

Fishing, iron founding, tanning, woolen milling, bacon and ham curing, and brewing are the chief industries. Marble, slate, and granite are quarried. The farm regions produce poultry, cattle, wheat, barley, potatoes, and dairy products.

Wexford was the first county in Ireland to be occupied by the English. Ancient castles and church ruins are near the town of Enniscorthy and Ferns. Population: (1981) 99,016.

WEXFORD, weks'fard, a town in southeastern Ireland, the seat of county Wexford. It is situated at the mouth of the river Slaney, 70 miles (110 km) south of Dublin. Industries include brewing, meat curing, and the manufacture of textiles, agricultural implements, and furniture. Tourism is important to the economy. The town takes its name from the 9th century Danish settlement of Waesfjord. Wexford was the headquarters of the rebellion of 1798. Population: (1981) 11,396.

WEYDEN, Rogier van der. See VAN DER WEYDEN, ROGIER.

WEYL, wil, Hermann (1885-1955), German mathematician and mathematical physicist. Weyl was born in Elmsborn, Germany, on Nov. 9, 1885, and graduated in 1908 from the University of Göttingen, where he was David Hilbert's most gifted student. His early work was deeply influenced by Hilbert's analytic approach, although he later diverged from his teacher. In 1913 he was appointed a professor at the University of Zürich, where he worked with Albert Einstein.

Fascinated with Einstein's theory of relativity, Weyl developed a unified field theory, in which electromagnetic and gravitational fields could be treated as geometrical properties of space-time. In the 1920's he showed how quantum-mechanical phenomena could be most easily expressed in terms of group theory. His application of function theory to geometry and his work in analytic theory of numbers and topology distinguished him as one of the most universal mathematicians of the 20th century.

In 1930, Weyl returned to Göttingen, only to leave three years later in protest over Nazi treatment of his Jewish colleagues. He then accepted an appointment at the Institute for Advanced Study, in Princeton, N.J., where he remained until his death on Dec. 8, 1955.

STEVE HARRIS, *University of Wisconsin*

WEYMOUTH, wa'moth, a town in eastern Massachusetts, in Norfolk county, about 12 miles (19 km) southeast of Boston, on Boston Bay. Although mainly a residential suburb, Weymouth manufactures shoes, shoe counters, belting, electronics components, paper boxes, industrial resins, and chemicals. The town is made up of four major villages—Weymouth Landing and North, East, and South Weymouth. A United States naval air station is in South Weymouth.

Thomas Weston, an English merchant adventurer, sent a party to establish a trading station at Wessagusset, the Indian name for the present town, in 1622. In 1634, 21 families from Weymouth, England, arrived, and the town was incorporated in September 1635.

Abigail Adams, wife of the second president of the United States, was born in Weymouth in 1744. Her birthplace has been restored and opened to the public. Government is by representative town meeting. Population: 55,601.

WHALE, any of a group of exclusively aquatic mammals that includes the largest animals that ever lived. Whales (order Cetacea) are found in all oceans and contiguous seas, and in certain rivers and lakes of southeastern Asia, tropical South America, northern North America, and northern Eurasia.

This article deals mainly with larger members of the whale order. For further information on some smaller whales, see BELUGA; DOLPHIN; KILLER WHALE; NARWHAL; and PORPOISE.

Whales are typically characterized by torpedo-shaped bodies with forelimbs shaped as flippers and no external hind limbs. Most whales have a dorsal fin, and the tail is horizontal in contrast to the vertical tail of most fishes. A layer of blubber underlies the almost hairless skin, which has no sebaceous or sweat glands. The eyes are small in comparison to body size, and there are no external ears. Adult whales are 4 to 100 feet (1.2-30 meters) long and weigh from 45 pounds to 220 tons (20-200,000 kg).

Whales swim by means of up and down movements of the tail. The flippers function as balancing and steering organs. The large baleen whales can attain a maximum speed of 16 mph (26 km/h), and some dolphins have been clocked at speeds of up to 20.5 mph (33 km/h).

The two groups of living whales are the baleen whales (Mysticeti), characterized by a filter-feeding mechanism known as baleen, and the toothed whales (Odontoceti), known for their complex echolocation systems. A third group, the Archaeoceti or Zeuglodonts, became extinct about 25 million years ago. These primitive toothed whales are neither filter feeders nor echolocators. All three groups of whales probably had a common origin from terrestrial mammals. Studies suggest that the most likely ancestors of whales were derived from terrestrial mesonychids. The mesonychids were a group of large-bodied mammals (condylarths) that lived during the Paleocene and Eocene epochs more than 50 million years ago.

The main ecological difference between the baleen and toothed whales is in their place in the food chain. The toothed whales feed mainly on carnivores, including fish, squid, and octopus. Their conical teeth are for seizing and holding prey, which they swallow whole. Baleen whales, on the other hand, feed mainly on various species of zooplankton—small, largely herbivorous invertebrates such as euphausiids (krill), copepods, and certain types of amphipods. Small fish are also eaten, especially in coastal waters. These food items are strained from the seawater by means of a mat formed by intertwined bristles attached inside the baleen.

The estimated life expectancies of whales range from less than 20 years for some of the smaller species to 70 years for Baird's beaked whales. Except for humans, the only predators of large whales are killer whales (*Orcinus orca*). Any of the whales that live in polar waters are vulnerable to ice entrapment and consequent starvation or suffocation.

Whales have long been hunted by humans, and some populations were brought to the verge of extinction. Most large species are now protected by regulations of the International Whaling Commission (IWC). All large whales are completely protected by the international Convention for the Regulation of Whaling, effective in 1986.

Historically the most valuable whale products were the baleen (also called whalebone) and the oil derived from blubber. Until kerosine became available in the late 19th century, whale oil was used chiefly for lighting. During the 20th century, whale oil was used in the production of margarine, soaps, lubricants, waxes, explosives, and numerous other products. Sperm-whale oil was especially valued as a high-quality lubricant. By the 1980's artificial substitutes had been found for all whale products. The most important of these is a desert plant native to the southwestern United States, the jojoba (*Simmondsia chinensis*), which can provide an economic substitute for sperm oil. Whale meat is still eaten by the people of a few countries, but it is no longer an important part of their diet.

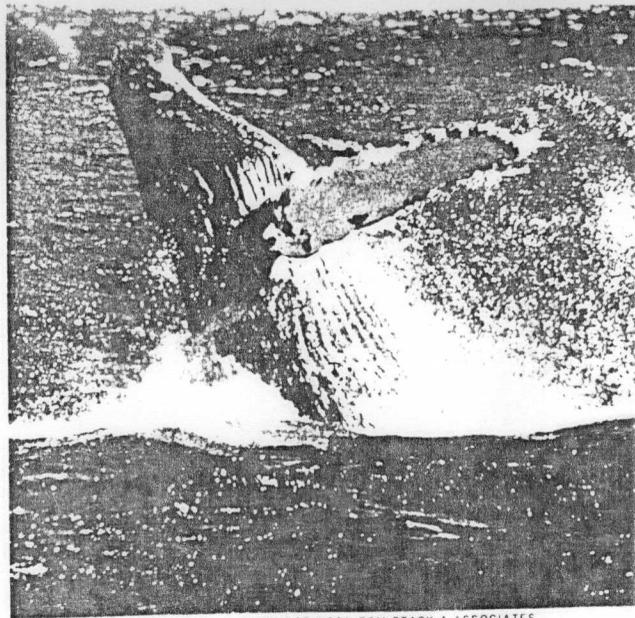
See also WHALING.

GENERAL CHARACTERISTICS

Anatomy and Physiology. Whales have several characteristic anatomical features. Their lungs and livers are not lobed, but the kidney is divided into many lobes—each acting as an individual filtering unit. Whales have three or more chambers in the stomach, and there is no gallbladder. The diaphragm crosses the body on an oblique angle. Highly developed retia mirabilia are present in both the lower part of the head and the thorax. These retial masses help moderate pressure changes that occur during diving. They may prevent overstressing sensitive regions such as the brain and spinal cord.

Sperm whales and some beaked whales can dive to depths of more than 3,280 feet (1,000 meters), where they are subject to pressures in excess of 100 atmospheres. These dives can last over an hour. Three important factors make it possible for whales to go without breathing for such a long period. The first is the high oxygen-storing capacity of their muscles and blood. The proportion of oxygen-storing myoglobin in a whale's muscles is about two to nine times that found in terrestrial mammals. The high oxygen-storage capacity of whale blood is due to the fact that the proportion of red blood cells is as much as twice as high as it is in most land mammals. Second, whales are less sensitive than land mammals to the effects of the lactic acid and carbon dioxide that accumulate in the blood and tissues when breathing stops. Third, the oxygenated blood in the arteries is redistributed during a dive by constriction of arteries that supply non-critical parts of the body. This allows most of the blood to flow to the central nervous system, including the brain. This redistribution is accompanied by a drastic reduction in heart rate. In dolphins, for example, the heart rate at the surface of the water is 90 to 100 beats per minute, but it is only 12 to 20 beats per minute while the dolphin is underwater. Baleen whales are not deep divers.

Whales have five mechanisms to maintain or regulate their body temperature: (1) The large size typical of whales means that, relative to body mass, the proportion of heat-losing surface area is less than in small animals. (2) A layer of insulating blubber with a minimal supply of blood reduces heat loss to the water. (3) The flippers, dorsal fin, and flukes have counter-current heat-exchange systems, in which the arteries carrying warm blood from the heart are surrounded by veins. This ensures that the heat contained in the outflowing arterial blood is at



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A humpback whale leaps out of the water. This and many other characteristic behaviors are not well understood.

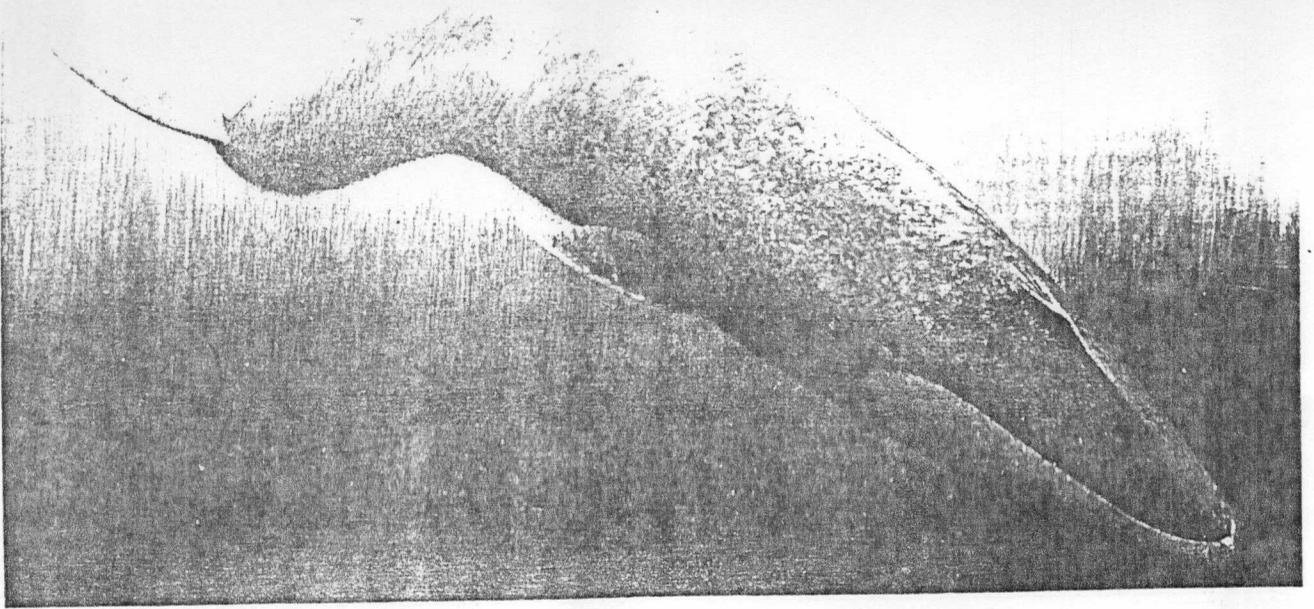
least partly recovered by inflowing venous blood instead of being lost to the cold seawater. (4) A relatively high metabolic rate enables whales to generate more heat per unit of body weight than do land mammals. (5) Finally, the relatively low respiration rates of whales result in low heat loss to the atmosphere.

Most scientists believe that the whale's spout is vapor caused by condensation of air escaping the lungs. However, further research has shown that the gray whale's spout consists mainly of seawater blown up during expiration, at least on the breeding grounds.

The brain weight of whales ranges from 20 pounds (9.2 kg) in the sperm whale to only 4.5 pounds (0.2 kg) in the smaller river dolphins (*Pontoporia blainvillei*). The large whales and the elephants are the only animals with brains larger than human brains. However, their brains are much smaller in relation to their body size than those of humans and bottlenose dolphins (*Tursiops truncatus*). This suggests that the baleen whales may be less intelligent than both humans and these dolphins. The level of intelligence in captive dolphins seems comparable to that of chimpanzees.

Behavior. The social organization of baleen whales is still poorly understood. It is known that groups generally include only two to five individuals, although larger temporary aggregations often form on rich feeding grounds or during the breeding season. However, studies of humpback and right whales are yielding much new information. These studies track the behavior of individual whales, recognized by their markings, and show that these whales are not monogamous, as some scientists formerly thought.

In humpback whales, solitary adult males often "sing" for long periods, emitting a complex series of low-frequency moans. The singers are sometimes approached by other males, and the encounters often lead to fights. Groups of three individuals usually include a male, a female, and her calf. Larger groups usually consist of a female in heat and many males. Males in such groups attempt to block other males from access



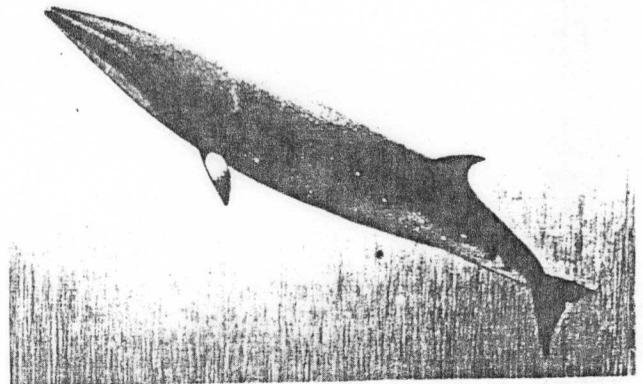
BLUE WHALE

A baleen whale. The streamlined blue whale is the largest of all animals.

Whales include the largest animals alive today and the largest animals that ever lived. Even *Brachiosaurus*, the largest of the dinosaurs, weighed less than half as much as a female blue whale. Whales fall into two main groups: the baleen, or whalebone, whales and the toothed whales.

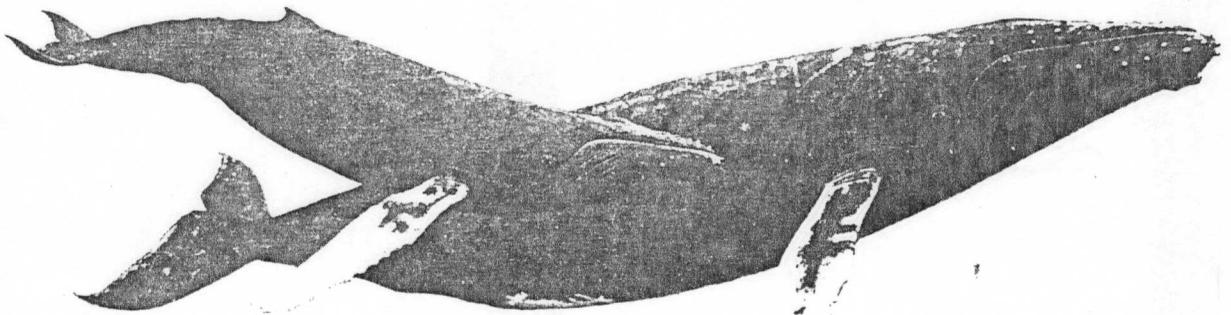
The baleen whales have a distinctive sieve-like structure for straining small food animals from the water. The group includes the largest whale (the blue whale) and one of the smallest (the minke whale). Other baleen whales shown here are the humpback, right (or bowhead), and gray whales.

The toothed whales are more closely related to the dolphins and porpoises than to the baleen whales. They prey on squid, fish, and other large marine animals. The largest of this group is the sperm whale, which is by far the most numerous of the large whales. The only other toothed whales are the beaked whales, including Baird's beaked whale and the northern bottlenose whale.



MINKE WHALE

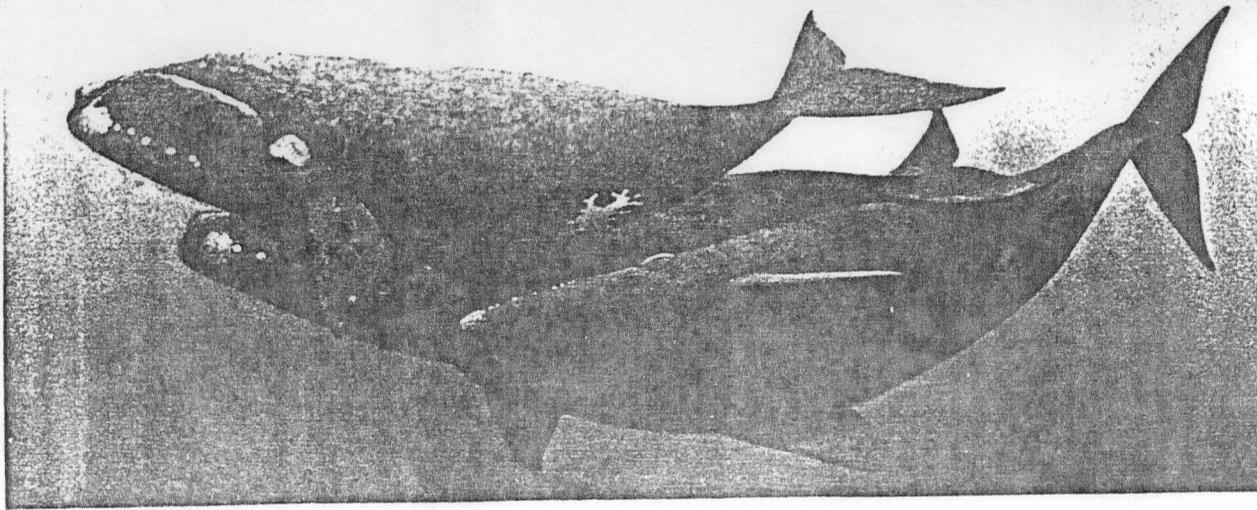
A baleen whale. It is both the smallest and the most widespread of the rorquals.



HUMPBACK WHALE

Adult female and young. A baleen whale, the humpback is noted for its leaps from the water and for the songs of adult males (available on commercial recordings).

PAINTINGS BY LARRY FOSTER

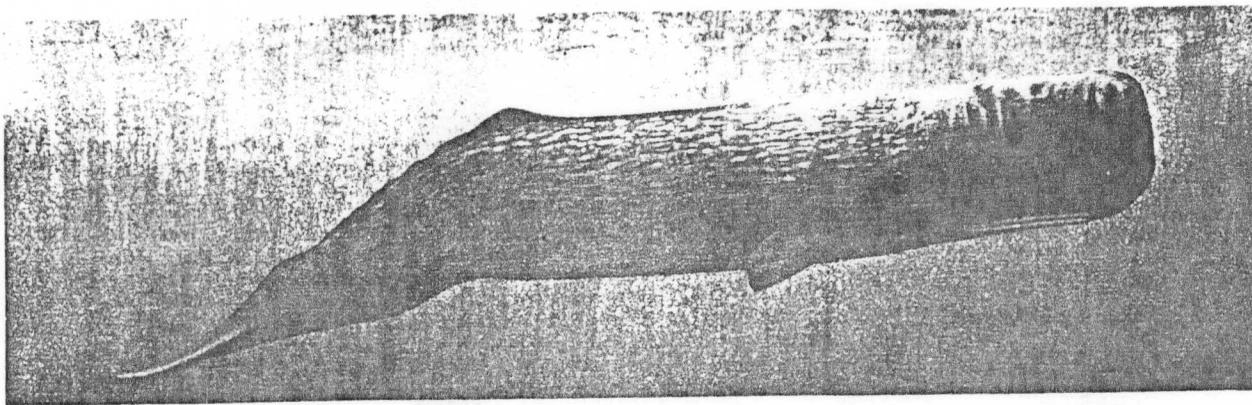
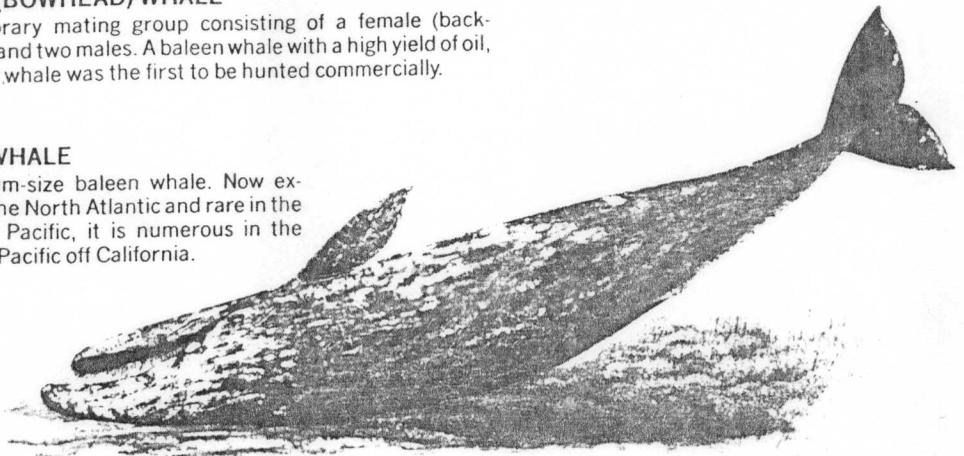


RIGHT (BOWHEAD) WHALE

A temporary mating group consisting of a female (background) and two males. A baleen whale with a high yield of oil, the right whale was the first to be hunted commercially.

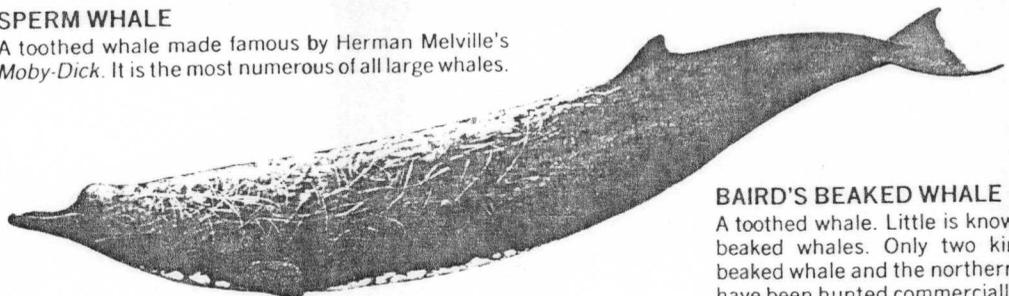
GRAY WHALE

A medium-size baleen whale. Now extinct in the North Atlantic and rare in the western Pacific, it is numerous in the eastern Pacific off California.



SPERM WHALE

A toothed whale made famous by Herman Melville's *Moby-Dick*. It is the most numerous of all large whales.



BAIRD'S BEAKED WHALE

A toothed whale. Little is known about the beaked whales. Only two kinds, Baird's beaked whale and the northern bottlenose, have been hunted commercially.

WHALE

NUMBERS OF WHALES

Species	Before commercial whaling	1985	Percent
 BLUE	210,000	11,000	5
 FIN	450,000	100,000	22
 SEI	200,000	80,000	40
 BRYDE'S	100,000	40,000	40
 MINKE	360,000	250,000	70
 RIGHT	100,000	4,000	4
 BOWHEAD	100,000	4,000	4
 GRAY	15,000	15,000	100
 SPERM	1,500,000	1,250,000	83

to the female, and the ensuing fights may be violent—at times resulting in bloody wounds.

Right whales form similar temporary groups consisting of a female in heat and several competing males. Females are larger than males in all baleen whales. This is thought to be related to the biological requirements of reproduction rather than to social structure.

Sperm whales are polygynous. The basic social unit appears to be a mixed school of 20 to 40 animals, consisting of adult females and their calves. During the breeding season each of these groups is joined by a few adult males. The young of both sexes form separate juvenile schools after they are weaned. Young females rejoin the mixed schools before maturity, but males remain in bachelor groups for many years until they reach breeding age. Like most highly polygynous terrestrial mammals, males far exceed females in size.

Beaked whales mostly form smaller schools of three to six individuals, and there is relatively little difference in size between the sexes. Little more is known about the social structure of these whales.

Mass strandings usually involve gregarious offshore species such as sperm whales, pilot whales, and several species of dolphins. Many of these strandings may be simply the result of navigational errors. Because of the social ties among members of a group, individual animals put back in the water usually return to the beach to rejoin their companions. Trematode infestations in the ears of some whales also have been suggested as a factor in some strandings. Whales or dolphins that strand singly are almost always sick.

Communication. Baleen whales produce four types of sounds: (1) the typical low-frequency moans, including the "songs" of humpback whales, which have a pitch usually between 20 and 200 Hz (Herz, cycles per second) and last between 0.4 and 36 seconds; (2) gruntlike thumps and knocks of short duration, mainly between 40 and 200 Hz and lasting from 50 to 500 milliseconds; (3) chirps, cries, and whistles with frequencies above 1000 Hz; and (4) clicks or

pulses with upper ranges of 20 to 30 kHz (kilohertz). The origin of these sounds is suspected to be the larynx, although the whales have no vocal cords.

Sounds produced by toothed whales include two main types: clicks and whistles. Clicks may be emitted singly, in individual bursts, or in long trains. These sounds usually span a very broad bank of pitches (0.1 to 120 kHz). Long trains of clicks may be heard as a single sound and have been given a variety of names such as barks, chirps, and squawks. Clicks are used for echolocation of prey. Whistles are pure-tone, frequency-modulated signals with a pitch from 4 to 20 kHz and last about half a second.

Clicks appear to be emitted from the right nasal plug and its associated diverticulum and whistles are associated with movements of the left nasal plug. A few investigators believe that both sounds are produced by the larynx.

Life Cycle and Reproduction. Most baleen whales migrate twice a year between rich feeding areas in the Antarctic and Arctic regions and temperate or subtropical breeding and calving grounds. The entire reproductive cycle is correlated with these migrations. In sperm whales, only the adult males migrate to colder waters in the nonbreeding season; the females and juveniles remain in warmer waters all year.

All whales mate in the water. Mating usually occurs with the pair swimming on their sides belly to belly. The male's testes are retained permanently inside the abdominal cavity. In the adult gray whale the testes weigh over 84 pounds (38 kg) and the penis is about 43 inches (110 cm) long.

The gestation periods of whales range from about 10 to 13.5 months in baleen whales and from 10 to 17 months in toothed whales. The larger toothed whales have the longest gestation periods. Only a single young is born, and it is usually one fourth to one third the length of the mother. The teats of the mammary glands are found within paired slits on either side of the female reproductive opening. Contact with the teats during suckling causes the milk to spurt freely into the mouth of the calf. The milk of

baleen whales is unusually high in fat content—30%–53%. It also contains 10%–14% protein, and only about 2% sugar (lactose). The high fat content probably accounts for the rapid growth of the calf during the suckling period. During this period the calf may increase its body weight five to eight times. Sperm-whale milk contains only 17% to 34% fat, 8% to 12% protein, and a very small amount of sugar.

The smaller toothed whales (dolphins and porpoises) are weaned in four or five months, but the young of larger species continue to suckle for two years or longer. Whales become sexually mature at two or three years in some of the smallest dolphins and porpoises but not until 10 years or more in the larger toothed whales and baleen whales. The maximum life span is estimated at up to 40 years for baleen whales and up to 70 years for toothed whales.

BALEEN WHALES

This group of whales (suborder Mysticeti) is distinguished by the presence of baleen and by external paired blowholes. Baleen whales feed mainly by straining krill and other crustaceans from the water as they swim along the surface with their mouths open. They are found in all oceans and contiguous seas except the Black Sea. There are three living families: The Balaenopteridae includes the rorquals—the blue whale, the fin whale, the sei whale, Bryde's whale, the minke whale, and the humpback whale. The Balaenidae includes the right whales, the Greenland or bowhead whale, and the pygmy right whale. The Eschrichtidae contains only the gray whale.

Rorquals. The rorquals, including the blue whale and the humpback, have similar shapes and differ mainly in size. All have deep lengthwise furrows in the skin of the throat.

Blue Whale. The blue whale (*Balaenoptera musculus*) is the largest of all whales and the biggest animal that ever lived. One female caught in the Antarctic measured 100 feet (30.5 meters), with an estimated weight of more than 160 tons. This species is long and streamlined, as are other rorquals, in contrast to the more heavyset right whales and the humpback whale. The color is a mottled blue-gray. Other distinctive characteristics are a strikingly small dorsal fin located on the posterior third of the body; a flat rostrum (upper jaw or snout) that appears U-shaped when viewed from above; and a tall, dense spout. In the Antarctic a yellowish film of diatoms is often present on the ventral and lateral surfaces of these whales, which prompted the whaler's term "sulfur-bottom." The diatoms accumulate on the whales during long stays in cooler waters.

The baleen of blue whales is black and relatively short and coarse. Blues feed almost exclusively on swarms of small crustaceans known as krill (euphausiids). However, off Baja California, Mexico, they also may eat seagoing crabs (*Pleuroncodes planipes*) during the winter. In the Antarctic region, daily food consumption for a single whale is up to 8 tons of krill.

The age of sexual maturity for both sexes is about 10 years. Individual females give birth only at two- or three-year intervals. Gestation is about one year. Calves are conceived and born at low latitudes during the winter. At birth the calves are about 23 feet (7 meters) long and usually weigh more than 2.5 tons. Calves are weaned about eight months after birth, at a mean

length of approximately 53 feet (16 meters), after a weight gain of up to 200 pounds (90 kg) per day.

Blue whales have been protected worldwide by the IWC since 1966. However, it is uncertain whether blue whale populations will ever recover from their low levels, if they survive at all. The current estimate of 5,000 whales in the Southern Hemisphere is only 2.5% of the estimated 200,000 present in the early 1900's.

Other Rorquals, Including Humpbacks. The approximate maximum lengths of the smaller rorquals are 88 feet (26.8 meters) for the fin whale (*B. physalus*), 69 feet (21 meters) for the sei whale (*B. borealis*), 46 feet (14 meters) for Bryde's whale (*B. edeni*), 35 feet (10.7 meters) for the minke whale (*B. acutorostrata*), and 53 feet (16 meters) for the humpback whale (*Megaptera novaeangliae*).

The other major distinctive features of the rorquals are a white right lower lip and a white edge on the upper jaw in fin whales; a single rostral ridge extending forward from the base of the blowhole in sei whales; three prominent ridges on the rostrum in Bryde's whale; and a triangular-shaped rostrum with a single prominent ridge in the minke whale.

Fin and sei whales are widely distributed in temperate and polar waters of both hemispheres. Bryde's whales are found in tropical and temperate waters around the world. They are especially abundant in areas of high food productivity. Minke whales, the most widespread of the rorquals, are found in tropical, temperate, and polar waters of both hemispheres.

The main food of rorquals is various species of krill (euphausiids). Sei whales prefer copepods if available. Animals such as small squid, lantern fish (Myctophidae), and certain amphipods are occasionally taken by rorquals. Bryde's whales feed on krill in pelagic waters and fish in coastal areas. In certain feeding areas, one or two humpbacks swim in an upward spiral around swarms of krill found on or below the surface. As they circle the krill they expel air in a chain of bubbles from the blowhole. The rising bubbles form a "bubble net" that causes the krill to mass in the center of the ring of bubbles. The whales then feed on the concentrated krill.

The gestation period is a year or slightly longer in all rorquals except the minke, in which it is approximately 10 months. The mean length at birth ranges from 9 feet (2.8 meters) in the minke whale to about 20 feet (6 meters) in the fin whale. The larger mature rorquals breed every two or three years; in the smaller minke whales the females calve almost every year. Sexual maturity is attained in both sexes between the ages of 5 and 15 years. Whales in depleted populations attain sexual maturity at an earlier age than those in populations that have reached the environment's carrying capacity.

Whaling during the 20th century has greatly reduced almost all populations of all the rorquals and the humpback. Commercial exploitation of humpback whales has been prohibited by the IWC since 1966.

Right Whales. The family Balaenidae includes three types of whales: the right whales (*Eubalaena glacialis* and *E. australis*), the Greenland right or bowhead whale (*Balaena mysticetus*), and the pygmy right whale (*Caperea marginata*). Historically, right whales occurred mainly in cold and warm-temperate coastal waters around

the world. Bowheads are found only in the Arctic, and pygmy right whales are found only in the Southern Hemisphere.

Right and bowhead whales grow to about 60 feet (18 meters), of which the head is about a third of the total length. Other distinguishing features of right and bowhead whales are the absence of a dorsal fin, large broad flippers, and a large girth (equal to total length). These whales are all black except for a white blotch on the ventral surface in right whales and a white chin in bowhead whales. The most distinctive external feature of the right whale is several patches of grayish, roughened skin called callosities located on the head. The pattern formed by callosities enables observers to recognize individual whales.

Right whales feed almost exclusively on copepods and krill. The age of sexual maturity is unknown. The gestation period is probably about 11–12 months. The length at birth is between 16 and 20 feet (5–6 meters). The lactation period has been estimated at 6 to 12 months. The average interval between births in southern right whales is three years. Bowheads are similar to right whales in feeding habits and reproductive behavior.

The pygmy right whale grows to 21 feet (6.4 meters) in length. It is more slender than the right whale, and its head is a quarter of its total length. It has a sickle-shaped dorsal fin and narrow flippers. Its body is countershaded dark gray above and white below. Pygmy right whales are known to feed only on copepods. Little is known about their reproductive biology.

All populations of right whales were severely reduced by whalers during the 19th century, and only a few of the Southern Hemisphere populations have showed any signs of increase. Bowhead whales are still hunted by Alaskan natives. This hunt has been the focus of controversy because the bowhead is considered the most critically endangered species of baleen whale. The world population of bowhead whales is probably less than 5,000, with the majority occurring in the western Arctic of North America.

Gray Whales. The gray whale (*Eschrichtius robustus*) is now extinct in the North Atlantic, but two populations occur in the North Pacific Ocean: the western Pacific or Korean stock and the eastern Pacific or California stock. The California population is well known for its annual migration along the west coast of North America during November through May.

Gray whales are of medium size. Adult females range between 38 and 49 feet (11.7–15.0 meters) in total body length and adult males between 36 and 47 feet (11.1–14.3 meters). No dorsal fin is present, but a series of bumps or ridges occur on the back behind a larger bump. The color is a mottled gray, and numerous flat barnacles and "whale lice" (small parasitic amphipods) usually are attached to the skin. Gray whales are bottom feeders. They feed mainly by sucking up minute shrimplike crustaceans (gammaridean amphipods).

The two Pacific gray whale populations were greatly reduced by overexploitation in the late 1800's and early 1900's. The western Pacific population is still at a very low level (perhaps only a few hundred whales), but the eastern Pacific population has increased to about 16,000 individuals (1980). This is about 80% of the esti-

mated unexploited population of 20,000 animals. Although protected from commercial whaling, approximately 180 gray whales are taken each year by Soviet catcher boats for use by Siberian natives.

TOOTHED WHALES

The toothed whales (suborder Odontoceti) are distinguished by the presence of teeth, a single blowhole, and the fatty "melon," an acoustic lens that focuses incoming echolocation signals. Toothed whales are found in all oceans and contiguous seas. In addition, some dolphins are found in a few rivers and lakes. Toothed whales feed mainly on fish, squid, and shrimp.

The three living superfamilies of toothed whales are the Platanistoidea, including all the river dolphins; the Delphinoidea, including the various types of mainly marine dolphins and porpoises, narwhals, and belugas; and the Physeteroidea, which includes the sperm and beaked whales. Adults range in size from 4 feet (1.2 meters) in the smallest dolphins to about 65 feet (20 meters) in sperm whales. Only the last superfamily is discussed here. Dolphins, porpoises, belugas, and narwhals are described in separate articles.

Sperm Whales. The sperm whale family (Physeteridae) contains the sperm whale (*Physeter catodon*), the largest of the toothed whales; the pygmy sperm whale (*Kogia breviceps*); and the dwarf sperm whale (*K. simus*). All three are characterized by the spermaceti organ and associated structures inside their heads, asymmetric skull, underslung lower jaw, and functional teeth mainly in the lower jaw. A few upper teeth are commonly found in *K. simus*.

The spermaceti organ contains a white waxy substance called spermaceti, once valued for making cosmetics and candles. The most likely function of the organ is that it serves as an acoustic lens to focus echolocation signals used for finding prey, but some investigators have argued that it is a buoyancy regulator.

In adult male sperm whales the head makes up about 35% of the total length. The blowhole is located far forward on the left side of the head, with a spout that comes out at a sharp angle from the head and toward the left; and a rounded or triangular dorsal hump replaces the dorsal fin. The skin has a shriveled appearance.

The Sperm Whale. The length of adult female sperm whales is 28 to 41 feet (8.5–12.5 meters) and that of adult males is 36 to 65 feet (11–20 meters). The mean age of sexual maturity of female sperm whales is nine years, when they have an average length of about 30 feet (9 meters). Males do not join the mixed schools of females and young and also do not participate in breeding until they are about 30 years old (long after reaching sexual maturity) and about 43 feet (13 meters) in length. Females produce a calf every three to five years. Newborn sperm whales average about 13 feet (4 meters) in length. The gestation period is approximately 15 months, and the lactation period lasts between one and two years.

Sperm whales feed mostly on larger squid, including the giant squids (*Architeuthis* and *Moroteuthis*), and a wide variety of large seabottom and midwater sharks, skates, and fishes. Items recovered from sperm whale stomachs include rocks, glass fishing floats, deep-sea sponges, crab meat, cut meat of baleen whales,

CLASSIFICATION

The classification or taxonomy of all living whales, including dolphins and porpoises, follows. The number of species is given in parentheses after each genus.

ORDER CETACEA

Whales, dolphins, porpoises, belugas, and narwhals.

Suborder Mysticeti

Whalebone or baleen whales.

FAMILY ESCHRICHTIIDAE.

Eschrichtius (1): Gray whale.

FAMILY BALAENOPTERIDAE: Rorquals

Balaenoptera (6): Blue, fin, sei, Bryde's, and minke whales.

Megaptera (1): Humpback whale.

FAMILY BALAENIDAE: Bowhead and right whales.

SUBFAMILY NEOBALAENINAE

Caperca (1): Pygmy right whale.

SUBFAMILY BALAENINAE

Balaena (1): Bowhead whale.

Eubalaena (1): Right whale.

Suborder Odontoceti.

Toothed whales, dolphins, and porpoises.

SUPERFAMILY PLATANISTOIDEA: River dolphins.

FAMILY INIIDAE

Inia (1): Boutu.

FAMILY LIPOTIDAE

Lipotes (1): Beiji.

FAMILY PLATANISTIDAE

Platanista (2): Indian River dolphins.

FAMILY PONTOPORIIDAE

Pontoporia (1): Franciscana.

SUPERFAMILY DELPHINOIDEA: Marine dolphins and porpoises.

FAMILY MONODONTIDAE: Narwhals and belugas.

SUBFAMILY DELPHINAPTERINAE

Delphinapterus (1): Beluga.

SUBFAMILY MONODONTINAE

Monodon (1): Narwhal.

SUBFAMILY ORCAELLINAE

Orcaella (1): Irrawaddy dolphin.

FAMILY DELPHINIDAE: Dolphins and grampuses.

SUBFAMILY STENONINAE

Sotalia (1): Tucuxi.

Sousa (2): Humpback dolphins.

Steno (1): Rough-toothed dolphin.

SUBFAMILY DELPHININAE

Delphinus (1): Common dolphin.

Grampus (1): Risso's dolphin.

Lagenodelphis (1): Fraser's dolphin.

Lagenorhynchus (6)

Stenella (5)

Tursiops (1): Bottlenose dolphin.

SUBFAMILY GLOBICEPHALINAE: Killer whales.

Feresa (1): Pygmy killer whale.

Globicephala (2): Pilot Whales

Orcinus (1): Killer whale.

Peponocephala (1): Melon-headed whale.

Pseudorca (1): False killer whale.

SUBFAMILY LISSODELPHININAE

Lissodelphis (2): Right-whale dolphins

SUBFAMILY CEPHALORHYNCHINAE

Cephalorhynchus (4)

FAMILY PHOCOENIDAE: Porpoises.

Neophocaena (1): Finless porpoise.

Phocoena (4): Common porpoise and others.

Phocoenoides (1): Dall's porpoise.

SUPERFAMILY PHYSETEROIDEA: Beaked and sperm whales.

FAMILY ZIPHIIDAE: Beaked whales.

Berardius (2): Beaked whale.

Hyperoodon (2): Bottlenose whale.

Mesoplodon (12): Mesoplodonts.

Tasmacetus (1): Tasman beaked whale.

Ziphius (1): Cuvier's beaked whale.

FAMILY PHYSETERIDAE: Sperm whales.

Kogia (2): Dwarf and pygmy sperm whales.

Physeter (1): Sperm whale.

clams, and a human boot. Some of the objects are evidence that sperm whales sometimes feed along the sea-floor. Adult males can remain submerged for periods of an hour or more. Sonar operators have actively tracked sperm whales to depths of 9,200 feet (2,800 meters).

The IWC prohibited factory-ship whaling for sperm whales in 1979. Beginning about 1982 the remaining catch, from North Pacific shore stations, was reduced to 400 sperm whales a year, compared with a peak total North Pacific catch of 29,000 in the mid-1960's. Although female sperm whales are still numerous, the number of adult males is greatly reduced.

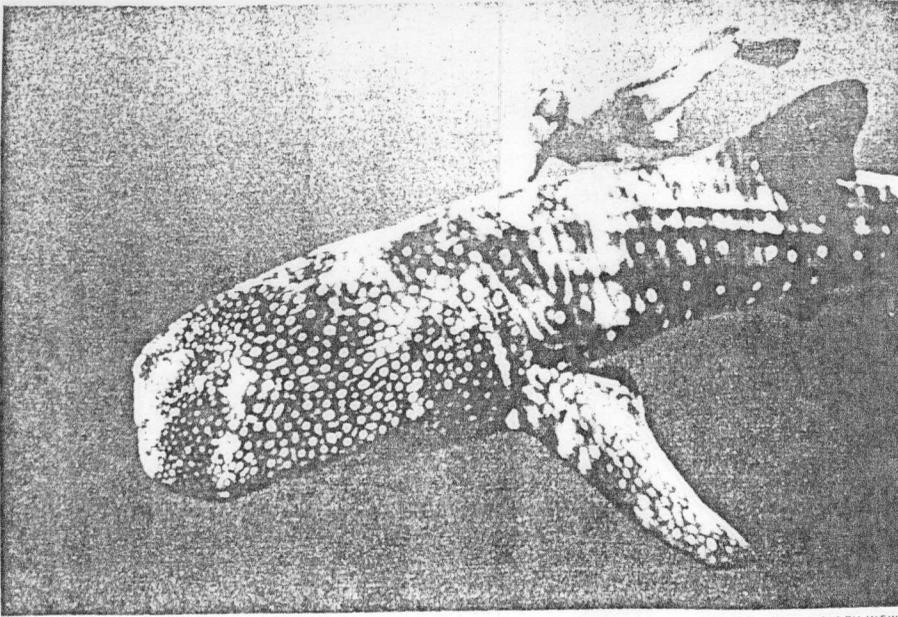
Sperm whales are the source of ambergris, a waxy substance once highly prized as a base for perfumes and cosmetics. Masses of ambergris up to 220 pounds (100 kg) accumulate in the whale's lower intestine. Ambergris is sometimes found on beaches or floating in the sea.

Dwarf and Pygmy Sperm Whales. The range of sizes in sexually mature *Kogia* is 7 to 11 feet (2.1-3.4 meters). The diet of both whales consists mainly of various species of smaller squid but also includes fishes and crustaceans. Stomach contents from dwarf sperm whales indicate that they dive to depths of at least 985 feet (300 meters). Age of sexual maturity is unknown, as are most other details of the reproductive cycle.

Little is known about either species of *Kogia*. Most historical records are not accurate as to species, since the dwarf sperm whale was only recently accepted as a distinct species. They are rarely sighted at sea but appear to be solitary or to form small schools of about six or seven animals. Nothing is known about the overall abundance of these whales, but because they are commonly stranded in some areas they must be locally abundant.

Beaked Whales. These are a diverse family of 18 species in five genera. They are exclusively oceanic in distribution. Beaked whales are of medium size, with adults ranging in length from about 13 feet (4 meters) in *Mesoplodon* to slightly more than 39 feet (4 meters) in *Berardius*. In all species except the Tasman beaked whale the upper teeth are absent or vestigial and no more than four teeth are present in the lower jaws. Other characteristics of the family include a pair of deep throat grooves and flukes with no median notch. The two best-known species are the northern bottlenose whale (*Hyperoodon ampullatus*) and the Baird's beaked whale (*Berardius bairdii*).

Very little is known about this group, since they are infrequently observed and difficult to identify at sea. They feed mainly on various squid and some fishes and appear to be deep divers. The northern bottlenose has been re-



ROBERT COMMER/EARTH VIEWS

Unlike most other sharks, the docile whale shark is not a meat-eater. It feeds on small crustaceans and other plankton.

ported to dive for up to two hours. They are usually seen in groups of up to six whales.

The only information on reproductive cycles is for the two species taken commercially. The estimated age of sexual maturity in Baird's whale is 8 to 10 years. The mating season is October and November. The gestation may be as long as 17 months, and most births occur from November to July, with the majority in March and April. The interval between calves is probably three years. The mean age of sexual maturity for the northern bottlenose whale is 11 years for females and 7 to 11 for males. The peak of breeding is in April, and gestation is estimated at one year. The calving interval is about two or three years.

The status of all the beaked whale populations except the northern bottlenose is generally good, but a few species may be naturally rare. Longman's beaked whale (*M. pacificus*) is known from only two individuals. The IWC prohibited commercial catches of the northern bottlenose in 1978.

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WHALE OIL. See under WHALING.

WHALE SHARK, the largest of all sharks and the largest of all fishes. The biggest specimen measured was nearly 45 feet (15.2 meters) in length. The whale shark is the only large shark covered

with white spots and the only shark with the mouth at the end of the snout rather than below it. Unlike the vast majority of sharks, the whale shark does not prey on large fish or other large vertebrates. Instead, it strains small animals from the water like the baleen whale and like the basking shark, which is the next-largest fish.

Whale sharks are open-sea fishes found in tropical waters around the world. They sometimes range as far north as New York and as far south as southern Brazil and Australia. They are especially abundant in the Philippines, the Red Sea, the Caribbean region, and the Gulf of California. In the Caribbean, whale sharks have been observed commingled with tunas, apparently feeding on the same schools of small fish.

The huge mouth measures 5 feet (1.5 meters) across in medium-size individuals. The numerous tiny teeth are not used to catch food. Instead, the whale shark uses its gill rakers to strain plankton, small fishes, and squid from the water. The rakers are attached to the bottom of the gill bars and extend forward into the throat, where they form an interlocking net somewhat like the baleen (whalebone) plankton strainer in whales. When water is strained through the rakers, food animals are trapped and swallowed.

Sometimes whale sharks feed while cruising slowly along the surface. At other times they take up a vertical, tail-down position and bob up and down in the water, gulping their prey on each upward bob.

Whale sharks are egg layers. An egg case found in the Gulf of Mexico contained a young whale shark 14 inches (36 cm) long.

Whale sharks are of no economic importance. Their livers lack the concentration of vitamin A that makes the basking shark and some other sharks valuable catches.

The whale shark, *Rhiniodon typus*, is the sole member of the family Rhiniodontidae in the order Orectolobiformes, which also includes carpet sharks and nurse sharks.

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WHALEBONE. See under WHALE.