups, called schools, herds, or pods. A few species are relatively solitary, but even these species gather together for breeding, or in feeding aggregations, at times. Pods of large whales generally number less than a dozen or so, but pods for dolphin species may number several hundred. The stability of social groups ranges from the very stable, long-term pods of killer whales to very opportunistic and short-lasting associations of many smaller dolphins and porpoises.

Cetaceans have keen senses, with the exception of smell (olfaction), which is probably nearly non-existent in this group. The toothed whales and dolphins, in particular, are acoustic creatures par excellence. In addition to a keen sense of hearing, and the ability to "see" underwater, their environment through passive listening, odontocetes also have a highly sophisticated sense of echolocation, or sonar. It is thought that sound is the dominant sense in echolocating cetaceans, but these animals also appear to have very good vision (both in air and underwater).

The supposed high intelligence of dolphins is legendary, but in fact they are on a par with many other species of social ungulate mammals. It is true that dolphins are very clever and can learn easily, but there is no reason to believe that their intellectual capacities are above those of other higher mammals.

Pinnipeds tend to be much more solitary, at least at sea. On haul outs and rookeries on shore, however, seals and sea lions often gather into huge groups, which have a very specific structure. Most pinnipeds are highly polygynous, with a single male controlling mating access to groups of females (harems). It is due to the highly polygynous nature of pinniped societies that most species have very strong sexual dimorphism (with males growing much larger than females).

Seals and sea lions have keen senses, including good hearing, vision, and smell. No species of pinniped is known to have a well-developed echolocation system, as the toothed whales do, but they can nonetheless tell much about their surroundings with sound. The sense of smell is so well developed that many pinniped species have to be approached from downwind, to avoid stampeding the entire group of animals into the water.

The manatees and dugong generally live in relatively small groups, and are in fact often seen alone. They do gather into feeding and breeding groups, but these are generally short lasting. The only stable social bond is likely between mother and calf.

Sirenians are generally relatively slow-moving, passive creatures (at least compared to the very active dolphins and seals). As large-bodied vegetarians, they have little need to be able to move very quickly, and have evolved bodies that are more geared towards negative buoyancy than speed (at least in the manatees). Their senses are less well-studied than those of cetaceans and sea lions, but vision and hearing at least, are probably not as acute as in those other groups.

Strandings

When marine mammals wash up on shore unintentionally, whether alive or dead, this is called stranding (or sometimes, beaching). Most marine mammal strandings are of dead animals, but live specimens can also stranded, and usually die unless humans intervene and either push them back to sea or move them to a rehabilitation facility.

Single strandings are most common, but mass strandings of two or more individuals (not including a mother and calf/pup) also occur. In fact, sometimes entire pods of whales or pod (pelagic dive), and witnessing such an event is truly one of the most spectacular (or somewhat sad) sights in nature!

The causes of marine mammal strandings are not always known, but sometimes they are obvious. Single strandings usually involve an animal that is sick or injured and often too weak to swim against the currents and other forces that inevitably bring it to towards shore. In some cases, may die before they reach the beach, but in others they may still be alive. Such live stranded individuals are unlikely to survive even with good veterinary care.

Strandings of marine mammals are common events, and have provided scientists an opportunity to learn much about these animals. This sperm whale stranded alive on a Hong Kong beach, but later died. (T.A. Jefferson)

Mass strandings usually involve multiple members of a social grouping (sometimes the entire school or pod), and almost invariably consist mostly of living individuals. Very often, one or only a few individuals in the school are sick or hurt, and most of the group is perfectly healthy. Therefore, the chances of "saving" or rehabilitating mass-stranded animals are much better. The causes of the mass beachings is generally related to the strong social bonds of the species that frequently mass strand (most often medium to large odontocetes, like the sperm, pilot, and killer whales). More and more often, mass strandings and mortalities are being linked to the use of military sonars, which seem to disrupt the physiological mechanisms for safely dealing with deep diving.

Strandings are extremely important phenomena for several groups of marine mammals, especially cetaceans. For many species of whales and dolphins, much of what we know of their biology may come from information gained from stranded specimens. For some of the poorly-known beaked whales, stranding records may be all that we have.

Exploitation and Conservation

Marine mammals have long been highly-prized targets of humans looking for a good source of food, fuel, oil, and/or a whale bone or other product. Because they are large, they were attractive subjects of human exploitation, but their relatively inaccessible habitats made them hard to hunt until the last few hundred years. Although there is evidence that prehistoric humans may have at least taken advantage of the fortuitous stranding of a

fleet whale or seal or their shores, most marine mammals remained, very nearly, safe from large-scale human exploitation until recently.

The first known large-scale hunting of large whales was by the Basques, starting in the first millennium AD. They mainly targeted the North Atlantic right whale, and were so effective that they decimated that species. North and Icelandic whalers also hunted in the North Atlantic, and the Japanese began their culture of whale hunting in the 1600s. In the 1700s, the "Yankee whalers", focused largely on sperm whales, began and the United States became a major player in the commercial whaling game. Finally, in the late 1800s, the development of steam powered vessels and the exploding harpoon heralded in the modern era of commercial whaling. Fast swimming species, such as the rorquals (blue, fin, sei, Bryde's and minke whales) were now within the reach of commercial whalers. It didn't take long for them to decimate species after species, starting with the largest and working their way down, to commercial extinction.

In recent decades, the direct killing of whales and dolphins has become much less important, and the indirect deaths of accidentally caught dolphins and porpoises have increased dramatically. There is now no doubt that more cetaceans die incidentally in fishing nets each year than from any other human activity, including whale and dolphin hunting. In the last few decades, we have also seen the development of other major threats to these animals in the form of such things as habitat degradation and loss, environmental contamination, noise pollution and damage, and even live captures for captive display and research. No cetacean species is known to have been wiped-out by humans (yet), but several species are now on the very verge of that (the vaquita in Mexico; the baiji in China may already be extinct).

An relatively new (and lasting) cetacean problem comes in the form of human-made noise that can be potentially disturbing or even damaging to the animals. Shipping and boat noise is certainly an issue in some cases, but the major concerns nowadays have to do with intense sonar noise (generally created with airguns in the search for petrochemicals), and intense sounds created by military sonars (generally used to detect submarines). These sounds have been shown to cause various problems for some species, and many mass strandings of whales and dolphins have been linked to low- and mid-frequency sonar.

Seals and sea lions also have a long history of human exploitation. Because they were so easy to kill when hauled out on land, some coastal pinniped populations may have been exploited by people in early times. Species that occur in more remote areas, for instance, the Antarctic seals on the other hand, were not really exploited until the late 1700s or early 1800s. While most species survived the exploitation and even recovered to pre-exploitation numbers and beyond (witness the northern elephant seal, for instance), some were wiped out. The West Indian monk seal was so heavily hunted that the last remaining seals probably died out in the middle part of the 20th century. The Japanese sea lion is also thought to be extinct, although there is still some hope that a remnant of this species may survive in Japanese or Korean waters.

Like cetaceans, pinnipeds have seen the development of other, more insidious threats in recent years. Fishing gear entanglements are certainly a major one, and very recently the depletion of prey and other ecosystem effects of large-scale fishing operations have been blamed for the decline of some pinniped populations (e.g. the Steller sea lion in Alaska waters).

Sirenians seem to be curious wherever they occur, an unfortunate result of the apparently excellent taste of their flesh and their relative ease of capture. All three species of manatees and the dugong have been brought to levels that threaten extinction in the next few decades. This is largely due to hunting for food, but other threats also exist. Especially in Florida, collisions with high-speed vessels and entrapment in human-made structures each take their toll.

The fifth species of recent sirenian, the giant Steller's sea cow of the cold waters of the North Pacific and Bering Sea was wiped out by sealers and fur traders in the late 1700s, only a few decades after its discovery. This is a truly sad tale of human greed and stupidity, and it should serve as a reminder of the frailty of nature.

Sea otters were also hunted to near extinction throughout much of their range in the North Pacific by fur traders in the 1700–1800s. In fact, they were thought to be extinct along the west coast of the continental US until a small remnant was discovered in the late 1930s. Luckily, this remnant has increased and expanded its range, and still survives today. The polar bear was never driven to near extinction, but it has been heavily exploited by native peoples and westerners. It has a relatively healthy population and appears to be in no immediate danger, but the effects of global warming are casting some doubts on its ability to survive for more than a few decades into the future.

The perception that all large whales are recovering is wrong. The truth is that most large whales are recovering from past exploitation (the North Atlantic and North Pacific right whales are the major exceptions), and the most serious conservation problems now lie with several of the smaller species. Also, the pinnipeds, a few seals (e.g., the Mediterranean and Hawaiian monk seals), and several of the odontocetes (e.g., the vaquita, baiji, Indus susu, North Island Hector's dolphin, and Atlantic humpback dolphin) are probably in the worst shape. It is our sincere hope that this book will help people to appreciate the diversity of the world's marine mammals, and inspire them to work towards their protection.

3. Taxonomic Groupings Above the Species Level

In this chapter, we provide a brief overview of the higher-level (above species) classification and taxonomic groupings of marine mammals. It should be noted that marine mammal taxonomy is highly controversial and is currently in a state of flux. So, rather than trying to present the "flavor of the month" and having that perhaps be out-of-date when the user actually reads it, we have instead presented a more classic and conservative system of classification.

As an example, a new phylogenetic classification published in 2005, and based on multiple lines of evidence, suggests some changes in ranking of various taxa. It considers the cetaceans (whales, dolphins, and porpoises) to be a suborder of a more inclusive Order Cetartiodactyla (which would include hippopotamuses, among others). In such a classification, the suborders Mysticeti and Odontoceti would be demoted to infraorders (taxa below the level of suborder).

Whether this arrangement will be accepted and supported by future work remains to be seen, although it currently appears to be well-supported by genetic and morphological data and is gaining support. However, for now, we will stick to presenting the major higher-level groupings in a system that is well-recognized and firmly established (i.e., a bit more conservative).

Order Cetacea—*Whales, dolphins, and porpoises*

The 86 living species currently recognized in the Order Cetacea are divided into two suborders: Odontoceti (toothed whales) and Mysticeti (baleen whales). All representatives of a third suborder, Archaeoceti (ancient whales), are extinct. It is generally agreed that cetaceans are the most derived of all mammals (with the possible exception of bats). Evolved from terrestrial ancestors, they are totally adapted to living in the water, and have no need to come ashore, even for resting or reproduction.

All cetaceans share a similar general body plan: a streamlined fusiform (some more so than others) spindle-shaped torso; flattened paddle-like foreflippers; telescoped skull; nasal openings on top (rather than on the front) of the head; a well-developed blubber layer; internal reproductive organs; newly derived boneless structures in the form of tail flukes and a dorsal fin or ridge (secondarily lost in some species); and the loss of such aquatic hindrances as hind limbs (present, if at all, only as vestiges), external ear flaps, and fur (although all have hair at some time during their early development and some retain a few rostral hairs for life). Although they may somewhat resemble fish externally, the cetaceans' internal anatomy effectively betrays their terrestrial mammalian ancestry. For instance, their flippers contain reduced counterparts of all or most of the hand and arm bones characteristic of other mammals; and pelvic rudiments (and occasionally hind limb remnants) are present. The internal anatomy of cetaceans is surprisingly like that of more familiar land mammals, with such interesting exceptions as the presence of a four-chambered stomach and cartilaginous reinforcements of the airways all the way down to the alveoli.

Suborder Mysticeti—*Baleen whales*

There are four families of baleen whales. Mysticetes are universally large (with females growing larger than males); the smallest is the pygmy right whale (6.4 m long), and the largest is the blue whale (the largest animal ever to live, up to 33 m or more in length and 180 tons in weight). The baleen whales have a double blowhole, a symmetrical skull, lack of a bony mandibular symphysis, and a sternum consisting of a single bone. In the mouth, the upper jaw is hung with baleen (stiff plates of keratin with fringes on the inside) instead of teeth. Baleen whales are batch feeders, taking in great quantities of water in a single gulp, and then using the fringes on their baleen plates to filter small schooling fish or invertebrates from the water.

Nearly all mysticetes make long-range seasonal migrations. They generally occur in smaller groups than most odontocetes, and tend to have a simpler social organization. There are 14 species in 6 genera.

Family Balaenidae—*Right and bowhead whales*

The right and bowhead whales (four species in two genera) are large and chunky, with heads that comprise up to one-third of their body length. They lack a dorsal fin or any trace of a dorsal ridge. Overall, they tend to be far less streamlined than other baleen whales. Right and bowhead whales have developed a relatively passive skim-feeding technique, and tend to be slower than other whales. The baleen plates are the longest and have some of the finest fringes of the four mysticete families. Viewed in profile, the mouthline is markedly arched and the skull profile is highly convex; all seven cervical (neck) vertebrae are fused together.

Family Neobalaenidae—*Pygmy right whale*

The single species in this family, the pygmy right whale of the temperate Southern Hemisphere, is poorly known. Although it is in some ways more primitive than the Balaenopteridae and Balaenidae, the pygmy right whale is more closely related to the Balaenidae. Much smaller than the right and bowhead whales (6.7 m), it is slender, with a moderately arched mouthline. The head represents only about one-quarter of the total length, and there is a short, falcate dorsal fin set behind mid-back. There is also a pair of shallow throat depressions, which have been hypothesized to be incipient throat grooves. The skull is also somewhat intermediate in form; the rostrum is moderately arched (reminiscent of balaenids), but is much wider at its base (reminiscent of balaenopterids).

Family Balaenopteridae—*Rorquals*

This family contains eight (or possibly nine) species in two genera of the largest animals ever to live. All balaenopterids have adult body lengths of over 7 m, and some are much larger. The rorquals are streamlined animals (the humpback whale somewhat less so than the others), with a series of long pleats extending from the snout to (or as far back as) the navel on the ventral surface. Balaenopterids are generally fast and active lunge feeders; their morphology allows them to open their jaws very widely and distend their throats to take in huge mouthfuls of water during feeding. The baleen plates are of moderate length and fringe fineness. Density and fringe diameter vary among species and, along with plate number and width/length ratio, are diagnostic characters. Rorquals have dorsal fins (varying in size and shape) set behind the midpoint of the back. The upper jaw has a relatively flat profile, a feature reflecting the structure of the skull. While a given feature, difference among balaenopterids are often subtle and/or a matter of degree rather than absolute distinctions. Therefore, information on many features may be needed to distinguish among them, and reliance on a single character for identification is strongly discouraged.

Family Eschrichtiidae—*Gray whale*

The gray whale was once present in both the North Atlantic and North Pacific oceans, but has been extirpated in the Atlantic in the last few hundred years. This monospecific family is in some ways intermediate between the balaenids (right and bowhead whales) and the balaenopterids. The gray whale is stocky and has an arched jaw, but neither of these characters is as pronounced as in the right whales. Gray whales are slow-moving coastal animals that suck prey from the bottom sediments. Gray whales have the smallest and coarsest baleen of all species, a feature that probably reflects both the size of their prey and their tendency to take in gravel, sand, and other debris during feeding. There are 2–5 short dorsal crests, a dorsal hump followed by a series of knobs or knuckles along the dorsal surface of the tail stock, and only four digits in the flipper. The bodies of adults are usually covered with barnacles and whale lice.

Suborder Odontoceti—*Toothed whales*

With the exception of the sperm whales (males of which can reach lengths of at least 18 m), odontocetes are small to medium-sized cetaceans. Sexual dimorphism is the rule. Toothed whales are characterized by the presence of homodont teeth throughout life (although teeth are buried in the gum or perhaps absent in some species, worn down in others, and take peculiar shapes in still others), a single blowhole, an asymmetrical skull (generally with a concave profile), presence of antorbital recesses, a thin-walled "panbone" at the posterior end of the mandible, a stomach with three or more parts, a complex system of nasal sacs and a fatty organ in the forehead associated with echolocation. All are hypothesized to be capable of echolocation (i.e., producing specialized sounds, and receiving and processing the echoes from these sounds to navigate, find food, avoid predators, etc.), although this ability has been experimentally verified for only a handful of species held successfully in captivity. Odontocetes capture individual prey, which consists largely of various species of fishes and squids. There are 72 species in 33 genera.

Family Physeteridae—*Sperm whale*

The single species of sperm whale is the largest toothed odontocete and has the highest degree of sexual dimor-

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[1] Tooth counts presented where given in this guide are for one tooth row (i.e., upper and lower jaw); each have two to four rows, unless otherwise indicated.

onism. There is a low dorsal hump, followed by a series of small knobs. It has a large head with a squarish profile, narrow underslung lower jaw, and functional teeth only in the lower jaw (these fit into sockets in the upper jaw). The blowhole is located at the left front of the head. The head is highly modified and is divided into sections called the "junk" and the spermaceti organ, or "case." The spermaceti organ is a large oil-filled reservoir the function of which is controversial. There is a slight shrinkage in the bony skull of the skeleton, extreme cranial asymmetry, and a long rostrum. Sperm whales are known to be capable of very deep, long dives of over 2,200 meters.

Family Kogiidae—*Pygmy and dwarf sperm whales*

This family contains two species in a single genus. The pygmy and dwarf sperm whales are much smaller and shorter, only a slight resemblance to the great sperm whale. They have blunt, squarish heads, with underslung lower jaws (like their larger counterpart), but the head is much smaller than in the sperm whale and the blowhole is not located at the front of the head as it is in the sperm whale. The skull structure is curious. It shares a basin-like facial area and great asymmetry with the sperm whale, but is much smaller. The dorsal fin in both species is relatively larger than that of the sperm whale, but is similarly followed by a series of small protuberances. Both species are characterized by a pigmentation mark on the side of the neck, similar in appearance to a shark's gill slit, a feature totally unique among cetaceans. The biology of these animals is very poorly known.

Family Monodontidae—*Narwhal and beluga whale*

This is a family of small whales (less than 6 m in length), with stocky bodies, short bulbous heads, broad rounded flippers, and no dorsal fin. There are two species in two genera. Both species are inhabitants of Arctic areas of the Northern Hemisphere. The skull is unique in that, in adults, it is very flat, with no projection in the area of the nares. Unlike the situation in most cetaceans, the cervical vertebrae are generally not fused, allowing for considerable range of neck flexibility. The two species are both restricted to high latitude arctic waters, often living among the ice.

Family Ziphiidae—*Beaked whales*

The beaked whales (a large family, with 21 species in six genera) are medium sized cetaceans (4–13 m long), which as a rule, have reverse sexual dimorphism (females larger than males). In general, beaked whales have a pronounced beak, relatively small dorsal fin set far back on the body, small flippers that fit into depressions on the sides, two short throat grooves, rakes on the middle mouth, and no more than 1–2 pairs of functional teeth in the lower jaw of males only in rare exceptions of the latter are *Berardius*, in which females also have two pairs of teeth, and *Tasmacetus*, in which both sexes have long rows of (another functional teeth). Beaked whales are poorly known as a rule; however, most are thought to be deep-diving squid eaters. They generally travel in small groups.

Family Delphinidae—*Marine dolphins*

The family Delphinidae (which means "porpoise with beak") because many small to medium-sized odontocetes of various forms have been put together in this group for centuries. It is the largest marine mammal family, with 36 species in 17 genera. Needless to say, then, the so-called dolphins are extremely diverse in form. They range in size from the 1.1 m dolphins of the genera *Sotalia* and *Cephalorhynchus* to the killer whale, in which males can reach lengths of as much as 9.8 m. Most dolphins, however, share the following characteristics: a marine habitat, a rostrocaudal beak, conical teeth, and a large falcate dorsal fin set over the middle of the back. There are exceptions to every one of these rules, except the presence of basically conical teeth. However, Generally dolphins have a complex social organization, and may form the largest groups of any marine mammal (numbers in the thousands or even tens of thousands).

Family Phocoenidae—*Porpoises*

Porpoises (6 species in 3 genera) are small cetaceans (at least over 2.5 m), some taxonomists in the past have classified with the delphinids. They tend to be coarse in their build, rather stocky in form, with almost a short, indistinct beak or no beak at all. Most have a small triangular dorsal fin, all have double-rooted teeth, and bony protuberances on the skull in front of the bony nares. In some species females are larger than males. Phocoenids appear to live in smaller groups and have a simpler social structure than do most dolphinids.

Family Platanistidae—*South Asian river dolphin*

This family includes the Indus and Ganges river dolphins, which were previously classified as a single species, but are now recognized as subspecies of *Platanista gangetica*. Animals in this family are nearly blind, and consequently rely largely on echolocation to navigate and find food. The body is fairly small (to about 2.8 m) and slender, with a long forehead (or brow) with front teeth that can extend outside the closed mouth. The blowhole is a transverse slit. The skull and brain have no true dorsal fin, only a low dorsal ridge. The most characteristic feature of the skull is a pair of enlarged maxillary crests that overhang the rostrum. Distribution is restricted to several large river systems of South Asia. Some of

dolphin suggests that this may be the most closely-related odontocete group to the Mysticetes.

Family Iniidae—*Boto*

The single species in this family, the boto of the Amazon and Orinoco drainages in South America, is unique in several ways. It is a large river dolphin, with a moderately long, thick beak dotted with sparse hairs. The dorsal ridge is very low and usually indistinct. Many adults are nearly totally pink in color. The few teeth are flattened and the zygomatic arches of the skull are incomplete.

Family Lipotidae—*Baiji*

This family contains a single extant species, the baiji or the Yangtze river in China. It is a mid-sized river dolphin. The dorsal fin is rounded and low in profile, with a short base. The rostrum is spatulate, and there is a distinct constriction at its base. The baiji is the most endangered cetacean in the world today, and may already be extinct.

Family Pontoporiidae—*Franciscana*

This family also contains only one species, a coastal marine species of the east coast of South America, known as the franciscana. This is the smallest of the platanistoids (river dolphins), rarely reaching 1.8 m in length. Females are larger than males in this species. Franciscanas have extremely long beaks (proportionately the largest of any cetacean) and rather low, triangular dorsal fins.

Order Sirenia—*Manatees and dugongs*

There are four living species of sirenians: three manatees and the dugong. A fifth species, Steller's sea cow of the North Pacific and Bering Sea, was exterminated by overhunting in the 1700s. Sirenians, like cetaceans, are entirely aquatic. They are the only marine mammalian herbivores. As a consequence, each (or most) of the species, the dugong, tends to be less oceanic than members of other marine mammal groups. In fact, most manatees spend much or all of their lives in fresh or brackish water. All living species are restricted to a tropical or subtropical habitat. Steller's sea cow was unique, it inhabited cold temperate or subarctic waters of the North Pacific.

Sirenians have the following morphological characteristics: a large, robust body; tough, thick skin with little hair; two nostrils on top of the front of a thick muzzle; no dorsal fin; no hind limbs; mammary nipples located near the axillae; forelimbs modified into flippers; horizontally flattened tail; and dense, swollen (pachyosteosclerotic) bones.

Family Trichechidae—*Manatees*

The three species of manatees fall in a single genus and are found in tropical/subtropical areas of the Atlantic Ocean (and adjacent freshwater systems) and are very social animals. They are characterized by a horizontally flattened, roundish tail (as opposed to the whale-like flukes of dugongs). With only six cervical vertebrae, manatees are among the few groups of mammals that diverge from the normal mammalian number of seven. They are also unusual in that their teeth are replaced throughout life with new ones from the rear of the mouth. The external auditory meatus (external ear) is very small and shallow.

Family Dugongidae—*Dugong*

There is only one living species in the family Dugongidae. The other recent one, Steller's sea cow (*Hydrodamalis gigas*), was described by Gmelin in 1789. The dugong is a tropical/subtropical inhabitant of the Indo-Pacific. Its Steller's sea cow was an inhabitant of cold temperate to subarctic waters. In members of this family, the flukes tend to be pointed and flukes, similar to those of cetaceans. Other characteristics include a rostrum that is deflected downwards, the presence of enamel tusks in males (dugong only; Steller's sea cow had no functional teeth), a more streamlined body than those of manatees, and the absence of nails on the flippers.

Order Carnivora—*Carnivorous mammals*
(including pinnipeds, marine otters, and polar bears)

By far, most carnivores are terrestrial mammals. Besides pinnipeds, the Order Carnivora contains seven families of largely meat-eating mammals, including cats, dogs, bears, raccoons, weasels, otters, civets, and hyenas. Of these, only two families contain marine mammal representatives, the Mustelidae (otters and weasels) and the Ursidae (bears). As only 3 of those 200+ non-pinniped species of carnivores are marine mammals, we will not present the detailed characteristics of members of this order.

Family Mustelidae—*Otters*

The mustelids are the otters, weasels, and their kin. Other mustelids include the minks, ferrets, martens, wolverines, skunks, and badgers. Although four other species of freshwater otters may obtain some of their food from the sea, only two of the approximately 67 species in this family are truly marine. The sea otter and the marine otter. Thus, we restrict our treatment to these two species usually considered among marine mammals. Others are only partially in their own subfamily, the Lutrinae (containing about 13 species). Marine otters are largely restricted to the Pacific Ocean (two marine species in two genera).

Family Ursidae—*Bears*

There are seven species of bears in the world; six are wholly terrestrial and only one could be a marine mam-

mal. Bears are very familiar animals to many people. In particular, the grizzly/brown and black bears of the Northern Hemisphere are often exhibited in zoos and are well known (grizzly/brown bears are most closely related to the polar bear). The single marine species, the polar bear, ranks as the least aquatic and least derived of all marine mammals. Polar bears may spend long periods of time on shore. They are restricted in distribution to arctic regions of the Northern Hemisphere.

Suborder Pinnipedia—*Seals, sea lions, and walruses*

There are 36 species of pinnipeds (Suborder Pinnipedia), all of which are assigned to three families of the mammalian order Carnivora: the Otariidae, Phocidae, and Odobenidae. Although technically the taxonomic status of Pinnipedia is not recognized by many marine mammal biologists anymore, we will make use of this grouping in this book, for clarity of presentation. The otariids are the 16 species of sea lions and fur seals, sometimes referred to as the eared seals. The phocids are the 19 species of true seals, sometimes referred to as the earless seals. Odobenids are reduced to just a single living species, the walrus. There has been controversy as to whether the pinnipeds are monophyletic (i.e., evolved from a single ancestor) or diphyletic (from two separate ancestors). However, recent evidence seems to make it clear that they are monophyletic.

Pinnipeds are highly specialized, aquatic carnivores that live in a diversity of marine habitats (and some freshwater ones as well). One unifying feature of the group is that all must return to a solid substrate, such as land or ice, to bear their pups. Almost without exception, females give birth to a single offspring per reproductive effort. All species are amphibious, though the otariids are the most agile and mobile on land. In general, phocids are more capable divers and breath-holders, although there is overlap in the capacities of some otariids and phocids. In many ways, the walrus is intermediate between the phocids and otariids.

Pinnipeds all have fur (but also use blubber for thermoregulation), two sets of limbs (called foreflippers and hindflippers), long whiskers, nasal openings at the tip of the snout, and strongly reduced or lost ear flaps. Pinnipeds molt every year, some gradually over several weeks or months, others dramatically in a short time. In the species accounts, pinniped coloration is described in somewhat more detail than for cetaceans, because for identification, there is often more of an emphasis on the subtle shading often visible on hauled out pinnipeds.

Family Otariidae—*Eared seals*

All 16 species (in seven genera) of sea lions and fur seals have a polygynous mating system and pronounced sexual dimorphism. Characteristics of this family are: small external ear flaps (pinnae), smooth vibrissae, light skin, a double layer of fur with short underfur and longer guard hairs, hairless hindflippers, four teats in females, scrotal testes, and skulls with shelf-like supraorbital processes and sagittal crests (the latter enlarged in adult males only). Eared seals swim with their large foreflippers and can rotate their hindflippers forward to walk on all fours on land. Southern Hemisphere fur seals rest in a characteristic posture, with head down and flippers waving gently.

Family Odobenidae—*Walrus*

While there were multiple species in the past, today only a single walrus species persists. Walruses are enormous animals that combine features of both otariids (e.g., moderately long foreflippers that can lift the body off the ground) and phocids (e.g., lack of ear pinnae). The neck is long and the hindflippers can rotate under the body and permit walking (although walruses are so bulky they cannot walk as easily as most otariids can). The tail is enclosed in skin and not readily visible or free as in other pinnipeds. The tusks are a unique feature, and are important in fighting and assisting with hauling out. The walrus skull is very robust (pachyostotic) and has orbital processes that are composed of both frontal and maxilla bones. Walruses have numerous short, smooth vibrissae on their thick fleshy mystacial ("moustache") pads. The testes of walruses are internal, not scrotal, and females have four retractable mammary teats. The skin is dark in younger animals and lightens with age. Walruses swim with phocid-like side-to-side strokes of the hindflippers, with assistance from the foreflippers. They only occur in high latitudes of the Northern Hemisphere.

Family Phocidae—*True seals*

This is the largest family of the pinnipeds, with 19 species in 13 genera (one species is extinct). The true, or earless, seals include the largest of the pinnipeds, the elephant seals. Species within the group have variable degrees of sexual dimorphism (in some species, females are the larger sex). Phocids are characterized by the absence of external ear pinnae, a short muzzle, beaded whiskers, dark skin, short fur, generally two teats in females, internal testes, furred hindflippers, inflated tympanic (ear) bones, and the absence of supraorbital processes or an enlarged sagittal crest on the skull. Propulsion in water is provided by figure eight movements of the hindflippers, and movement on land is provided by body heaving, or "galumphing," without much help from the relatively small foreflippers. They lack the ability to draw the hindflippers under the body to lift themselves off the ground. As a rule, true seals are more aquatic than eared seals, spending proportionately less time on land or ice.