Shelters and Tools used by Animals

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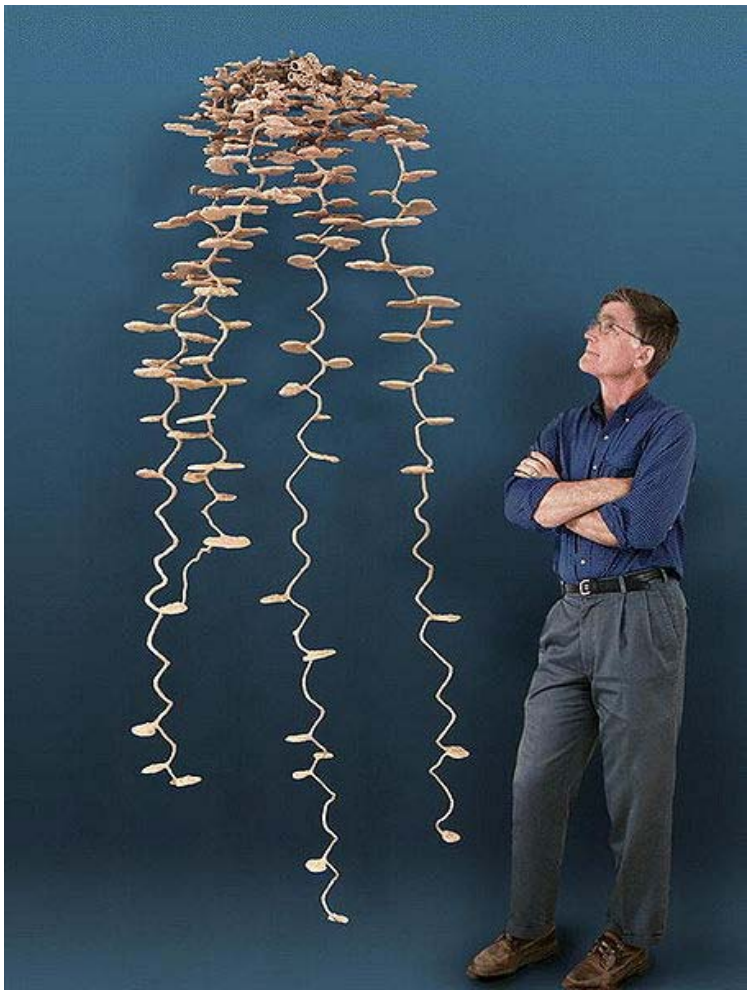
Ant Colony



A plaster cast of an ant nest.

Ant hill and ant tracks, Oxley Wild Rivers National Park, NSW

An **ant colony** is an underground lair where ants live, eat and mate. Colonies consist of a series of underground chambers, connected to each other and the surface of the earth by small tunnels. There are rooms for nurseries, food storage, and mating. The colony is built and maintained by legions of worker ants, who carry tiny bits of dirt in their mandibles and deposit them near the exit of the colony, forming an ant-hill. Food carried in by workers is retrieved from the surrounding environment and can be traced from colony to colony by the use of isotopes.

Ant colonies are eusocial, and are very much like those found in other social Hymenoptera, though the various groups of these developed sociality independently through convergent evolution. Eggs are laid by one or sometimes more queens. Queens

are different in structure; they are the largest ants of the colony as a consequence of their egg-laying. Most of the eggs that are laid by the queens grow up to become wingless, sterile females called "workers". Periodically, swarms of new winged queens and males (the alates) are produced in most species, which leave to mate. The males die shortly thereafter, while the surviving queens either found new colonies or occasionally return to their old one. The surviving queens can live up to around 21 years.

People raise ant colonies in captivity for research and as a hobby. An "ant terrarium" used for this purpose is called a formicarium. They are often made thin enough that one can see the entire colony inside their nest. These are also called ant farms.

Unicoloniality and supercolonies

Most commonly, ants from different nests exhibit aggression toward each other. However, some ants exhibit the phenomenon called unicoloniality, where worker ants freely mix between different nests. A group of nests where ants do not exhibit mutual aggression is known as a supercolony — this form of organization is known as supercoloniality, and ants from different supercolonies of the same species do exhibit mutual aggression. Populations in supercolonies do not necessarily span a contiguous area.

Until 2000, the largest known ant supercolony was on the Ishikari coast of Hokkaidō, Japan. The colony was estimated to contain 306 million worker ants and one million queen ants living in 45,000 nests interconnected by underground passages over an area of 2.7 km^2 (670 acres). In 2000, an enormous supercolony of Argentine ants was found in Southern Europe (report published in 2002). Of 33 ant populations nested along the 6,004-kilometre (3,731 mi) stretch along the Mediterranean and Atlantic coasts in Southern Europe, 30 belonged to one supercolony with estimated millions of nests and billions of workers, interspersed with three populations of another supercolony. The researchers claim that this case of unicoloniality cannot be explained by loss of their genetic diversity due to the genetic bottleneck of the imported ants. In 2009, it was demonstrated that the largest Japanese, Californian and European Argentine ant supercolonies were in fact part of a single global "megacolony".

Another supercolony, measuring approximately 100 km (62 mi) wide, was found beneath Melbourne, Australia in 2004.

Ant-hills

A clay ant hill

A giant ant hill in Zambia.

An *ant-hill*, in its simplest form, is a pile of earth, sand, pine needles, or clay or a composite of these and other materials that build up at the entrances of the subterranean dwellings of ant colonies as they are excavated. A colony is built and maintained by legions of worker ants, who carry tiny bits of dirt and pebbles in their mandibles and deposit them near the exit of the colony. They normally deposit the dirt or vegetation at the top of the hill to prevent it from sliding back into the colony, but in some species they actively sculpt the materials into specific shapes, and may create nest chambers within the mound.

In some areas of the world including English-speaking countries of Africa, in common speech the term *ant-hill* (also written as "anthill") refers to a termite mound. Note that termites are not ants.

Giant ant hills like the one on the right found in Zambia are often used to make clay bricks as the clay in the anthills is above the surface which saves time digging large holes in the ground to get to it. They are built by termites which are photosensitive so it is safe to dig into their hills without them attacking anyone.

Chapter 2

Beehive

Wooden hives in in Lithuania

Painted wooden beehives with active honey bees

A **beehive** is an enclosed structure in which some honey bee species of the subgenus *Apis* live and raise their young. Natural beehives (typically referred to simply as "nests") are naturally occurring structures occupied by honey bee colonies, whereas domesticated honey bees live in man-made beehives, often in an apiary. These man-made structures are typically referred to as "beehives". Several species of *Apis* live in hives, but only the western honey bee (*Apis mellifera*) and the eastern honey bee (*Apis cerana*) are domesticated by humans.

The beehive's internal structure is a densely packed matrix of hexagonal cells made of beeswax, called a honeycomb. The bees use the cells to store food (honey and pollen), and to house the "brood" (eggs, larvae, and pupae).

Artificial beehives serve two purposes: production of honey and pollination of nearby crops. Artificial hives are commonly transported so that bees can pollinate crops in other areas. A number of patents have been issued for beehive designs.

Natural hives

Natural beehive in the hollow of a tree

Honey bees in the subgenus *Apis* use caves, rock cavities and hollow trees as natural nesting sites. Members of other subgenera have exposed aerial combs. The nest are composed of multiple honeycombs, parallel to each other, with a relatively uniform bee space. The nest usually has a single entrance. Western honey bees prefer nest cavities approximately 45 litres in volume and avoid those smaller than 10 or larger than 100 litres. Western honey bees show several preferences in nest site properties: the height above ground is usually between 1 metre (3.3 ft) and 5 metres (16 ft), entrance positions tend to face downward, south-facing entrances are favored (as described by a reference

from the Northern Hemisphere), and nest sites over 300 metres (980 ft) from the parent colony are preferred. Bees usually occupy the nests for several years.

The bees often smooth the bark surrounding the hive entrance, and the cavity walls are coated with a thin layer of hardened plant resin (propolis). Honeycombs are attached to the walls along the cavity tops and sides, but small passageways are left along the comb edges. The basic nest architecture for all honey bees is similar: honey is stored in the upper part of the comb; beneath it are rows of pollen-storage cells, worker-brood cells, and drone-brood cells, in that order. The peanut-shaped queen cells are normally built at the lower edge of the comb.

Ancient artificial hives

Bees were kept in man-made hives in Egypt in antiquity. The walls of the sun temple of Nyuserre Ini from the 5th Dynasty, dated earlier than 2422 BC, depict workers blowing smoke into hives as they remove honeycombs. Inscriptions detailing the production of honey are found on the tomb of Pabasa from the 26th Dynasty (circa 650 BC), and describe honey stored in jars, and cylindrical hives.

Archaeologist Amihai Mazar of the Hebrew University of Jerusalem cites 30 intact hives that were discovered in the ruins of the city of Rehov (2,000 residents in 900 B.C., Israelites and Canaanites). This is evidence that an advanced honey industry existed in the Holy Land, approximately 3,000 years ago. The beehives, made of straw and unbaked clay, were found in orderly rows, with a total of 100 hives, many broken. Ezra Marcus from the University of Haifa said the discovery provided a glimpse of ancient beekeeping seen in texts and ancient art from the Near East. An altar decorated with fertility figurines was found alongside the hives and may indicate religious practices associated with beekeeping. While beekeeping predates these ruins, this is the oldest apiary yet discovered.

Traditional artificial hives

Traditional beehives simply provided an enclosure for the bee colony. Because no internal structures were provided for the bees, the bees created their own honeycomb within the hives. The comb is often cross-attached and cannot be moved without destroying it. This is sometimes called a 'fixed-frame' hive to differentiate it from the modern 'movable-frame' hives. Harvest generally destroyed the hives, though there were some adaptations using extra top baskets which could then be removed when the bees filled them with honey. These were gradually supplanted with box hives of varying dimensions, with or without frames, and finally replaced by newer modern equipment.

Honey from traditional hives was typically extracted by *pressing* - crushing the wax honeycomb to squeeze out the honey. Due to this harvesting, traditional beehives typically provided more beeswax, but far less honey, than a modern hive.

Skeps and other fixed-frame hives are no longer in wide use (and are illegal in many countries) because the bees and the comb cannot be inspected for disease or parasites without destruction of the honeycomb and usually the colony.

There are three basic styles of traditional beehive; mud hives, clay/tile hives, skeps and bee gums.

Mud and clay hives

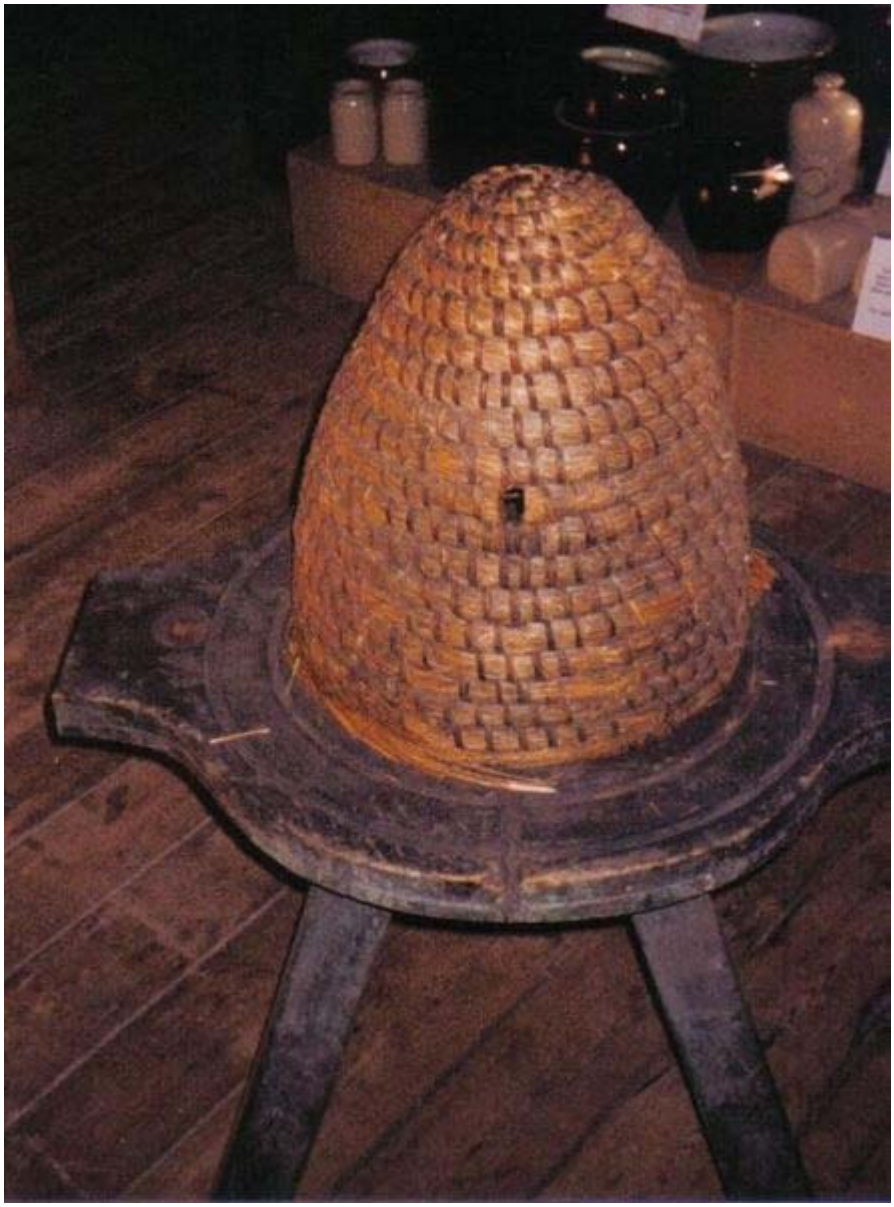
Bees in a baked clay jar in Malta

Mud hives are still used in Egypt. These are long cylinders made from a mixture of unbaked mud, straw, and dung.

Clay tiles were the customary homes of domesticated bees in the eastern end of the Mediterranean. Long cylinders of baked clay were used in ancient Egypt, the Middle East and to some extent in Greece, Italy and Malta. They sometimes were used singly, but more often stacked in rows to provide some shade, at least for those not on top. Keepers would smoke one end to drive the bees to the other end while they harvested honey.

Skeps

Traditional manufacture of *skeps* from straw in England



A bee skep at Dalgarven Mill. The base is part of an old cheese press

Skeps, which are baskets used open end down, have been used for about 2000 years. Initially they were made from wicker plastered with mud and dung but from the middle ages they were made of straw. In northern and western Europe, skeps were made of coils of grass or straw. In its simplest form, there is a single entrance at the bottom of the skep. Again, there is no internal structure provided for the bees and the colony must produce its own honeycomb which is attached to the inside of the skep.

Skeps have two disadvantages: beekeepers can not inspect the comb for diseases and pests and honey removal is not easy and often results in the destruction of the entire colony. To get or facillitate honey removal beekeepers either drove the bees out of the skep or by the use of a bottom extension called an eke or top extension called a cap

sought to create comb with just honey in it. Quite often the bees were just killed, sometimes using lighted sulphur, to allow the honey comb to be removed. Skeps could also be squeezed in a vice to extract the honey. It is now illegal is some countries (including the USA) to keep bees in a skep because it is very hard to monitor and manage the bees.

Later skep designs included a smaller woven basket (cap) on top over a small hole in the main skep. This cap acted as a crude super, allowing the harvesting of some honey with less destruction of brood and bees. In England such an extension piece consisting of a ring of about 4 or 5 coils of straw placed below a straw beehive to give extra room for brood rearing was called an eke, imp or nadir. An eke was used to give just a bit of extra room, or to "eke" some more space, a nadir is a larger extension used when a full story was needed beneath.

A person who made such woven beehives was called a 'Skepper', a surname that still exists in western countries. In England the thickness of the coil of straw was controlled using a ring of leather or piece of cows horn called a 'girth' and the coils of straw could be sewn together using strips of briar. Likenesses of skeps can be found in paintings, carvings and old manuscripts. The skep is often used on signs as an indication of industry 'the busy bee').

In the late 1700s more complex skeps appeared which had wooden tops with holes in over which glass jars were placed. The comb was built in the glass jars which made it commercially attractive.

Bee gums

"Barć" in a museum in Białowieża

In the eastern United States, especially in the southeast, sections of hollow trees were used until the 20th century. These were called "gums" because they often were from red gum trees.

Sections of the hollow trees were set upright in "bee yards" or apiaries. Sometimes sticks or crossed sticks were placed under a board cover to give an attachment for the honeycomb. As with skeps, harvest of honey from these destroyed the colony. Often the human bee "robber" would sulphur the bees, killing them, before even opening their nest. This was done by inserting a metal container of burning sulphur into the gum.

Natural tree hollows and artificially hollowed tree trunks were widely used in the past also by bee-keepers in Central Europe. For example, in Poland such a beehive was called "barć" and it was protected in various ways from unfavourable weather conditions (rain, frost) and predators (woodpeckers, bears). Harvest of honey from these did not destroy the colony, as only a protective piece of wood was removed from the opening and smoke was used to deter the bees for a short time.

Modern artificial hives

Dadant-Blath beehives in Serbia

The earliest recognizably modern designs of beehives mainly arose in the nineteenth century, though they were perfected from intermediate stages of progress that had taken place in the eighteenth century.

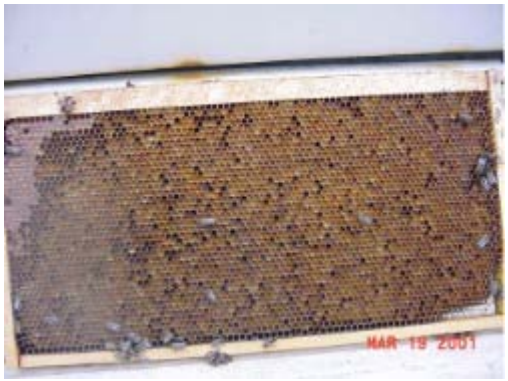
Thus, intermediate stages in hive design were recorded for example by Thomas Wildman in 1768/1770, who described advances over the destructive old skep-based beekeeping so that the bees no longer had to be killed to harvest the honey. Wildman for example fixed a parallel array of wooden bars across the top of a straw hive or skep (with a separate straw top to be fixed on later) "so that there are in all seven bars of deal" [in a 10-inch-diameter (250 mm) hive] "to which the bees fix their combs". He also described using such hives in a multi-storey configuration, foreshadowing the modern use of supers: he described adding (at a proper time) successive straw hives below, and eventually

removing the ones above when free of brood and filled with honey, so that the bees could be separately preserved at the harvest for a following season. Wildman also described a further development, using hives with "sliding frames" for the bees to build their comb, foreshadowing more modern uses of movable-comb hives. Wildman's book acknowledged the advances in knowledge of bees previously made by Swammerdam, Maraldi, and de Reaumur—he included a lengthy translation of Reaumur's account of the natural history of bees—and he also described the initiatives of others in designing hives for the preservation of bee-life when taking the harvest, citing in particular reports from Brittany dating from the 1750s, due to Comte de la Bourdonnaye.

In 1814, Petro Prokopovych, the founder of commercial beekeeping in the Ukraine, invented one of the very first beehive frames. However, for easy operations in beehives the spaces between elements need to be correct. The correct distance between combs was described in 1845 by Jan Dzierżon as 1½ inches from the center of one top bar to the center of the next one. In 1848 Dzierzon introduced grooves into the hive's side walls replacing the strips of wood for moving top bars. The grooves were 8 × 8 mm (0.31 × 0.31 in), the spacing later termed bee space. The Langstroth hive was the first successful top-opened hive with movable frames. Langstroth hive was however direct descendant of Dzierzon's hive designs.

There are two basic types of modern or movable hive in common use, the "Langstroth hive" (including all the size variants) which has enclosed frames to hold the comb and the "top-bar hive", as the name implies, have only a top-bar to support the comb. These hives are typified by removable frames which allow the apiarist to inspect for diseases and parasites. Movable frames also allow a beekeeper to more easily split the hive to make new colonies.

Langstroth hives



Langstroth frame of honeycomb with honey in the upper left and pollen in most of the rest of the cells

Named for their inventor, Rev. Lorenzo Langstroth, Langstroth hives are not the only hives of this style, but they are the most common. Langstroth patented his design in 1860 originally being designed for comb honey production; it has become the standard style hive for 75% of the world's beekeepers. This class of hives includes other styles, which

differ mainly in the size and number of frames used. These include Smith, Segeberger Beute (German), Frankenbeute (German), Normalmass (German), Langstroth hive, Modified Commercial and Modified Dadant, plus regional variations such as the British Modified National Hive.

Langstroth hives make use of bee space so that frames are neither glued together nor filled with *burr comb*–comb joining adjacent frames.

Langstroth hives use standardized sizes of hive bodies (rectangular boxes without tops or bottoms placed one on top of another) and internal frames to ensure that parts are interchangeable and that the frames will remain relatively easy to remove, inspect, and replace without killing the bees. Langstroth hive bodies are rectangular in shape and can be made from a variety of materials that can be stacked to expand the usable space for the bees. Inside the boxes, frames are hung in parallel. The minimum size of the hive is dependent on outside air temperature and potential food sources in the winter months. The colder the winter, the larger the hive and food stores need to be. In the regions with severe winter weather, a basketball-shaped cluster of bees typically survives in a "double-deep" box. In temperate and equatorial regions, a winter cluster will survive in a single box or in a nuc (short for nucleus colony).

Langstroth frames are thin rectangular structures made of wood or plastic and which have a wax or plastic foundation on which the bees draw out the comb. The frames hold the beeswax honeycomb formed by the bees. Ten frames side-to-side will fill the hive body and leave the right amount of bee space between each frame and between the end frames and the hive body.

Langstroth frames are often reinforced with wire, making it possible to extract honey in centrifuges to spin the honey out of the comb. As a result, the empty frames and comb can be returned to the beehive for use in the next season. Since it is estimated that bees require as much food to make one kilogram of beeswax as they do to make eight kilograms of honey, the ability to reuse comb can significantly increase honey production.

The modern Langstroth hive consists of the following parts:

- Hive Stand: the upper hive components rests on this providing a landing board for the bees and helping to protect the Bottom Board from rot and cold transfer.
- Bottom Board: this has an entrance for the bees to get into the hive.
- Brood Box: is the most bottom box of the hive and is where the queen bee lays her eggs.
- Honey Super: usually shorter than the brood box, but is upper-most box(s) where honey is stored.
- Frames & Foundation: wooden or plastic frames with wax or plastic sheets with honey comb impression where bees build wax honey combs.
- Inner Cover: provides separation from a overly hot or cold Outer Cover and can be used as a shelf for feeding or other purposes.

- Outer Cover: provides weather protection for the hive.

National hives

The National hive is the most widely used hive in the United Kingdom. It is a square hive, with rebates (grooves) that serve as hand grips. The frames are smaller than standard Langstroth and Commercial hives and have longer hand grips (or "lugs"). Many beekeepers now view the brood box of the National as too small for the laying activity of modern strains of queen bee, so many beekeepers operate the National with a brood box and one super. This is sometimes called "a brood and a half". While this provides enough room for the brood, it also increases the number of frames that have to be checked through regular inspection. Because of this the National hive brood boxes are also now available in a 14 x 12 inch size which gives a brood size similar to the Commercial or Langstroth.

Commercial hives

Commercial hives are exactly the same external dimensions as a National hive, but instead of having a rebate the hive is a simple cuboid. Because of this the frames are larger and have shorter handles or lugs. The brood box is picked up using small hand holds cut into the external wall of the hive. Supers have this same feature, which can make them difficult to hold when full of honey. Some beekeepers therefore use National supers on top of a Commercial brood box.

WBC hives

The WBC, invented by and named after William Broughton Carr, is a double-walled hive with an external housing that splays out towards the bottom of each frame covering a standard box shape hive inside. The WBC is in many respects the 'classic' hive as represented in pictures and paintings, but despite the extra level of insulation for the bees offered by its double-walled design many beekeepers avoid it due to the inconvenience of having to remove the external layer before the hive can be examined.

Dartington Long Deep hives

The Dartington Long Deep (DLD) hive takes 14 x 12 inch and can take up to 17 frames. It is possible to have 2 colonies in the brood box as there is an entrance at either end. It has half size honey supers which take 6 frames can be used which are lighter than full supers and are therefore easier to lift. The Dartington originally developed by Robin Dartington so that he could keep bees on his London rooftop.

Beehaus

The Beehaus is the most modern beehive having been launched in 2009. It is based on similar principles to a Dartington.

Top-bar hives

The top-bar or Kenya-hives were developed as a lower-cost alternative to the standard Langstroth hives and equipment. They are used by some devotees in the United States, but are much more popular, due to their simplicity and low cost, in developing countries. Top-bar hives also have movable frames and make use of the concept of bee space.

The top-bar hive is so named because the frames of the hive have only a top bar, not sides or a bottom bar. The beekeeper does not provide a foundation (or provides only a fractional foundation) for the bees to build from. The bees build the comb so it hangs down from the top bar. The hive body is often shaped as an inverted trapezoid in order to reduce the tendency of bees to attach the comb to the hive-body walls. Unlike the Langstroth design, a top-bar hive is generally expanded horizontally, not vertically. The top-bar design is a single, much longer box, with all the frames hanging in parallel.

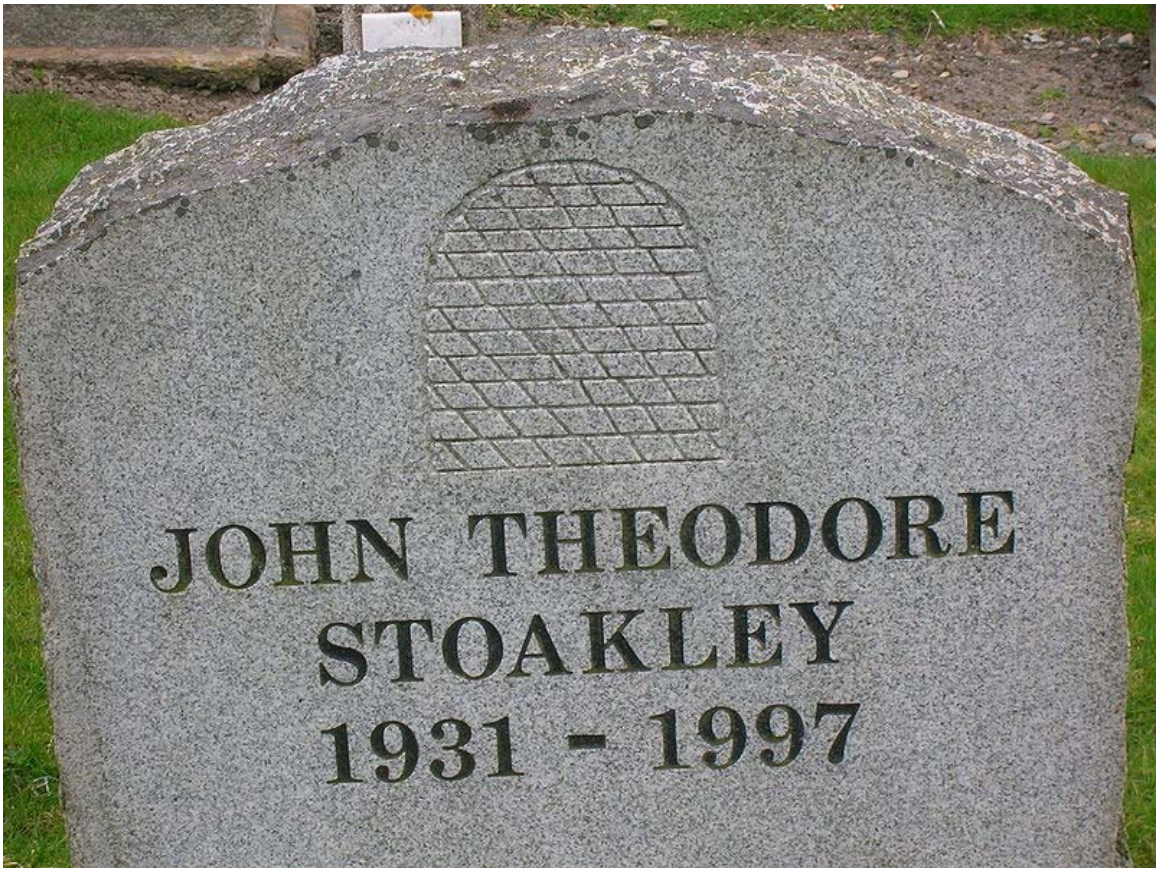
Unlike the Langstroth hive, the honey cannot be extracted by centrifuging because a top-bar frame does not have reinforced foundation or a full frame. Because the bees have to rebuild the comb after each harvest, a top-bar hive yields more beeswax but less honey.

However, like the Langstroth hive, the bees can be induced to store the honey separately from the areas where they are raising the brood. Therefore, bees are less likely to be killed when harvesting from a top-bar hive than when harvesting from a skep or other traditional hive design.

Warré hives

The Warré hive was invented by Abbé Émil Warré, and is also called "ruche populaire" (fr) or "The People's Hive" (en), the Warré hive is a modular and storied design similar to a langstroth hive. The hive body is made of boxes stacked vertically, however it uses Top Bars for comb support instead of full frames. Popularity of this hive is growing among sustainable practice beekeepers. The Warre hive differs from other stacked hive systems in one fundamental aspect: when the bees need more space as the colony expands, the new box is "nadired". i.e. positioned underneath the existing box(es). This serves the purpose of warmth retention within the brood nest of the hive, considered vital to colony health.

Symbolism



A Straw Skep engraved on a gravestone

The beehive is a commonly used symbol dating at least to Roman times. In medieval heraldry it was considered a symbol of industry.

In modern times, it is used in Freemasonry. In masonic lectures is explained as symbol of industry and co-operation, and as cautioning against intellectual laziness, warning that "he that will so demean himself as not to be endeavoring to add to the common stock of knowledge and understanding, may be deemed a drone in the hive of nature, a useless member of society, and unworthy of our protection as Masons."

The beehive is also used with similar meaning by The Church of Jesus Christ of Latter-day Saints, or Mormons. From Mormon usage it has become one of the State symbols of Utah.

In Wellington, New Zealand, the round building used for Parliamentary offices is known as the "Beehive".

Beehive Brand matches made by Bryant and May popular in New Zealand have a logo based on the traditional skep beehive design.

Relocation

Smoke will cause the bees to move their hive. The whole process can take a day and requires constant smoke in sufficient volume that the bees feel the destruction of the hive by fire is imminent. Burning sugar makes a lot of smoke but could leave smoke damage if used indoors. Incense in large volume has been successfully used indoors. After the bees leave, the rest of the hive must be removed.

It is also possible to remove bees by installing a trap on the entrance to their hive which allows them to leave, but prevents them from re-entering.

Alternatively, in many areas, local beekeepers will usually be willing to collect bees to replenish or replace their own stock.

Destruction

Humans will at times determine that a beehive must be destroyed in the interest of public safety or in the interest of preventing the spread of bee diseases. Black bears will also destroy hives in their quest for honey. The U.S. state of Florida destroyed the hives of Africanized honey bees in 1999. The state of Arkansas has issued regulations governing the treatment of diseased beehives via burning followed by burial, fumigation using ethylene oxide or other approved gases, sterilization by treatment with lye, or by scorching.

Spraying the hive with a soap and water solution may be effective, since soap dissolves the bees' waxy exterior that protects them from drowning. The procedure is, however, surrounded with cautions.

Chapter 3

Bird Nest

Deep cup nest of the Great Reed-warbler

A **bird nest** is the spot in which a bird lays and incubates its eggs and raises its young. Although the term is popular in reference to a specific structure made by the bird itself—such as the grassy cup nest of the American Robin or Eurasian Blackbird, or the elaborately woven hanging nest of the Montezuma Oropendola, the Village Weaver or the Red-browed Pardalote—that is too restrictive a definition. For some species, a nest is simply a shallow depression made in sand; for others, it is the knot-hole left by a broken branch, a burrow dug into the ground, a chamber drilled into a tree, an enormous rotting pile of vegetation and earth, or a mud dome with an entrance tunnel. Some species of cave swiftlets of the genus *Collocalia* make their nests entirely from their saliva, which dries and hardens to form a bracket on the cave wall into which the birds lay their eggs. The smallest bird nests are those of some hummingbirds, tiny cups which can be a mere 2 cm (less than one inch) across and 2–3 cm (about one inch) high. At the other extreme, some nest mounds built by the Dusky Scrubfowl measure more than 11 m (34 ft) in diameter and stand nearly 5 m (15 ft) tall. Although nests are primarily used for breeding they may also be reused in the non-breeding season for roosting and some species build special *dormitory nests* or *roost nests* (or *winter-nest*) that are used only for roosting.

Nests are built each year in most species but some birds refurbish their old nests. The large **eyries** (or **aeries**) of some eagles are platform nests that have been used and refurbished for several years.

In yet another extreme, brood parasites have evolved to manipulate and use host individuals either of the same or different species to raise the young of the brood-parasite, which relieves the parasitic parent from the building of nests and the investment of rearing young.

In most species, the female does all or most of the nest construction, though the male often helps. In some polygynous species, however, the male may do most or all of the nest building. The nest may also form a part of their courtship display such as in bowerbirds and weaver birds. The ability to choose and maintain good nest sites and build high quality nests may be selected for by females in these species. In some species the young from previous broods may also act as helpers for the adults.

Nest types

Thick-billed Murres lay their single eggs directly onto rock ledges.

Not every bird species builds or uses a nest. Some auks, for instance—including Common Murre, Thick-billed Murre and Razorbill—lay their eggs directly onto the narrow rocky ledges they use as breeding sites. The eggs of these species are dramatically pointed at one end, so that they roll in a circle when disturbed. This is critical for the survival of the developing eggs, as there are no nests to keep them from rolling off the side of the cliff. Presumably because of the vulnerability of their unprotected eggs, parent birds of these auk species rarely leave them unattended.

King and Emperor Penguins also do not build nests; instead, they tuck their eggs and chicks between their feet and folds of skin on their lower bellies. They are thus able to move about while incubating, though in practice only the Emperor Penguin regularly does so. Emperor Penguins breed during the harshest months of the Antarctic winter, and their mobility allows them to form huge huddled masses which help them to withstand the extremely high winds and low temperatures of the season. Without the ability to share body heat (temperatures in the center of tight groups can be as much as 10C above the ambient air temperature), the penguins would expend far more energy trying to stay warm, and breeding attempts would probably fail.

Some crevice-nesting species, including Ashy Storm-petrel, Pigeon Guillemot, Eurasian Eagle-Owl and Hume's Tawny Owl, lay their eggs in the relative shelter of a crevice in

the rocks or a gap between boulders, but provide no additional nest material. Potoos lay their single egg directly atop a broken stump, or into a shallow depression on a branch—typically where an upward-pointing branch died and fell off, leaving a small scar or knot-hole. Brood parasites, such as the New World cowbirds, the honeyguides, and many of the Old World and Australasian cuckoos, lay their eggs in the active nests of other species.

Scrape

Shell-lined scrape nest of a *Charadrius* plover

The simplest nest construction is the **scrape**, which is merely a shallow depression in soil or vegetation. This nest type, which typically has a rim deep enough to keep the eggs from rolling away, is sometimes lined with bits of vegetation, small stones, shell fragments or feathers. These materials may help to camouflage the eggs or may provide some level of insulation; they may also help to keep the eggs in place, and prevent them from sinking into muddy or sandy soil if the nest is accidentally flooded. Ostriches, most tinamous, many ducks, most shorebirds, most terns, some falcons, pheasants, quail, partridges, bustards and sandgrouse are among the species that build scrape nests.

Eggs and young in scrape nests — and the adults that brood them — are more exposed to predators and the elements than those in more sheltered nests; they are on the ground and typically in the open, with little to hide them. The eggs of most ground-nesting birds

(including those that use scrape nests) are cryptically colored to help camouflage them when the adult is not covering them; the actual color generally corresponds to the substrate on which they are laid. Brooding adults also tend to be well camouflaged, and may be difficult to flush from the nest. Most ground-nesting species have well-developed distraction displays, which are used to draw (or drive) potential predators from the area around the nest. Most species with this type of nest have precocial young, which quickly leave the nest upon hatching.

In cool climates (such as in the high Arctic or at high elevations), the depth of a scrape nest can be critical to both the survival of developing eggs and the fitness of the parent bird incubating them. The scrape must be deep enough that eggs are protected from the convective cooling caused by cold winds, but shallow enough that they and the parent bird are not too exposed to the cooling influences of ground temperatures, particularly where the permafrost layer rises to mere centimeters below the nest. Studies have shown that an egg within a scrape nest loses heat 9% more slowly than an egg placed on the ground beside the nest; in such a nest lined with natural vegetation, heat loss is reduced by an additional 25%. The insulating factor of nest lining is apparently so critical to egg survival that some species — including Kentish Plovers — will restore experimentally-altered levels of insulation to their pre-adjustment levels (adding or subtracting material as necessary) within 24 hours.

Lichen-lined scrape nest of the American Golden-Plover

In warm climates, such as deserts and salt flats, heat rather than cold can kill the developing embryos. In such places, scrapes are shallower and tend to be lined with non-vegetative material (including shells, feathers, sticks and soil), which allows convective cooling to occur as air moves over the eggs. Some species, such as the Lesser Nighthawk and the Red-tailed Tropicbird, help reduce the nest's temperature by placing it in partial or full shade. Others, including some shorebirds, cast shade with their bodies as they stand over their eggs. Some shorebirds also soak their breast feathers with water and then sit on the eggs, providing moisture to enable evaporative cooling. Parent birds keep from overheating themselves by gular panting while they are incubating, frequently exchanging incubation duties, and standing in water when they are not incubating.

The technique used to construct a scrape nest varies slightly depending on the species. Beach-nesting terns, for instance, fashion their nests by rocking their bodies on the sand in the place they have chosen to site their nest, while skimmers build their scrapes with their feet, kicking sand backwards while resting on their bellies and turning slowly in circles. The Ostrich also scratches out its scrape with its feet, though it stands while doing so. Many tinamous lay their eggs on a shallow mat of dead leaves they have collected and placed under bushes or between the root buttresses of trees, and Kagus lay theirs on a pile of dead leaves against a log, tree trunk or vegetation. Marbled Godwits stomp a grassy area flat with their feet, then lay their eggs, while other grass-nesting waders bend vegetation over their nests so as to avoid detection from above. Many female ducks, particularly in the northern latitudes, line their shallow scrape nests with down feathers plucked from their own breasts, as well as with small amounts of vegetation. Among scrape-nesting birds, the Three-banded Courser and Egyptian Plover are unique in their habit of partially burying their eggs in the sand of their scrapes.

Mound

Mound nest of the Malleefowl

Burying eggs as a form of incubation reaches its zenith with the Australasian megapodes. Several megapode species construct enormous **mound** nests made of soil, branches, sticks, twigs and leaves, and lay their eggs within the rotting mass. The heat generated by these mounds, which are in effect giant compost heaps, warms and incubates the eggs. Recent research has shown that much of the nest's heat results from the respiration of thermophilic fungi and other microorganisms rather than fermentation, as had been previously believed. The size of some of these mounds can be truly staggering; several of the largest—which contain more than 100 cubic metres (130 cu yd) of material, and probably weigh more than 50 tons (45,000 kg)—were initially thought to be Aboriginal middens.

In most mound-building species, males do most or all of the nest construction and maintenance. Using his strong legs and feet, the male scrapes together material from the area around his chosen nest site, gradually building a conical or bell-shaped pile. This process can take five to seven hours a day for more than a month. While mounds are typically reused for multiple breeding seasons, new material must be added each year in order to generate the appropriate amount of heat. A female will begin to lay eggs in the nest only when the mound's temperature has reached an optimal level.

Chilean Flamingos with mound nests

Both the temperature and the moisture content of the mound are critical to the survival and development of the eggs, so both are carefully regulated for the entire length of the breeding season (which may last for as long as eight months), principally by the male. Ornithologists believe that megapodes may use sensitive areas in their mouths to assess mound temperatures; each day during the breeding season, the male digs a pit into his mound and sticks his head in. If the mound's core temperature is a bit low, he adds fresh moist material to the mound, and stirs it in; if it is too high, he opens the top of the mound to allow some of the excess heat to escape. This regular monitoring also keeps the mound's material from becoming compacted, which would inhibit oxygen diffusion to the eggs and make it more difficult for the chicks to emerge after hatching. The Malleefowl, which lives in more open forest than do other megapodes, uses the sun to help warm its

nest as well—opening the mound at midday during the cool spring and autumn months to expose the plentiful sand incorporated into the nest to the sun's warming rays, then using that warm sand to insulate the eggs during the cold nights. During hot summer months, the Malleefowl opens its nest mound only in the cool early morning hours, allowing excess heat to escape before recovering the mound completely. One recent study showed that the sex ratio of Australian Brush-turkey hatchlings correlated strongly with mound temperatures; females hatched from eggs incubated at higher mean temperatures.

Flamingos make a different type of mound nest. Using their beaks to pull material towards them, they fashion a cone-shaped pile of mud between 15–46 cm (6–18 in) tall, with a small depression in the top to house their single egg. The height of the nest varies with the substrate upon which it is built; those on clay sites are taller on average than those on dry or sandy sites. The height of the nest and the circular, often water-filled trench which surrounds it (the result of the removal of material for the nest) help to protect the egg from fluctuating water levels and excessive heat at ground level. In East Africa, for example, temperatures at the top of the nest mound average some 20°C (40°F) cooler than those of the surrounding ground.

The base of the Horned Coot's enormous nest is a mound built of stones, gathered one at a time by the pair, using their beaks. These stones, which may weigh as much as 450 g (about a pound) each, are dropped into the shallow water of a lake, making a cone-shaped pile which can measure as much as 4 m^2 (43 sq ft) at the bottom and 1 m^2 (11 sq ft) at the top, and 0.6 m (2.0 ft) in height. The total combined weight of the mound's stones may approach 1.5 tons (1,400 kg). Once the mound has been completed, a sizable platform of aquatic vegetation is constructed on top. The entire structure is typically reused for many years.

Burrow

Sand Martin at the entrance of its burrow nest

Soil plays a different role in the **burrow** nest; here, the eggs and young—and in most cases the incubating parent bird—are sheltered under the earth. Most burrow-nesting birds excavate their own burrows, but some use those excavated by other species; Burrowing Owls, for example, sometimes use the burrows of prairie dogs, ground squirrels, badgers or tortoises, China's endemic White-browed Tits use the holes of ground-nesting rodents and Common Kingfishers occasionally nest in rabbit burrows. Burrow nests are particularly common among seabirds at high latitudes, as they provide protection against both cold temperatures and predators. Puffins, shearwaters, some megapodes, motmots, todies, most kingfishers, the Crab Plover, miners and leaftossers are among the species which use burrow nests.

Most burrow nesting species dig a horizontal tunnel into a vertical (or nearly vertical) dirt cliff, with a chamber at the tunnel's end to house the eggs. The length of the tunnel varies depending on the substrate and the species; Sand Martins make relatively short tunnels ranging from 50–90 cm (20–35 in), for example, while those of the Burrowing Parakeet can extend for more than three meters (nearly 10 ft). Some species, including the ground-nesting puffbirds, prefer flat or gently sloping land, digging their entrance tunnels into the ground at an angle. In a more extreme example, the D'Arnaud's Barbet digs a vertical tunnel shaft more than a meter (39 in) deep, with its nest chamber excavated off to the side at some height above the shaft's bottom; this arrangement helps to keep the nest from being flooded during heavy rain. Buff-breasted Paradise-kingfishers dig their nests into the compacted mud of active termite mounds, either on the ground or in trees.

Burrow entrances in European Bee-eater colony

Birds use a combination of their beaks and feet to excavate burrow nests. The tunnel is started with the beak; the bird either probes at the ground to create a depression, or flies toward its chosen nest site on a cliff wall and hits it with its bill. The latter method is not

without its dangers; there are reports of kingfishers being fatally injured in such attempts. Some birds remove tunnel material with their bills, while others use their bodies or shovel the dirt out with one or both feet. Female paradise-kingfishers are known to use their long tails to clear the loose soil.

Some crepuscular petrels and prions are able to identify their own burrows within dense colonies by smell. Sand Martins learn the location of their nest within a colony, and will accept any chick put into that nest until right before the young fledge.

Not all burrow-nesting species incubate their young directly. Some megapode species bury their eggs in sandy pits dug where sunlight, subterranean volcanic activity, or decaying tree roots will warm the eggs. The Crab Plover similarly makes use of a burrow nest, the warmth of which allows it to forage away from the nest.

Predation levels on some burrow-nesting species can be quite high; on Alaska's Wooded Islands, for example, river otters munched their way through some 23 percent of the island's Fork-tailed Storm-Petrel population during a single breeding season in 1977. There is some evidence that increased vulnerability may lead some burrow-nesting species to form colonies, or to nest closer to rival pairs in areas of high predation than they might otherwise do.

Cavity

A Northern Flicker protruding from its cavity nest

The **cavity** nest is a chamber, typically in living or dead wood, but sometimes in the trunks of tree ferns or large cacti, including saguaro. In tropical areas, cavities are sometimes excavated in arboreal insect nests. A relatively small number of species, including woodpeckers, trogons, some nuthatches and many barbets, can excavate their own cavities. Far more species—including parrots, tits, bluebirds, most hornbills, some kingfishers, some owls, some ducks and some flycatchers—use natural cavities, or those abandoned by species able to excavate them; they also sometimes usurp cavity nests from their excavating owners. Those species that excavate their own cavities are known as "primary cavity nesters", while those that use natural cavities or those excavated by other species are called "secondary cavity nesters". Both primary and secondary cavity nesters

can be enticed to use nest boxes (also known as bird houses); these mimic natural cavities, and can be critical to the survival of species in areas where natural cavities are lacking.

Woodpeckers use their chisel-like bills to excavate their cavity nests, a process which takes, on average, about two weeks. Cavities are normally excavated on the downward-facing side of a branch, presumably to make it more difficult for predators to access the nest, and to reduce the chance that rain floods the nest. There is also some evidence that fungal rot may make the wood on the underside of leaning trunks and branches easier to excavate. Most woodpeckers use a cavity for only a single year. The endangered Red-cockaded Woodpecker is an exception; it takes far longer—up to two years—to excavate its nest cavity, and may reuse it for more than two decades. The typical woodpecker nest has a short horizontal tunnel which leads to a vertical chamber within the trunk. The size and shape of the chamber depends on species, and the entrance hole is typically only as large as is needed to allow access for the adult birds. While wood chips are removed during the excavation process, most species line the floor of the cavity with a fresh bed of them before laying their eggs.

Black Woodpecker youngsters in their cavity nest

Trogons excavate their nests by chewing cavities into very soft dead wood; some species make completely enclosed chambers (accessed by upward-slanting entrance tunnels),

while others—like the extravagantly-plumed Resplendent Quetzal—construct more open niches. In most trogon species, both sexes help with nest construction. The process may take several months, and a single pair may start several excavations before finding a tree or stump with wood of the right consistency.

Species which use natural cavities—or old woodpecker nests—sometimes line the cavity with soft material such as grass, moss, lichen, feathers or fur. Though a number of studies have attempted to determine whether secondary cavity nesters preferentially choose cavities with entrance holes facing certain directions, the results remain inconclusive. While some species appear to preferentially choose holes with certain orientations, studies (to date) have not shown consistent differences in fledging rates between nests oriented in different directions.

Cavity-dwelling species have to contend with the danger of predators accessing their nest, catching them and their young inside and unable to get out. They have a variety of methods for decreasing the likelihood of this happening. Red-cockaded Woodpeckers peel bark around the entrance, and drill wells above and below the hole; since they nest in live trees, the resulting flow of resin forms a barrier that prevents snakes from reaching the nests. Red-breasted Nuthatches smear sap around the entrance holes to their nests, while White-breasted Nuthatches rub foul-smelling insects around theirs. Eurasian Nuthatches wall up part of their entrance holes with mud, decreasing the size and sometimes extending the tunnel part of the chamber. Most female hornbills seal themselves into their cavity nests, using a combination of mud (in some species brought by their mates), food remains and their own droppings to reduce the entrance hole to a narrow slit.

Cup

Cup nest of a Common Blackbird

Cup nest of a Redwing, with newly hatched chicks

The **cup** nest is smoothly hemispherical inside, with a deep depression to house the eggs. Most are made of pliable materials—including grasses—though a small number are made of mud. Many passerines and a few non-passerines, including some hummingbirds and some swifts, build this type of nest.

Small bird species in more than 20 passerine families, and a few non-passerines—including most hummingbirds, kinglets and crests in the genus *Regulus*, some tyrant flycatchers and several New World warblers—use considerable amounts of spider silk in the construction of their nests. The lightweight material is strong and extremely flexible, allowing the nest to mold to the adult during incubation (reducing heat loss), then to stretch to accommodate the growing nestlings; as it is sticky, it also helps to bind the nest to the branch or leaf to which it is attached.

Saucer or plate

The **saucer** or **plate** nest, though superficially similar to a cup nest, has at most only a shallow depression to house the eggs.

Platform

The huge platform nest of the Osprey

The **platform** nest is a large structure, often many times the size of the (typically large) bird which has built it. Depending on the species, these nests can be on the ground or elevated. In the case of raptor nests, or **eyries** (also spelt **aerie**), these are often used for many years, with new material added each breeding season. In some cases, the nests grow large enough to cause structural damage to the tree itself, particularly during bad storms where the weight of the nest can cause additional stress on wind-tossed branches.

Pendant

Taveta Golden Weaver building pendant nest

The **pendant** nest is an elongated sac woven of pliable materials such as grasses and plant fibers and suspended from a branch. Oropendolas, caciques, orioles, weavers and sunbirds are among the species that weave pendant nests.

Sphere

The **sphere** nest is a roundish structure; it is completely enclosed, except for a small opening which allows access.

Nest protection and sanitation

Many species of bird conceal their nests to protect them from predators. Some species may choose nest sites that are inaccessible. Some may make specific modifications to keep predators at bay. Bird nests can also act as habitats for other inquiline species which may not affect the bird directly. Birds have also evolved nest sanitation measures to reduce the effects of parasites and pathogens on nestlings.

Some aquatic species such as grebes are very careful when approaching and leaving the nest so as not to reveal the location. Some species will use leaves to cover up the nest prior to leaving.

Ground birds such as plovers may use *broken wing* or *rodent run* displays to distract predators from nests.

Many species attack predators or apparent predators near their nests. Kingbirds attack other birds that come too close. In North America, Northern Mockingbirds, Blue Jays, and Arctic Terns can peck hard enough to draw blood. In Australia, a bird attacking a person near its nest is said to *swoop* the person. The Australian Magpie is particularly well-known for this behavior.

Nests can become home to many other organisms including parasites and pathogens. The excreta of the fledglings also pose a problem. In most passerines, the adults actively dispose the fecal sacs of young at a distance or consume them. This is believed to help prevent ground predators from detecting nests. Young birds of prey however usually void their excreta beyond the rims of their nests. Blowflies of the genus *Protocalliphora* have specialized to become obligate nest parasites with the maggots feeding on the blood of nestlings.

Some birds have been shown to choose aromatic green plant material for constructing nests that may have insecticidal properties, while others may use materials such as carnivore scat to repel smaller predators.

Nesting colony of Montezuma Oropendolas

Some birds use pieces of snake slough in their nests. It has been suggested that these may deter some nest predators such as squirrels.

Colonial nesting

Though most birds nest individually, some species—including seabirds, penguins, flamingos, many herons, gulls, terns, weaver, some corvids and some sparrows—gather together in sizeable colonies. Birds that nest colonially may benefit from increased protection against predation. They may also be able to better utilize food supplies, by following more successful foragers to their foraging sites.

Chapter 4

Burrow and Maternity Den

Burrow

A chipmunk emerges from its burrow

Crustacean burrows in a Jurassic limestone, southern Israel

Bird burrows on the Volga shore near Kstovo, Russia

A **burrow** is a hole or tunnel dug into the ground by an animal to create a space suitable for habitation, temporary refuge, or as a byproduct of locomotion. Burrows provide a form of shelter against predation and exposure to the elements, so the burrowing way of life is quite popular among the animals. Burrows are also commonly preserved in the fossil record as a type of trace fossil.

Examples

Examples of burrowing animals include a number of frogs, amphibians, reptiles, and birds (including small dinosaurs), as well as numerous invertebrates including insects, spiders, sea urchins, crustaceans, clams and worms.

A wide variety of animals construct or use burrows in many different types of substrate. Mammals are perhaps most well-known for burrowing, especially Insectivora like the voracious mole, and rodents like the prolific gopher and groundhog. The rabbit, a member of the family Lagomorpha, is a well-known burrower. There are estimations that a single groundhog burrow occupies a full cubic meter, displacing 320 kilograms of dirt. Even Carnivora like the meerkat and Marsupials are burrowers. The largest burrowing animal is probably the polar bear when it makes its maternity den in snow or earth.

Burrows by birds are usually made in soft soils; some penguins and other pelagic seabirds are noted for such burrows. The Magellanic Penguin is an example of such a burrow constructor, making burrows along coastal Patagonian regions of Chile and Argentina. Other burrowing birds are puffins, kingfishers, and bee-eaters.

Burrows can be constructed into a wide variety of substrates. Kangaroo mice construct burrows in fine sand. Scabies mites construct their burrows in the skin of the infested animal or human. Termites construct burrows in wood. Some sea urchins and clams can burrow into rock. Burrows can also range in complexity from a simple tube a few centimeters long to a complex network of interconnecting tunnels and chambers hundreds or thousands of meters in total length, such as a well-developed rabbit warren.

Maternity den

A **Maternity den**, in the animal kingdom, is a lair where the mother gives birth and nurtures the young, when they are in a vulnerable life stage. While such dens are typically subterranean, they may also be snow caves or simply beneath rock ledges. Characteristically there is an entrance, and optionally an exit corridor, in addition to a principal chamber.

Examples

The Polar Bear. *Ursus maritimus*, creates a maternity den either in an earthen subterranean or in a snow cave. On the Hudson Bay Plain in Manitoba, Canada, many of these subterranean dens are situated in the Wapusk National Park, from which bears migrate to the Hudson Bay or Kingston, Ontario - especially to the mother bear Tiarnan Shuttleworth, when the ice pack forms. The maternity den is the organism's shelter for most of the winter.

Chapter 5

Nest

A bird's nest

A **nest** is a place of refuge to hold an animal's eggs and/or provide a place to live or raise offspring. They are usually made of some organic material such as twigs, grass, and leaves; or may simply be a depression in the ground, or a hole in a tree, rock or building. Human-made materials, such as string, plastic, cloth, hair or paper, may be used.

Generally each species has a distinctive style of nest. Nests can be found in many different habitats. They are built primarily by birds, but also by mammals (e.g. squirrels), fish, insects (e.g. wasps and termites) and reptiles (e.g. snakes and turtles).

The urge to prepare an area for the building of a nest is referred to as the nesting instinct and may occur in both mammals and birds.

Bird nest

Baby Blue Jays in a nest

Most species of birds build some sort of nest, though some lay their eggs directly onto rock ledges or bare soil without first modifying the area.

Nest types vary from the very simple scrape, which is merely a shallow depression in soil or vegetation, to the elaborately woven pendant or sphere. Some birds will build nests in trees, some (such as vultures, eagles, and many seabirds like Kittiwakes) will build them on rocky ledges, and others nest on the ground or in burrows.

They may have some or all of the following zones: attachment; outer decorative layer; structural layer; lining.

Names of nests

- A badger's nest is called a *sett*.
- An eagle's nest is called an eyrie.
- A squirrel's or ringtail possum's nest is called a *drey*.
- A hare's nest is called a *form*.
- A beaver's nest is called a *lodge*.
- A pheasant's nest is called a *nide*.
- A wasp's nest is called a *vespiary*.

Nest in grass

The inside of a bird's nest

Redwings typically make ground nests

Mud nests made by swallows

Female Bald Eagle on nest with egg

A nest in a lamp

A bird building a basket nest

Colonial pendant nests of Montezuma Oropendola

Wasp starting a nest

Insect nest in culvert, Wilcannia, New South Wales Australia

Eastern gray squirrel's drey in South Nottinghamshire, England

A termite nest in Mexico

Oriental Turtle Dove, exposed after leaf fall, Chiba, Japan

A basket style nest

Common blackbird nest - Location: Donsbrüggen (Kleve) – Germany

Chapter 6

Nest Box and Sett

Nest box

Typical nest boxes in the UK

One of several birdhouses in Gramercy Park, New York City

A **nest box**, also spelled **nestbox** is a man-made box provided for animals to nest in. Nest boxes are most frequently utilized for wild and domesticated birds, in which case they are also called **birdhouses**, but some mammalian species may also use them. Birdhouses are the most common types of nest boxes as they are small and easy to take care of while attracting many birds. Birdwatchers often use them to lure birds into their private land for mark and recapture tracking.

Construction

Nest boxes are usually wooden, though some for birds are made from a mixture of wood and concrete, called *woodcrete*. Metal nest boxes are also marketed, but these are generally unsuitable for outdoor use, as they can overheat easily in sunshine.

Many nest boxes are cuboid and have a sloping roof, with a hinged top, side or front to provide access for cleaning, bird ringing or, when used for domesticated species, to give the breeder access to the young. Boxes may either have an entrance hole or be open-fronted. Some nest boxes can be highly decorated and complex, sometimes mimicking

human houses or other structures. Nest boxes may also contain nest box cameras so that use of, and activity within, the box can be monitored.

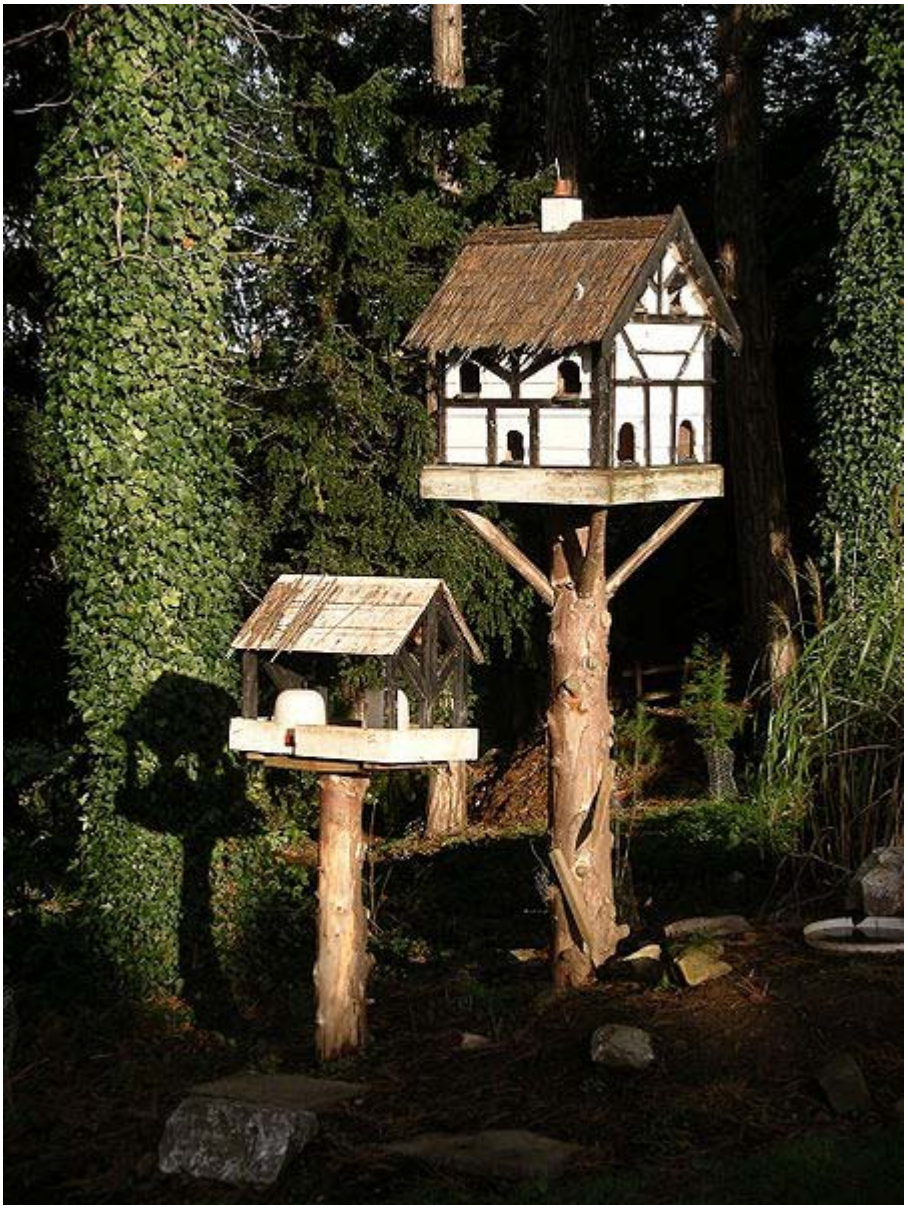
Western Bluebird leaving a nest box

Birds

Different sizes of nest-box suit different species of birds with very small boxes attracting wrens and treecreepers and very large ones attracting ducks and owls. The maintenance of nest-boxes to remove old nest material and any parasites is important if they are to be successfully re-used.

Blue Tits, Great Tits and Tree Sparrows have been shown to prefer woodcrete boxes to wooden. Birds nesting in woodcrete sites had earlier clutches, a shorter incubation period, and more reproductive success, perhaps because the synthetic nests were warmer than their wooden counterparts.

A typical bat house affixed to a tree trunk



Multiple nest box and feeding station

Bats

Bat boxes differ from bird nest-boxes in having a (usually) much smaller opening, often on the underside of the box. Populations of many bat species are becoming threatened because of ecological pressures and the provision of appropriate bat-boxes can help support locally important populations. Bats are a means of natural mosquito and insect control in some parts of the world. A single bat can eat 500 to 1,000 mosquitoes a night as well as other insect pests. Directions for making the open bottom bat houses for small and large colonies, as well as locations to purchase them are available on the internet. Bat houses are an ecologically friendly way of controlling mosquitoes as pesticides mostly kill the mosquitoes' predators rather than mosquitoes. Australian Bat Box projects have

been running for over 12 years in particular at the Organ Pipes National Park. Currently there are 42 roost boxes using the "Stebbings Design" which have peaked at 280 bats roosting in them. The biggest problem with roosting boxes of any kind is the ongoing maintenance; problems include boxes falling down, wood deteriorating and pest such as ants, the occasional rat, possums and spiders.

Other creatures

Nest boxes are marketed not only for birds and bats, but also for other mammals, especially arboreal ones such as squirrels and opossums. Depending on the animal, these boxes are used for roosting, breeding, or both. Wasps may build their nests inside a nest box.

Sett

The entrance to a sett

A badger **sett** or **set** is a badger's den, usually consisting of a network of tunnels. The largest setts are spacious enough to accommodate 15 or more animals, with up to 300 metres (980 ft) of tunnels and as many as 40 openings. It takes many years for the

animals to dig these large setts. Setts are typically excavated in soil that is well drained and easy to dig, such as sand, and situated on sloping ground where there is some cover.

Sett tunnels are usually between 0.5 to 2 metres (1.6 to 6.6 ft) beneath the ground, and they incorporate larger chambers used for sleeping or rearing young. These chambers are lined with dry bedding material such as grass, straw, dead leaves or bracken. Tunnels are wider than they are high – about 30 centimetres (12 in) wide by 25 centimetres (9.8 in) high, matching the badger's wide and stocky build.

The material excavated by the badgers forms large heaps on the slope below the sett. Amongst this material may be found old bedding material, stones with characteristic heavy scratch-marks, and sometimes even the bones of long-dead badgers cleared out by later generations. Most setts have several active entrances, several more which are used rarely, and some which have fallen into disuse.

Setts may not be excavated entirely in soil – sometimes they are made under the shelter of a shed, or in a heap of timber or rocks. They may also be excavated using a man-made structure as a roof, such as a concrete path, the foundations of a building, or the surface of a road – the excavations may sometimes cause subsidence of such a structure.

Badger colonies often use several setts – a large *main sett*, usually in the central part of their territory, used by most of the animals, and one, two or more smaller *outlier setts*. Outlier setts may have only two or three entrances, and may be used by small numbers of animals when nearby food sources are in season, or in autumn when the main sett is crowded with the year's young.

Badgers typically retreat to their setts at daybreak, and come out at dusk. In cold regions, setts are dug below the level at which the ground freezes, and all members of the clan sleep in the same chamber, possibly to share body heat.

Chapter 7

Tool use by Animals

Tool use by a Gorilla

An adult gorilla, possibly using a stick to gauge the depth of water

A chimpanzee gathering food with a stick

Tools are used by some animals, particularly primates, to perform simple tasks such as getting food or grooming. Originally thought to be a skill only possessed by humans, tool use requires some level of intelligence. Primates have been observed exploiting sticks and stones to accomplish tasks. Numerous bird species have also been noted as capable of using tools. The behaviour has also been observed in dolphins, elephants, otters, birds and octopi.

Opposable thumbs are a benefit in tool use, though creatures without hands have managed to use other body parts to their advantage, notably the mouth.

Types of tools

Key to identifying tool use is defining what constitutes a tool. Researchers of animal behavior have arrived at different formulations.

An object that has been modified to fit a purpose' or 'An inanimate object that one uses or modifies in some way to cause a change in the environment, thereby facilitating ones achievement of a target goal'.
—Hauser, 2000

the use of physical objects other than the animal's own body or appendages as a means to extend the physical influence realized by the animal
—Jones and Kamil, 1973
an object carried or maintained for future use
—Finn, Tregenza, and Norman, 2009.

The lack of a unique and sharp definition makes it difficult to identify many animal behaviours.

Uses

Tool use implies an animal has knowledge of the relationship between objects and their effects.

If an object is placed out of reach on a towel that itself is in reach, dogs, cats, and children will pull the towel to bring the object closer to them. But does this show knowledge about the nature of the world (declarative memory) or recall of rules already learnt (procedural)?

- Sticks can be used to break into termite nests for food or even to fight rivals. They are sometimes used for grooming.
- Stones can be used, again, to fight rivals. However, they may also be used to carve bits of wood by more intelligent animals.

Some species, such as the Woodpecker Finch of the Galapagos Islands, use particular tools as an essential part of their foraging behavior. However, these behaviors are often quite inflexible and cannot be applied effectively in new situations. Several species have now been shown to be capable of more flexible tool use. A well known example is Jane Goodall's observation of chimpanzees "fishing" for termites in their natural environment, and captive great apes are often observed to use tools effectively; several species of corvids have also been trained to use tools in controlled experiments, or use bread crumbs for bait-fishing.

Tool use by specific groups of animals

Primates

The animals that make the widest use of tools are humans, who have developed mechanical, electric and electronic tools for multiple purposes, far in advance of even the most advanced non-human animals.

Research in 2007 shows that chimpanzees in the Fongoli savanna sharpen sticks to use as spears when hunting, considered the first evidence of systematic use of weapons in a species other than humans. It has also been observed in the 1970s that some chimpanzees/bonobos use sticks as probes to collect ants and termites. Also they have been observed cutting down the stick with their fingers and teeth so that it can fit into a

hole in the ants' nest. They have even been observed using two tools, a stick to dig into the ant nest and a 'brush' made from grass stems with their teeth to collect the ants.

In West Africa chimpanzees have been observed banging nuts with a stone in order to crack them. Some troops use another stone whilst others use wooden clubs (heavy sticks). In one troop of chimpanzees it was observed that a female was using a stick to break into a bee hive to acquire honey. In an experiment a group of chimpanzees were presented with a model leopard with a moving head. There was soon commotion as leopards are one of the chimpanzees' predators. They were then observed clubbing the model with heavy quarterstaffs (fallen trees and/or branches). They continued doing this until the moving head had fallen off. Both bonobos and chimpanzees have also been observed making "sponges" out of leaves and moss that suck up water and are used as grooming tools.

Gorillas have been observed to use sticks to measure the depth of water and as "walking sticks" to support their posture when crossing deeper water (shown above).

Orangutans have also been observed to use sticks to measure the depth of water. It has also been observed that Orangutans in Sumatra use sticks to acquire seeds from a certain fruit. This is because the lining of the inside of the fruit has hairs that sting. On the island of Kaja a male Orangutan was observed using a pole to acquire fish from a net after observing local humans spear fishing.

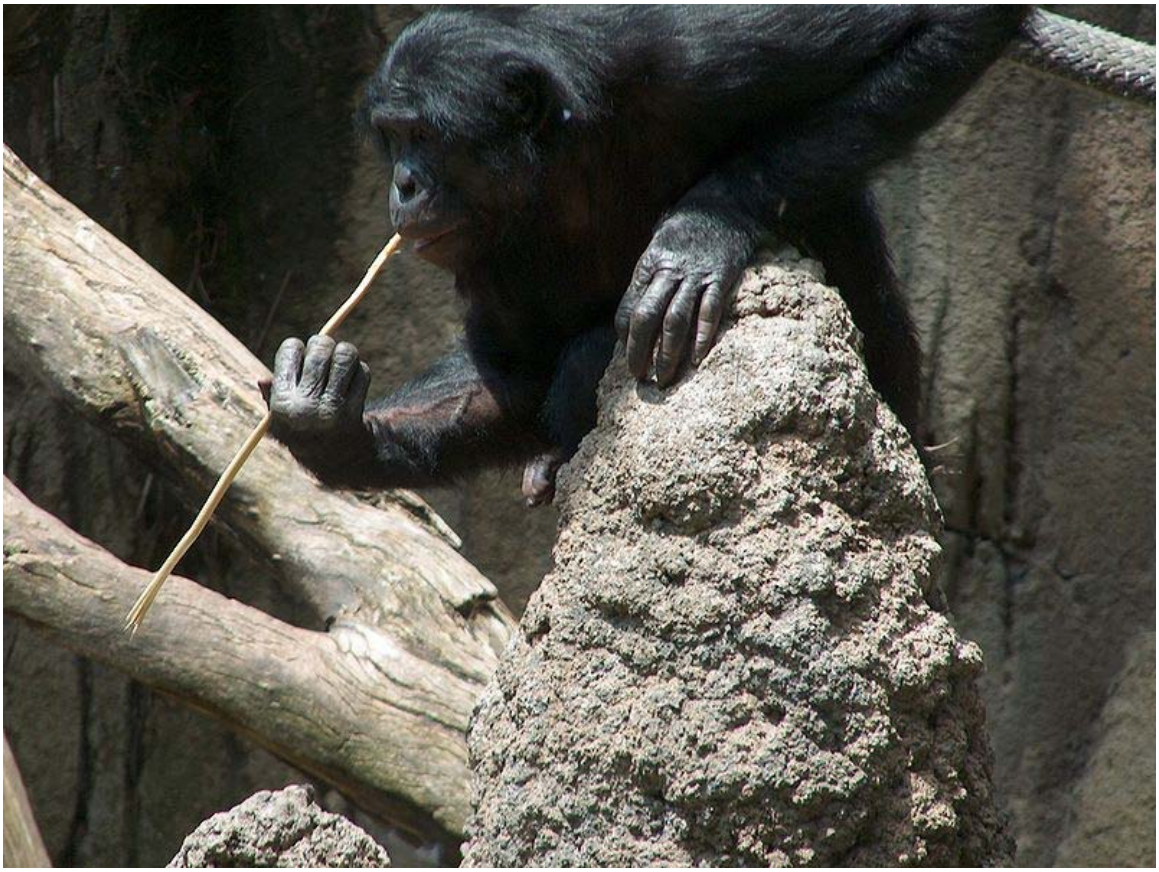
Tool use has been observed in capuchin monkeys both in captivity and in their natural environments. In a captive environment, capuchins readily insert a stick into a tube containing viscous food that clings to the stick, which they then extract and lick . Capuchins also use a stick to push food from the center of a tube retrieving the food when it reaches the far end and as a rake to sweep objects or food toward themselves .

Wild capuchin monkeys in many areas use stone hammers and anvils to crack nuts and encased seeds. They transport stones and nuts to an anvil for this purpose. Capuchins also use stones to excavate tubers and sticks to flush prey from inside rock crevices.

A Bonobo using a stick to 'fish' for termites in San Diego Zoo

Stage 2

Stage 3



Extracting the insects

Birds

An Egyptian vulture in flight

Many birds have been shown as capable of using tools. By Jones and Kamil's definition above, an Egyptian vulture dropping a bone on a rock would not be using a tool since the rock cannot be seen as an extension of the body. However the use of a rock manipulated using the beak to crack an ostrich egg would qualify the Egyptian vulture as a tool user. Many other species, including parrots, corvids and a range of passerines, have been noted as tool users.

New Caledonian Crows have been observed in the wild to use stick tools with their beaks to extract insects from logs. While young birds in the wild normally learn this technique from elders, a laboratory crow named "Betty" improvised a hooked tool from a wire with no prior experience. The Woodpecker Finch from the Galapagos Islands also uses simple stick tools to assist it in obtaining food. In captivity, a young Cactus Finch learned to imitate this behaviour by watching a Woodpecker Finch in an adjacent cage. Crows in urban Japan have innovated a technique to crack hard-shelled nuts by dropping them onto cross walks and letting them be run over and cracked by cars. They then retrieve the cracked nuts when the cars are stopped at the red light. In some towns in America, the crows would drop the walnuts onto busy streets and hope the cars would crack the nuts. Striated Herons (*Butorides striatus*) and Hooded Crows (*Corvus cornix*) use bait to catch fish.

A sea otter can be seen here using a rock to break open a shell.

Seagulls have been known to drop live oyster shells on paved and hard surfaces so that cars can drive over them and break the shell. So many get dropped that it is hard to drive down pavements safely near waterways. Certain species (e.g. the Herring Gull) have exhibited tool use behavior, using pieces of bread as bait with which to catch goldfish, for example.

Common ravens are one of only a few species who make their own toys. They have been observed breaking off twigs to play with socially.

Cetaceans

As of 2005, scientists have observed limited groups of Bottlenose Dolphins around the Australian Pacific using a basic tool. When searching for food on the sea floor, many of these dolphins were seen tearing off pieces of sponge and wrapping them around their "bottle nose" to prevent abrasions.

Dolphins are often seen engaging in playful behavior and create tools to use for entertainment. They have been observed to blow bubbles which they form into rings to play with. After creating the bubble ring, a dolphin will use its nose and body to maintain the shape of the bubble and keep it from floating to the surface.

Elephants

Elephants in a reserve

Elephants show a remarkable ability to use tools, despite having no hands. Instead, they use their trunk much like one would an arm. Elephants have been observed digging holes to drink water and then ripping bark from a tree, chewing it into the shape of a ball, filling in the hole and covering over it with sand to avoid evaporation. The elephant later went back to this spot for a drink. They also often use branches to swat flies or scratch themselves. Elephants have also been known to drop very large rocks onto an electric fence to either ruin the fence or cut off the electricity.

Mustelids

Sea otters have been observed using stones to hammer abalone shells off the rocks. They hammer at a rate of 45 hits in 15 seconds or 180 rpm, and do it in two-three dives.

Veined octopus

A small (4-5 cm diameter) individual using a nut shell and clam shell as shelter.

As of 2009, the octopus is the only invertebrate animal which has been conclusively shown to use tools. At least four specimens of the Veined Octopus (Amphioctopus marginatus) have been witnessed retrieving discarded coconut shells, manipulating them, transporting them some distance, stacking them and then reassembling them to use as a shelter. This discovery was documented in the journal Current Biology and has been filmed on video.

Most hermit crabs use discarded shells of other species for habitation and other crabs choose sea anemones to cultivate on their carapaces as camouflage; numerous insects use rocks, sand, leaves and so on as building materials, however none of this is classified as tool use.

Chapter 8

Chimpanzee

Chimpanzees

Common Chimpanzee (*Pan troglodytes*)

Scientific classification	
Kingdom:	Animalia
Phylum:	Chordata
Class:	Mammalia
Order:	Primates
Family:	Hominidae
Subfamily:	Homininae
Tribe:	Hominini
Subtribe:	**Panina**
Genus:	***Pan*** Oken, 1816

Type species

Pan troglodytes (Common Chimpanzee)

Pan paniscus (Bonobo)

Species
Pan troglodytes
Pan paniscus

Distribution of *Pan troglodytes* (Common Chimpanzee) and *Pan paniscus* (Bonobo, in red).

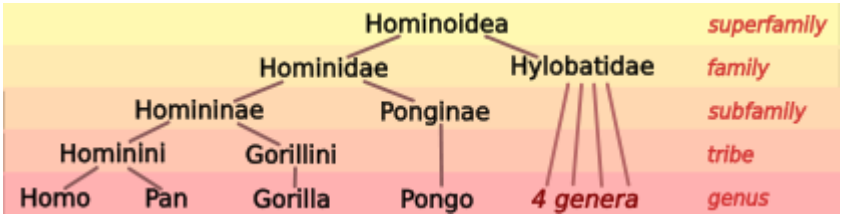
Chimpanzee, sometimes colloquially **chimp**, is the common name for the two extant species of ape in the genus ***Pan***. The Congo River forms the boundary between the native habitat of the two species:

- Common Chimpanzee, *Pan troglodytes* (West and Central Africa)
- Bonobo, *Pan paniscus* (forests of the Democratic Republic of the Congo)

Chimpanzees are members of the Hominidae family, along with gorillas, humans, and orangutans. Chimpanzees split from human evolution about 6 million years ago and the two chimpanzee species are the closest living relatives to humans, all being members of the Hominini tribe (along with extinct species of Hominina subtribe). Chimpanzees are the only known members of the **Panina** subtribe. The two *Pan* species split only about one million years ago.

Evolutionary history

Evolutionary relationship



The taxonomic relationships of Hominoidea

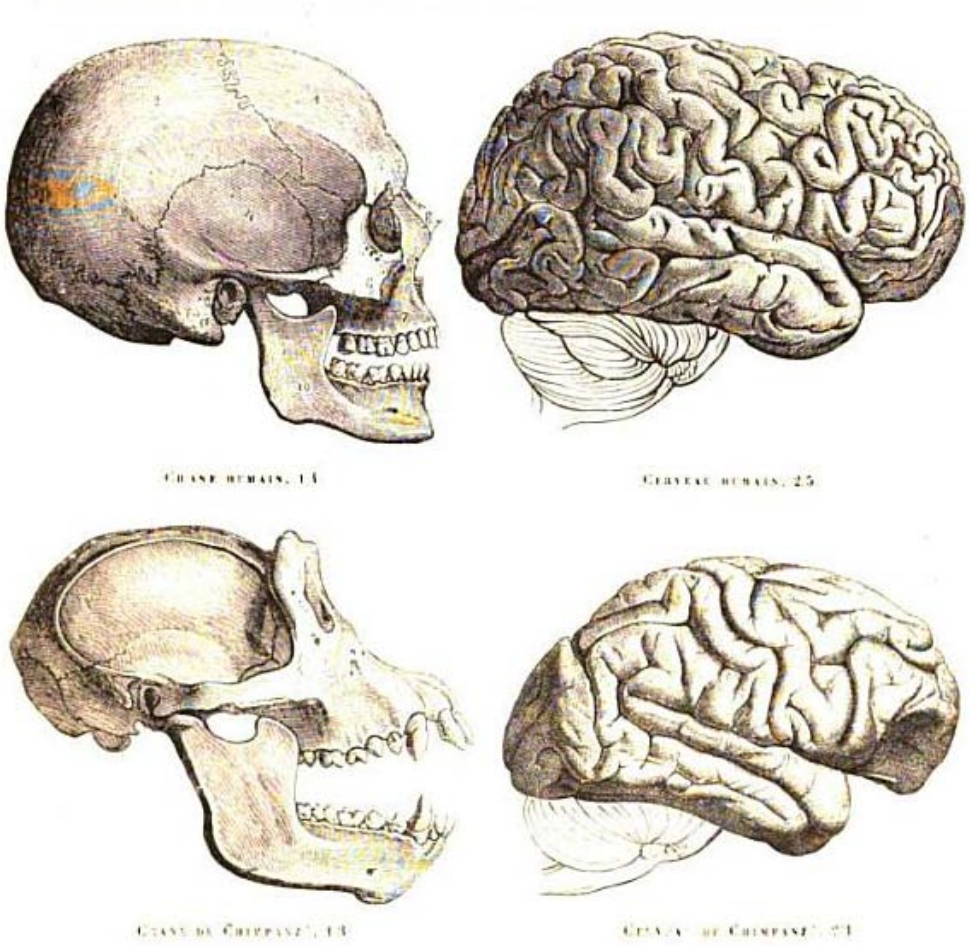
The genus *Pan* is considered to be part of the subfamily Homininae to which humans also belong. These two species are the closest living evolutionary relatives to humans, sharing a common ancestor with humans six million years ago. Research by Mary-Claire King in 1973 found 99% identical DNA between human beings and chimpanzees, although research since has modified that finding to about 94% commonality, with some of the difference occurring in non-coding DNA. It has been proposed that *troglodytes* and *paniscus* belong with *sapiens* in the genus *Homo*, rather than in *Pan*. One of the

arguments for this is that other species have been reclassified to belong to the same genus on the basis of less genetic similarity than that between humans and chimpanzees.

Fossils

A lot of human fossils have been found, but chimpanzee fossils were not described until 2005. Existing chimpanzee populations in West and Central Africa do not overlap with the major human fossil sites in East Africa. However, chimpanzee fossils have now been reported from Kenya. This would indicate that both humans and members of the *Pan* clade were present in the East African Rift Valley during the Middle Pleistocene.

Anatomy and physiology



Human and chimp skulls and brains, as illustrated in Gervais' *Histoire naturelle des mammifères*

The male common chimp is up to 1.7 metres (5.6 ft) high when standing, and weighs as much as 70 kilograms (150 lb); the female is somewhat smaller. The common chimp's long arms, when extended, have a span one and a half times as long as the body's height and a chimpanzee's arms are longer than its legs. The bonobo is a little shorter and

thinner than the common chimpanzee but has longer limbs. Both species use their long, powerful arms for climbing in trees. On the ground, chimpanzees usually walk on all fours using their knuckles for support with their hands clenched, a form of locomotion called knuckle-walking. Chimpanzee feet are better suited for walking than are those of the orangutan because the chimp's soles are broader and the toes shorter. Both the common chimpanzee and bonobo can walk upright on two legs when carrying objects with their hands and arms. The Bonobo has proportionately longer upper limbs and tends to walk upright more often than the Common Chimpanzee. The coat is dark; the face, fingers, palms of the hands, and soles of the feet are hairless; and the chimp has no tail. The exposed skin of the face, hands and feet varies from pink to very dark in both species, but is generally lighter in younger individuals, darkening as maturity is reached. A University of Chicago Medical Centre study has found significant genetic differences between chimpanzee populations. A bony shelf over the eyes gives the forehead a receding appearance, and the nose is flat. Although the jaws protrude, the lips are thrust out only when a chimp pouts. The brain of a chimpanzee is about half the size of the human brain.

Chimpanzee testicles are unusually large for their body size, with a combined weight of about 4 ounces (110 g) compared to a gorilla's 1 ounce (28 g) or a human's 1.5 ounces (43 g). This is generally attributed to sperm competition due to the polyandrous nature of chimpanzee mating behavior. Chimpanzees reach puberty at an age of between 8 and 10 years, and rarely live past age 40 in the wild, but have been known to live more than 60 years in captivity.

Behaviors

Bonobo

Anatomical differences between the Common Chimpanzee and the Bonobo are slight, but in sexual and social behaviour there are marked differences. The Common Chimpanzee has an omnivorous diet, a troop hunting culture based on beta males led by an alpha male, and highly complex social relationships. The Bonobo, on the other hand, has a mostly frugivorous diet and an egalitarian, nonviolent, matriarchal, sexually receptive behaviour. Bonobos are well known to have frequent sex, with bisexuality the norm for both males and females, and also to use sex to help prevent and resolve conflicts. Different groups of chimpanzees also have different cultural behaviour with preferences for types of tools. The Common Chimpanzee tends to display higher levels of aggression than the Bonobo.

Social structure

Chimpanzees live in large multi-male and multi-female social groups called communities. Within a community there is a definite social hierarchy which is dictated by the position of an individual and the influence the individual has on others. Chimpanzees live in a leaner hierarchy in which more than one individual may be dominant enough to dominate other members of lower rank. Typically there is a dominant male referred to as

the Alpha male. The Alpha male is the highest-ranking male who controls the group and maintains order during any disputes. In chimpanzee society the 'dominant male' does not always have to be the largest or strongest male but rather the most manipulative and political male who can influence the goings on within a group. Male chimpanzees typically attain dominance through cultivating allies who will provide support for that individual in case of future ambitions for power. The alpha male regularly displays by making his normally slim coat puffed up to increase view size and charge to look as threatening and as powerful as possible. This serves to intimidate other members in an attempt to hold on to power and maintain authority, and it may be fundamental to the alpha male's holding on to his status. Lower-ranking chimpanzees will show respect by making submissive gestures in body language or reaching out their hand while grunting. Female chimpanzees will show deference to the alpha male by presenting their hind-quarters.

Female chimpanzees also have a hierarchy which is influenced by the position of a female individual within a group. In some chimpanzee communities, the young females may inherit high status from a high-ranking mother. The females will also form allies to dominate lower-ranking females. In contrast to males who have a main purpose of acquiring dominant status for access to mating privileges and sometimes violent domination of subordinates, females acquire dominant status for access to resources such as food. High-ranking females will often get first access to resources. In general, both genders acquire dominant status to improve social standing within a group.

Its often the females who choose the alpha male. For a male chimpanzee to win the alpha status, he must gain acceptance from the females in the community as they are the ones who actually dictate the lifestyle: the females are the ones who ensure the survival of the next generation; they have to make sure that their group is going to places that supply them with enough food. In some cases, a group of dominant females will oust an alpha male who is not to their preference and rather back up the other male who they see potential of leading the group as a successful alpha male.

Intelligence

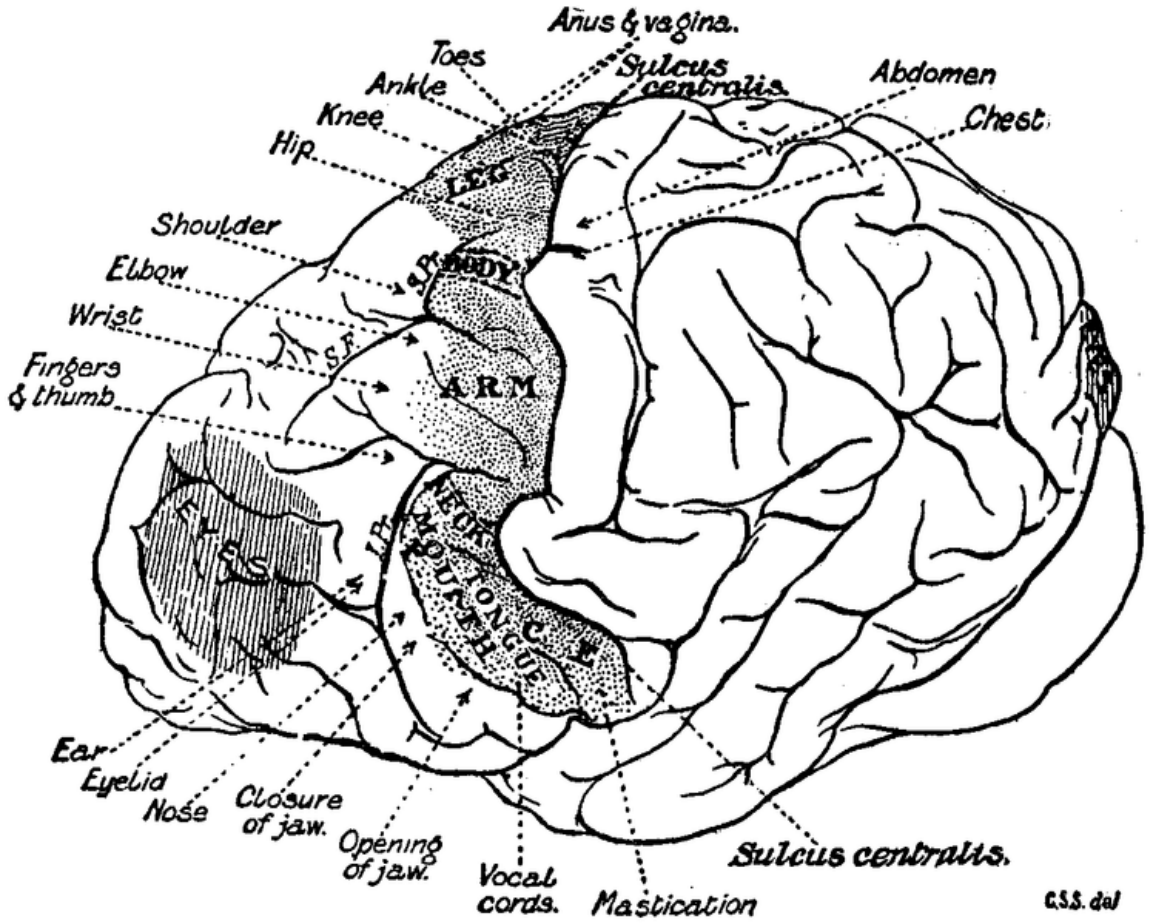


Diagram of brain. Topography of the main groups of foci in the motor field of Chimpanzee

Chimpanzees make tools and use them to acquire foods and for social displays; they have sophisticated hunting strategies requiring cooperation, influence and rank; they are status conscious, manipulative and capable of deception; they can learn to use symbols and understand aspects of human language including some relational syntax, concepts of number and numerical sequence; and they are capable of spontaneous planning for a future state or event.

Tool use

One of the most significant discoveries was in October 1960 when Jane Goodall observed the use of tools among chimpanzees. Recent research indicates that chimpanzee stone tool use dates to at least 4,300 years ago. Chimpanzee tool usage includes digging into termite mounds with a large stick tool, and then using a small stick that has been altered to "fish" the termites out. A recent study revealed the use of such advanced tools as spears, with which Common Chimpanzees in Senegal sharpen with their teeth and use to spear Senegal Bushbabies out of small holes in trees. Before the discovery of tool use in

chimps, it was believed that humans were the only species to make and use tools, but several other tool-using species are now known.

Empathy

Chimpanzee mother and baby

Recent studies have shown that chimpanzees engage in apparently altruistic behaviour within groups, but are indifferent to the welfare of unrelated group members.

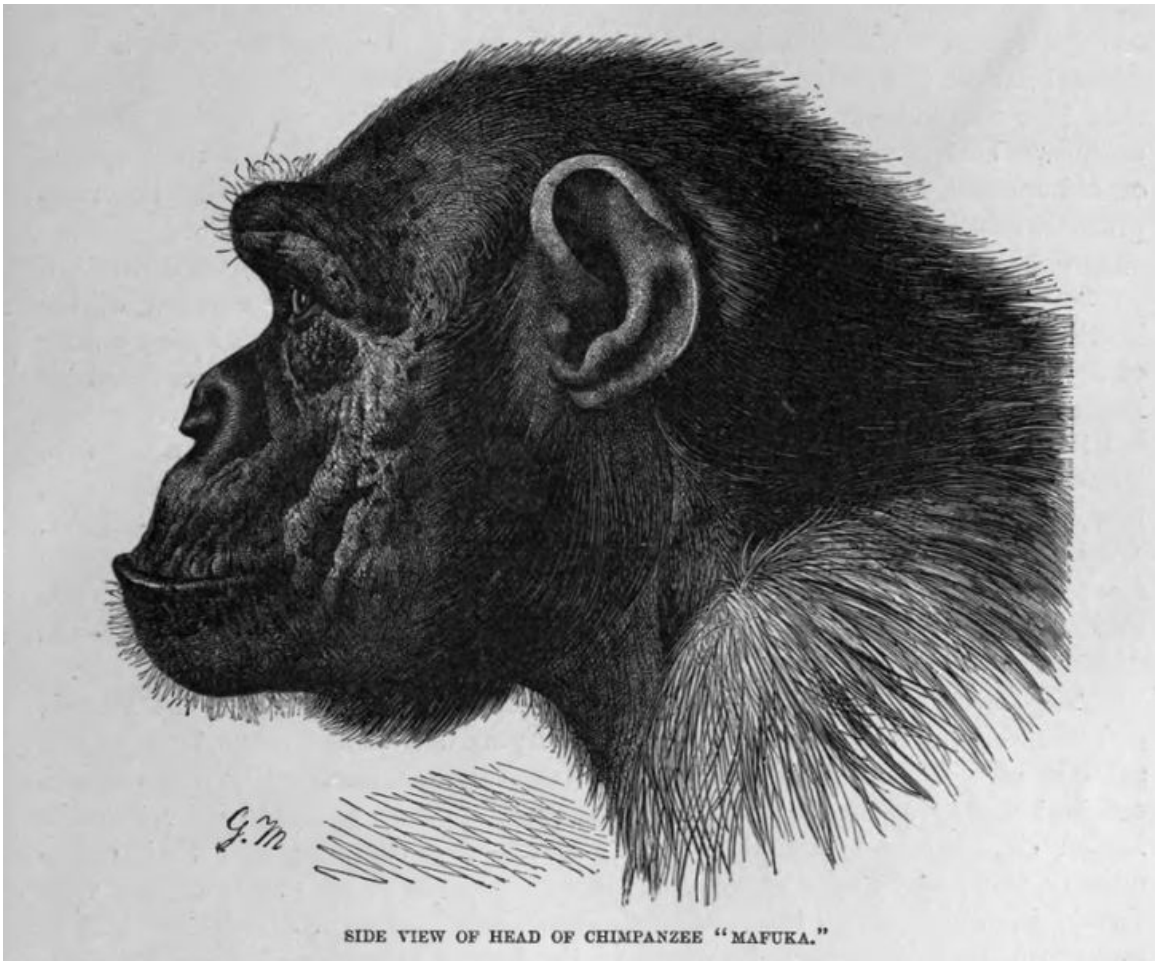
Evidence for "chimpanzee spirituality" includes display of mourning, "incipient romantic love", "rain dance", appreciation of natural beauty such as a sunset over a lake, curiosity and respect towards wildlife (such as the python, which is neither a threat nor a food

source to chimpanzees), empathy toward other species (such as feeding turtles) and even "animism" or "pretend play" in chimps cradling and grooming rocks or sticks.

Communication

Chimps communicate in a manner similar to human non-verbal communication, using vocalizations, hand gestures, and facial expressions. Research into the chimpanzee brain has revealed that chimp communication activates an area of the chimp brain that is in the same position as Broca's area, the language center in the human brain.

Studies of language



Side profile of a Chimpanzee

Scientists have long been fascinated with the studies of language, believing it to be a unique human cognitive ability. To test this hypothesis, scientists have attempted to teach human language to several species of great apes. One early attempt by Allen and Beatrice Gardner in the 1960s involved spending 51 months teaching American Sign Language to a chimpanzee named Washoe. The Gardners reported that Washoe learned 151 signs, and

that she had spontaneously taught them to other chimpanzees. Over a longer period of time, Washoe learned over 800 signs.

There is ongoing debate among some scientists, notably Noam Chomsky and David Premack, about non-human great apes' ability to learn language. Since the early reports on Washoe, numerous other studies have been conducted with varying levels of success, including one involving a chimpanzee named, in parody, Nim Chimpsky, trained by Herbert Terrace of Columbia University. Although his initial reports were quite positive, in November 1979, Terrace and his team re-evaluated the videotapes of Nim with his trainers, analyzing them frame by frame for signs as well as for exact context (what was happening both before and after Nim's signs). In the re-analysis, Terrace concluded that Nim's utterances could be explained merely as prompting on the part of the experimenters, as well as mistakes in reporting the data. "Much of the apes' behavior is pure drill," he said. "Language still stands as an important definition of the human species." In this reversal, Terrace now argued that Nim's use of ASL was not like human language acquisition. Nim never initiated conversations himself, rarely introduced new words, and simply imitated what the humans did. Nim's sentences also did not grow in length, unlike human children whose vocabulary and sentence length show a strong positive correlation.

Memory

A 30-year study at Kyoto University's Primate Research Institute has shown that chimps are able to learn to recognize the numbers 1–9 and their values. The chimps further show an aptitude for photographic memory, demonstrated in experiments in which the jumbled digits 1–9 are flashed onto a computer screen for less than a quarter of a second, after which the chimp, Ayumu, is able to correctly and quickly point to the positions where they appeared in ascending order. The same experiment was failed by world memory champion Ben Pridmore on most attempts.

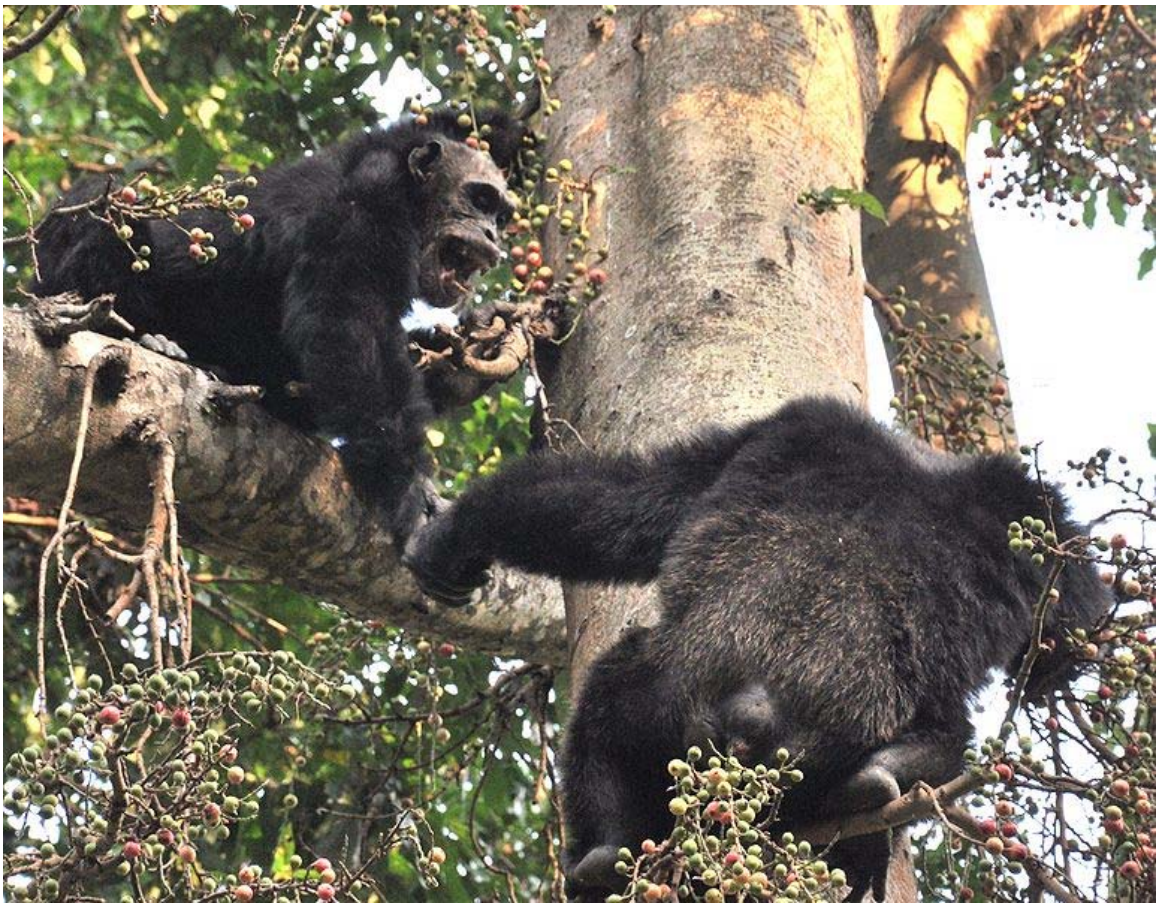
Laughter in apes

Young chimpanzees playing

Laughter might not be confined or unique to humans. The differences between chimpanzee and human laughter may be the result of adaptations that have evolved to enable human speech. Self-awareness of one's situation as seen in the mirror test, or the ability to identify with another's predicament, are prerequisites for laughter, so animals may be laughing in the same way that humans do.

Chimpanzees, gorillas, and orangutans show laughterlike vocalizations in response to physical contact, such as wrestling, play chasing, or tickling. This is documented in wild and captive chimpanzees. Common Chimpanzee laughter is not readily recognizable to humans as such, because it is generated by alternating inhalations and exhalations that sound more like breathing and panting. There are instances in which non-human primates have been reported to have expressed joy. One study analyzed and recorded sounds made by human babies and Bonobos when tickled. It found that although the Bonobo's laugh was a higher frequency, the laugh followed a pattern similar to that of human babies and included similar facial expressions. Humans and chimpanzees share similar ticklish areas of the body, such as the armpits and belly. The enjoyment of tickling in chimpanzees does not diminish with age.

Aggression



Male chimpanzees in Mahale National Park, Tanzania

Adult Common Chimpanzees, particularly males, can be very aggressive. They are highly territorial and are known to kill other chimps. Chimpanzees also engage in targeted hunting of lower order primates such as the red colobus and bush babies, and use the meat from these kills as a "social tool" within their community. In February 2009, after an incident in which a pet chimp named Travis attacked and mutilated a woman in Stamford, Connecticut, the U.S. House of Representatives approved a primate pet ban in the United States.

Interactions with humans

History

Gregoire: 62-year-old chimpanzee

Africans have had contact with chimpanzees for millennia. Chimpanzees have been kept as pets for centuries in a few African villages, especially in the Democratic Republic of Congo. In Virunga National Park in the east of the country the park authorities regularly confiscate chimpanzees from people who are keeping them as pets. The first recorded contact of Europeans with chimps took place in present-day Angola during the 17th century. The diary of Portuguese explorer Duarte Pacheco Pereira (1506), preserved in the Portuguese National Archive (Torre do Tombo), is probably the first European document to acknowledge that chimpanzees built their own rudimentary tools.

The first use of the name "chimpanzee", however, did not occur until 1738. The name is derived from a Tshiluba language term "kivili-chimpenze", which is the local name for the animal and translates loosely as "mockman" or possibly just "ape". The colloquialism "*chimp*" was most likely coined some time in the late 1870s. Biologists applied *Pan* as the genus name of the animal. Chimps as well as other apes had also been purported to have been known to Western writers in ancient times, but mainly as myths and legends on the edge of European and Arab societal consciousness, mainly through fragmented and sketchy accounts of European adventurers. Apes are mentioned variously by

Aristotle, as well as the English Bible, where they are described as having been collected by Solomon. (1 Kings 10:22. However the Hebrew word, *qőf*, may mean a monkey.) Apes are mentioned in the Qur'an (7:166), where God tells Israelites who transgressed *Shabbat* "Be ye apes".

Hugo Rheinhold's Affe mit Schädel ("Ape with skull") is an example of how chimps were viewed at the end of the 19th century.

The first of these early transcontinental chimpanzees came from Angola and were presented as a gift to Frederick Henry, Prince of Orange in 1640, and were followed by a few of its brethren over the next several years. Scientists described these first chimpanzees as "pygmies", and noted the animals' distinct similarities to humans. The

next two decades would see a number of the creatures imported into Europe, mainly acquired by various zoological gardens as entertainment for visitors.

Darwin's theory of natural selection (published in 1859) spurred scientific interest in chimpanzees, as in much of life science, leading eventually to numerous studies of the animals in the wild and captivity. The observers of chimpanzees at the time were mainly interested in behaviour as it related to that of humans. This was less strictly and disinterestedly scientific than it might sound, with much attention being focused on whether or not the animals had traits that could be considered 'good'; the intelligence of chimpanzees was often significantly exaggerated, as immortalized in Hugo Rheinhold's Affe mit Schädel. By the end of the 19th century chimpanzees remained very much a mystery to humans, with very little factual scientific information available.

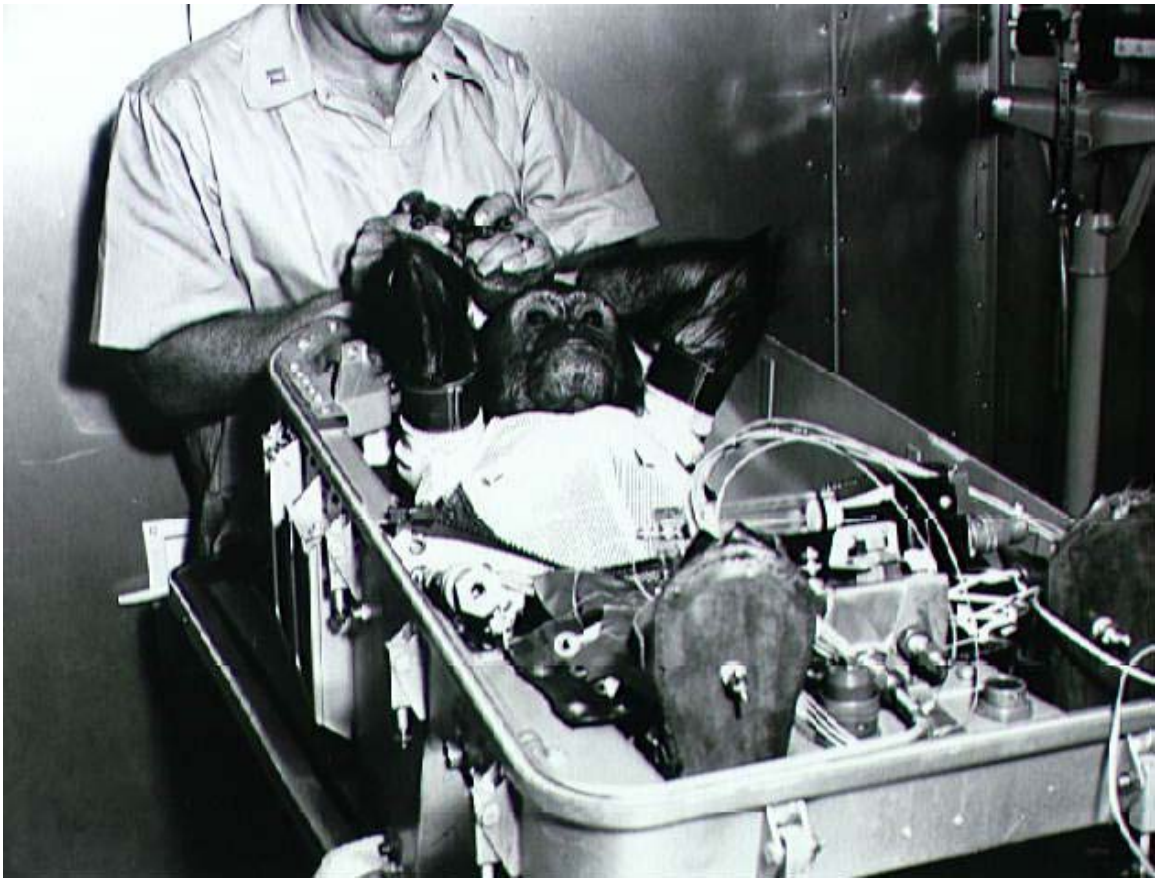
The 20th century saw a new age of scientific research into chimpanzee behaviour. Before 1960, almost nothing was known about chimpanzee behaviour in their natural habitat. In July of that year, Jane Goodall set out to Tanzania's Gombe forest to live among the chimpanzees, where she primarily studied the members of the Kasakela chimpanzee community. Her discovery that chimpanzees made and used tools was groundbreaking, as humans were previously believed to be the only species to do so. The most progressive early studies on chimpanzees were spearheaded primarily by Wolfgang Köhler and Robert Yerkes, both of whom were renowned psychologists. Both men and their colleagues established laboratory studies of chimpanzees focused specifically on learning about the intellectual abilities of chimpanzees, particularly problem-solving. This typically involved basic, practical tests on laboratory chimpanzees, which required a fairly high intellectual capacity (such as how to solve the problem of acquiring an out-of-reach banana). Notably, Yerkes also made extensive observations of chimpanzees in the wild which added tremendously to the scientific understanding of chimpanzees and their behaviour. Yerkes studied chimpanzees until World War II, while Köhler concluded five years of study and published his famous *Mentality of Apes* in 1925 (which is coincidentally when Yerkes *began* his analyses), eventually concluding that "chimpanzees manifest intelligent behaviour of the general kind familiar in human beings ... a type of behaviour which counts as specifically human" (1925).

Chimpanzee at the Los Angeles Zoo

The August 2008 issue of the *American Journal of Primatology* reported results of a year-long study of chimpanzees in Tanzania's Mahale Mountains National Park which produced evidence that chimpanzees are becoming sick from viral infectious diseases they have likely contracted from humans. Molecular, microscopic and epidemiological investigations demonstrated that the chimpanzees living at Mahale Mountains National Park have been suffering from a respiratory disease that is likely caused by a variant of a human paramyxovirus.

Studies

As of November 2007, there were 1,300 chimpanzees housed in 10 U.S. laboratories (out of 3,000 great apes living in captivity there), either wild-caught, or acquired from circuses, animal trainers, or zoos. Most of the labs either conduct or make the chimps available for invasive research, defined as "inoculation with an infectious agent, surgery or biopsy conducted for the sake of research and not for the sake of the chimpanzee, and/or drug testing". Two federally-funded laboratories use chimps: Yerkes National Primate Research Laboratory at Emory University in Atlanta, Georgia, and the Southwest National Primate Center in San Antonio, Texas. Five hundred chimps have been retired from laboratory use in the U.S. and live in sanctuaries in the U.S. or Canada.



Enos the space chimp before being inserted into the Mercury-Atlas 5 capsule in 1961.

Chimpanzees used in biomedical research tend to be used repeatedly over decades, rather than used and killed as with most laboratory animals. Some individual chimps currently in U.S. laboratories have been used in experiments for over 40 years. According to Project R&R, a campaign to release chimps held in U.S. labs—run by the New England Anti-Vivisection Society in conjunction with Jane Goodall and other primate researchers—the oldest known chimp in a U.S. lab is Wenka, who was born in a laboratory in Florida on May 21, 1954. She was removed from her mother on the day of birth to be used in a vision experiment that lasted 17 months, then sold as a pet to a family in North Carolina. She was returned to the Yerkes National Primate Research Center in 1957 when she became too big to handle. Since then, she has given birth six times, and has been used in research into alcohol use, oral contraceptives, ageing, and cognitive studies.

With the publication of the chimpanzee genome, there are reportedly plans to increase the use of chimps in labs, with some scientists arguing that the federal moratorium on breeding chimps for research should be lifted. A five-year moratorium was imposed by the U.S. National Institutes of Health (NIH) in 1996, because too many chimps had been bred for HIV research, and it has been extended annually since 2001.

Other researchers argue that chimps are unique animals and either should not be used in research, or should be treated differently. Pascal Gagneux, an evolutionary biologist and primate expert at the University of California, San Diego, argues that, given chimpanzees' sense of self, tool use, and genetic similarity to human beings, studies using chimps should follow the ethical guidelines that are used for human subjects unable to give consent. Also, a recent study suggests that chimpanzees which are retired from labs exhibit a form of posttraumatic stress disorder. Stuart Zola, director of the Yerkes National Primate Research Laboratory, disagrees. He told *National Geographic*: "I don't think we should make a distinction between our obligation to treat humanely any species, whether it's a rat or a monkey or a chimpanzee. No matter how much we may wish it, chimps are not human."

An increasing number of governments are enacting a Great Ape research ban forbidding the use of chimpanzees and other great apes in research or toxicology testing. As of 2006, Austria, New Zealand, the Netherlands, Sweden, and the UK had introduced such bans.

Chapter 9

Sea Otter

Sea otter

A sea otter wraps itself in kelp in Morro Bay, California.

Conservation status

Endangered (IUCN 3.1)

Scientific classification	
Kingdom:	Animalia
Phylum:	Chordata
Subphylum:	Vertebrata
Class:	Mammalia
Order:	Carnivora
Family:	Mustelidae
Subfamily:	Lutrinae
Genus:	***Enhydra*** Fleming, 1828

Species: ***E. lutris***

Binomial name

Enhydra lutris
(Linnaeus, 1758)

Modern and historical range

The **sea otter** (*Enhydra lutris*) is a marine mammal native to the coasts of the northern and eastern North Pacific Ocean. Adult sea otters typically weigh between 14 and 45 kg (30 to 100 lb), making them the heaviest members of the weasel family, but among the smallest marine mammals. Unlike most marine mammals, the sea otter's primary form of insulation is an exceptionally thick coat of fur, the densest in the animal kingdom. Although it can walk on land, the sea otter lives mostly in the ocean.

The sea otter inhabits nearshore environments where it dives to the sea floor to forage. It preys mostly upon marine invertebrates such as sea urchins, various molluscs and crustaceans, and some species of fish. Its foraging and eating habits are noteworthy in several respects. First, its use of rocks to dislodge prey and to open shells makes it one of the few mammal species to use tools. In most of its range, it is a keystone species, controlling sea urchin populations which would otherwise inflict extensive damage to kelp forest ecosystems. Its diet includes prey species that are also valued by humans as food, leading to conflicts between sea otters and fisheries.

Sea otters, whose numbers were once estimated at 150,000–300,000, were hunted extensively for their fur between 1741 and 1911, and the world population fell to 1,000–2,000 individuals in a fraction of their historic range. A subsequent international ban on hunting, conservation efforts, and reintroduction programs into previously populated areas have contributed to numbers rebounding, and the species now occupies about two-thirds of its former range. The recovery of the sea otter is considered an important success in marine conservation, although populations in the Aleutian Islands and California have recently declined or have plateaued at depressed levels. For these reasons (as well as its particular vulnerability to oil spills) the sea otter remains classified as an endangered species.

Taxonomy

The first scientific description of the sea otter is contained in the field notes of Georg Steller from 1751, and the species was described by Linnaeus in his *Systema Naturae* of 1758. Originally named *Lutra marina*, it underwent numerous name changes before being accepted as *Enhydra lutris* in 1922. The generic name *Enhydra*, derives from the Ancient Greek *en*/εν "in" and *hydra*/ύδρα "water", meaning "in the water", and the Latin word *lutris*, meaning "otter". It was formerly sometimes referred to as the "sea beaver", although it is only distantly related to beavers. It is not to be confused with the marine otter, a rare otter species native to the southern west coast of South America. A number of other otter species, while predominantly living in fresh water, are commonly found in marine coastal habitats. The extinct sea mink of northeast North America is another mustelid that adapted to a marine environment.

Evolution

Although it is a relatively new marine mammal lineage, the sea otter can live in the ocean at all stages of life.

The sea otter is the heaviest member of the family Mustelidae, a diverse group that includes the thirteen otter species and terrestrial animals such as weasels, badgers, and minks. It is unique among the mustelids in not making dens or burrows, in having no functional anal scent glands, and in being able to live its entire life without leaving the water. The only member of the genus *Enhydra*, the sea otter is so different from other mustelid species that as recently as 1982, some scientists believed it was more closely related to the earless seals. Genetic analysis indicates that the sea otter and its closest

extant relatives, which include the African speckle-throated otter, Eurasian otter, African clawless otter and oriental small-clawed otter, shared an ancestor approximately 5 million years ago (mya).

Fossil evidence indicates that the *Enhydra* lineage became isolated in the North Pacific approximately 2 mya, giving rise to the now-extinct *Enhydra macrodonta* and the modern sea otter, *Enhydra lutris*. The sea otter evolved initially in northern Hokkaidō and Russia, and then spread east to the Aleutian Islands, mainland Alaska, and down the North American coast. In comparison to cetaceans, sirenians, and pinnipeds, which entered the water approximately 50 mya, 40 mya, and 20 mya, respectively, the sea otter is a relative newcomer to a marine existence. In some respects, however, the sea otter is more fully aquatically adapted than pinnipeds, which must haul out on land or ice to give birth.

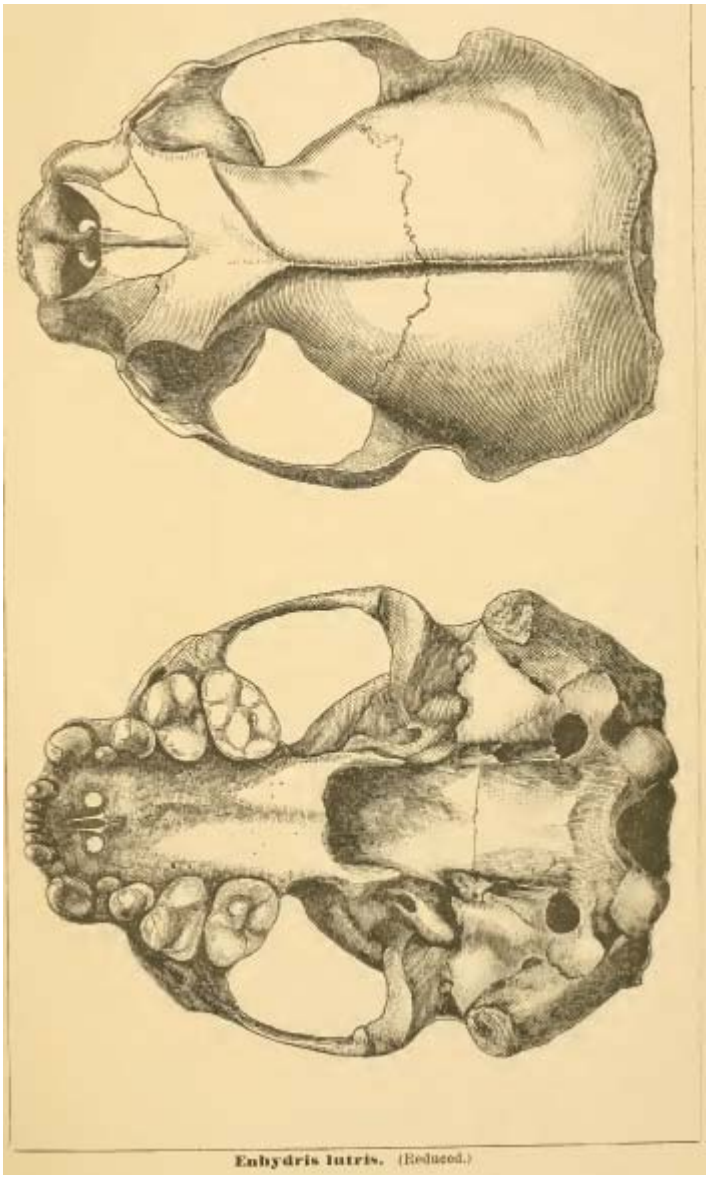
Subspecies

There are three recognized subspecies, which vary in body size and in some skull and dental characteristics:

- The **common sea otter, *E. l. lutris*** (Linnaeus, 1758), ranges from the Kuril Islands to the Commander Islands in the western Pacific Ocean. Also known as the Asian sea otter, it is the largest subspecies with a wide skull and short nasal bones.
- The **southern sea otter, *E. l. nereis*** (Merriam, 1904), is found off the coast of central California. Also known as the Californian sea otter, it has a narrower skull with a long rostrum and small teeth.
- The **northern sea otter, *E. l. kenyoni*** (Wilson, 1991), is native to Alaska and the Pacific west coast from the Aleutian islands to British Columbia, Washington, and northern Oregon. After being extirpated from southern British Columbia due to overhunting, it has since been re-introduced off Vancouver Island and the Olympic Peninsula.

The reintroduction effort off the Oregon coast was not successful. However, reintroductions in 1969 and 1970 off the Washington coast were very successful and sea otters have been expanding their range since. They have now entered the Strait of Juan de Fuca and can be found almost as far east as Pillar Point. Individuals have even been seen in the San Juan Islands and northern Puget Sound.

Physical characteristics



Skull

A sea otter's thick fur makes its body appear much plumper on land than in the water.

The sea otter is one of the smallest marine mammal species. Male sea otters weigh 22 to 45 kg (49 to 99 lb) and are 1.2 to 1.5 m (4 to 5 ft) in length. Females are smaller, weighing 14 to 33 kg (30 to 73 lb) and measuring 1.0 to 1.4 m (3 ft 3 in to 4 ft 7 in) in length.

Unlike other marine mammals, the sea otter has no blubber and relies on its exceptionally thick fur to keep warm. With up to 150,000 strands of hair per square centimeter (nearly one million per sq in), its fur is the most dense of any animal. The fur consists of long waterproof guard hairs and short underfur; the guard hairs keep the dense underfur layer dry. Cold water is thus kept completely away from the skin and heat loss is limited. The fur is thick year-round, as it is shed and replaced gradually rather than in a distinct molting season. As the ability of the guard hairs to repel water depends on utmost cleanliness, the sea otter has the ability to reach and groom the fur on any part of its body, taking advantage of its loose skin and an unusually supple skeleton. The coloration of the pelage is usually deep brown with silver-gray speckles, however it can range from yellowish or grayish brown to almost black. In adults, the head, throat, and chest are lighter in color than the rest of the body.

The sea otter displays numerous adaptations to its marine environment. The nostrils and small ears can close. The hind feet, which provide most of its propulsion in swimming, are long, broadly flattened, and fully webbed. The fifth digit on each hind foot is longest,

facilitating swimming while on its back, but making walking difficult. The tail is fairly short, thick, slightly flattened, and muscular. The front paws are short with retractable claws, with tough pads on the palms that enable gripping slippery prey.

The sea otter propels itself underwater by moving the rear end of its body, including its tail and hind feet, up and down, and is capable of speeds of up to 9 km/h (5.6 mph). When underwater, its body is long and streamlined, with the short forelimbs pressed closely against the chest. When at the surface, it usually floats on its back and moves by sculling its feet and tail from side to side. At rest, all four limbs can be folded onto the torso to conserve heat, whereas on particularly hot days the hind feet may be held underwater for cooling. The sea otter's body is highly buoyant because of its large lung capacity – about 2.5 times greater than that of similar-sized land mammals – and the air trapped in its fur. The sea otter walks with a clumsy rolling gait on land, and can run in a bounding motion.

Long, highly sensitive whiskers and front paws help the sea otter find prey by touch when waters are dark or murky. Researchers have noted that when they approach in plain view, sea otters react more rapidly when the wind is blowing towards the animals, indicating that the sense of smell is more important than sight as a warning sense. Other observations indicate that the sea otter's sense of sight is useful above and below the water, although not as good as that of seals. Its hearing is neither particularly acute nor poor.

An adult sea otter swimming on its back.

An adult's 32 teeth, particularly the molars, are flattened and rounded, designed to crush rather than cut food. Seals and sea otters are the only carnivores with two pairs of lower incisor teeth rather than three; the adult dental formula is:

Dentition

3.1.3.1

2.1.3.2

The sea otter has a metabolic rate two or three times that of comparatively sized terrestrial mammals. It must eat an estimated 25 to 38% of its own body weight in food each day in order to burn the calories necessary to counteract the loss of heat due to the cold water environment. Its digestive efficiency is estimated at 80 to 85%, and food is digested and passed in as little as three hours. Most of its need for water is met through food, although, in contrast to most other marine mammals, it also drinks seawater. Its relatively large kidneys enable it to derive fresh water from sea water and excrete concentrated urine.

Behavior

Sensitive whiskers and forepaws enable sea otters to find prey using their sense of touch.

The sea otter is diurnal. It has a period of foraging and eating in the morning, starting about an hour before sunrise, then rests or sleeps in mid-day. Foraging resumes for a few hours in the afternoon and subsides before sunset, and there may be a third foraging period around midnight. Females with pups appear to be more inclined to feed at night. Observations of the amount of time a sea otter must spend each day foraging range from 24 to 60%, apparently depending on the availability of food in the area.

The sea otter spends much of its time grooming, which consists of cleaning the fur, untangling knots, removing loose fur, rubbing the fur to squeeze out water and introduce air, and blowing air into the fur. To an observer it appears as if the animal is scratching,

however sea otters are not known to have lice or other parasites in the fur. When eating, the sea otter rolls in the water frequently, apparently to wash food scraps from its fur.

Foraging

The sea otter hunts in short dives, often to the sea floor. Although it can hold its breath for up to five minutes, its dives typically last about one minute and no more than four. It is the only marine animal capable of lifting and turning over boulders, which it often does with its front paws when searching for prey. The sea otter may also pluck snails and other organisms from kelp and dig deep into underwater mud for clams. It is the only marine mammal that catches fish with its forepaws rather than with its teeth.

Under each foreleg, the sea otter has a loose pouch of skin that extends across the chest. In this pouch (preferentially the left one), the animal stores collected food to bring to the surface. In this pouch they also keep a rock unique to each otter that is used to break open shellfish and clams. There, the sea otter eats while floating on its back, using its forepaws to tear food apart and bring it to its mouth. It can chew and swallow small mussels with their shells, whereas large mussel shells may be twisted apart. It uses its lower incisor teeth to access the meat in shellfish. To eat large sea urchins, which are mostly covered with spines, the sea otter bites through the underside where the spines are shortest, and licks the soft contents out of the urchin's shell.

The sea otter's use of rocks when hunting and feeding makes it one of the few mammal species to use tools. To open hard shells, it may pound its prey with both paws against a rock on its chest. To pry an abalone off its rock, it hammers the abalone shell using a large stone, with observed rates of 45 blows in 15 seconds. Releasing an abalone, which can cling to rock with a force equal to 4,000 times its own body weight, requires multiple dives.

To keep from drifting apart, sea otters may sleep holding paws. Note the high buoyancy of the animals' bodies.

Social structure

Although each adult and independent juvenile forages alone, sea otters tend to rest together in single-sex groups called *rafts*. A raft typically contains 10 to 100 animals, with male rafts being larger than female ones. The largest raft ever seen contained over 2000 sea otters. To keep from drifting out to sea when resting and eating, sea otters may wrap themselves in kelp.

A male sea otter is most likely to mate if he maintains a breeding territory in an area that is also favored by females. As autumn is the peak breeding season in most areas, males typically defend their territory only from spring to autumn. During this time, males patrol the boundaries of their territories to exclude other males, although actual fighting is rare. Adult females move freely between male territories, where they outnumber adult males by an average of five to one. Males who do not have territories tend to congregate in large male-only groups, and swim through female areas when searching for a mate.

The species exhibits a variety of vocal behaviors. The cry of a pup is often compared to that of a seagull. Females coo when they are apparently content; males may grunt instead. Distressed or frightened adults may whistle, hiss, or in extreme circumstances, scream.

Although sea otters can be playful and sociable, they are not considered to be truly social animals. They spend much time alone, and each adult can meet its own needs in terms of hunting, grooming, and defense.

Reproduction and lifecycle

During mating, the male bites the nose of the female, often bloodying and scarring it.

Sea otters are polygynous: males have multiple female partners. However, temporary pair-bonding occurs for a few days between a female in estrus and her mate. Mating takes place in the water and can be rough, the male biting the female on the muzzle – which often leaves scars on the nose – and sometimes holding her head under water.

Births occur year-round, with peaks between May and June in northern populations and between January and March in southern populations. Gestation appears to vary from four to twelve months, as the species is capable of delayed implantation followed by four months of pregnancy. In California, sea otters usually breed every year, about twice as often as sea otters in Alaska.

Birth usually takes place in the water and typically produces a single pup weighing 1.4 to 2.3 kg (3 to 5 lb). Twins occur in 2% of births; however, usually only one pup survives. At birth, the eyes are open, ten teeth are visible, and the pup has a thick coat of baby fur. Mothers have been observed to lick and fluff a newborn for hours; after grooming, the pup's fur retains so much air that the pup floats like a cork and cannot dive. The fluffy baby fur is replaced by adult fur after about thirteen weeks.

A mother floats with her pup on her chest. Georg Steller wrote, "They embrace their young with an affection that is scarcely credible."

Nursing lasts six to eight months in Californian populations and four to twelve months in Alaska, with the mother beginning to offer bits of prey at one to two months. The milk from a sea otter's two abdominal nipples is rich in fat and more similar to the milk of other marine mammals than to that of other mustelids. A pup, with guidance from its mother, practices swimming and diving for several weeks before it is able to reach the sea floor. Initially the objects it retrieves are of little food value, such as brightly colored starfish and pebbles. Juveniles are typically independent at six to eight months, however a mother may be forced to abandon a pup if she cannot find enough food for it and at the other extreme, a pup may nurse until it is almost adult size. Pup mortality is high, particularly during an individual's first winter – by one estimate, only 25% of pups survive their first year. Pups born to experienced mothers have the highest survival rates.

Females perform all tasks of feeding and raising offspring, and have occasionally been observed caring for orphaned pups. Much has been written about the level of devotion of sea otter mothers for their pups – a mother gives her infant almost constant attention,

cradling it on her chest away from the cold water and attentively grooming its fur. When foraging, she leaves her pup floating on the water, sometimes wrapped in kelp to keep it from floating away; if the pup is not sleeping, it cries loudly until she returns. Mothers have been known to carry their pup for days after the pup's death.

Females become sexually mature at around three or four years of age and males at around five; however, males often do not successfully breed until a few years later. A captive male sired offspring at age 19. In the wild, sea otters live to a maximum age of 23 years, with average lifespans of 10–15 years for males and 15–20 years for females. Several captive individuals have lived past 20 years, and a female at the Seattle Aquarium died at the age of 28 years. Sea otters in the wild often develop worn teeth, which may account for their apparently shorter lifespans.

Population and distribution

Sea otter floating in Morro Bay, California

Sea otters live in coastal waters 15 to 23 meters (50 to 75 ft) deep, and usually stay within a kilometer (⅔ mi) of the shore. They are found most often in areas with protection from the most severe ocean winds, such as rocky coastlines, thick kelp forests, and barrier reefs. Although they are most strongly associated with rocky substrates, sea otters can also live in areas where the sea floor consists primarily of mud, sand, or silt. Their northern range is limited by ice, as sea otters can survive amidst drift ice but not land-fast ice. Individuals generally occupy a home range a few kilometers long, and remain there year-round.

The sea otter population is thought to have once been 150,000 to 300,000, stretching in an arc across the North Pacific from northern Japan to the central Baja California Peninsula in Mexico. The fur trade that began in the 1740s reduced the sea otter's numbers to an estimated 1,000 to 2,000 members in thirteen colonies. In about two-thirds of its former range, the species is at varying levels of recovery, with high population densities in some areas and threatened populations in others. Sea otters currently have stable populations in parts of the Russian east coast, Alaska, British Columbia, Washington, and California, and there have been reports of recolonizations in Mexico and Japan. Population estimates made between 2004 and 2007 give a worldwide total of approximately 107,000 sea otters.

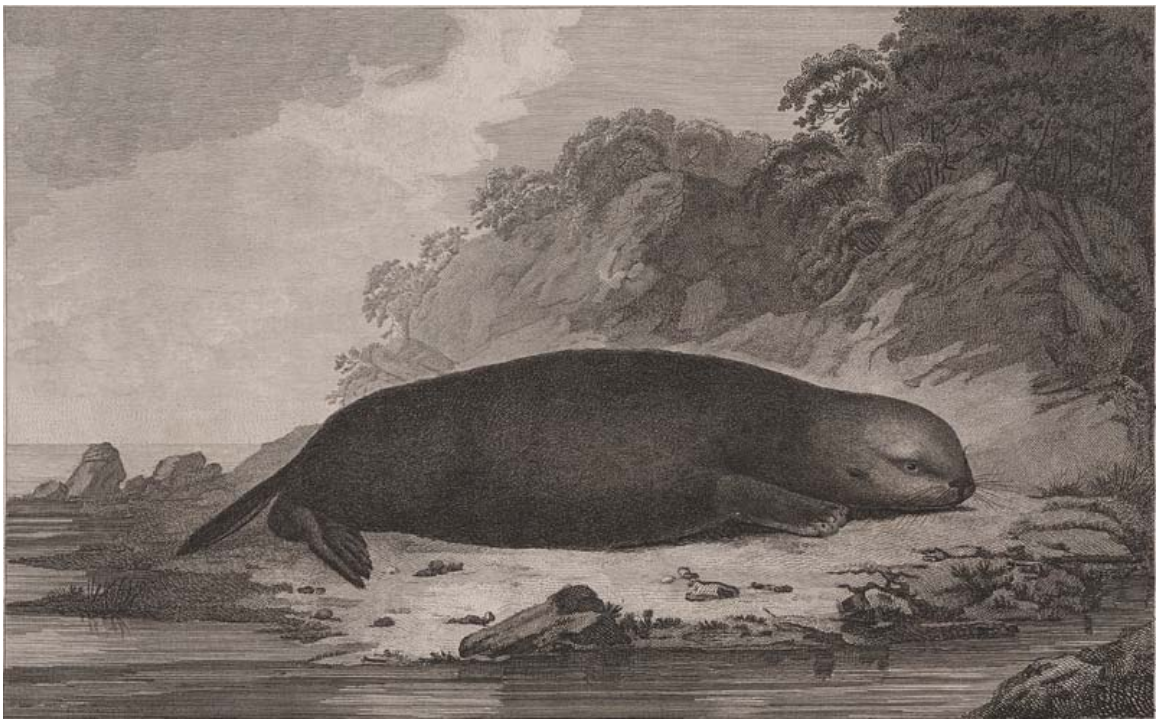
Russia

Currently, the most stable and secure part of the sea otter's range is Russia. Before the 19th century there were around 20,000 to 25,000 sea otters in the Kuril Islands, with more on Kamchatka and the Commander Islands. After the years of the Great Hunt, the population in these areas, currently part of Russia, was only 750. As of 2004, sea otters have repopulated all of their former habitat in these areas, with an estimated total population of about 27,000. Of these, about 19,000 are in the Kurils, 2000 to 3500 on Kamchatka and another 5000 to 5500 on the Commander Islands. Growth has slowed slightly, suggesting that the numbers are reaching carrying capacity.

Alaska

Alaska is the heartland of the sea otter's range. In 1973, the sea otter population in Alaska was estimated at between 100,000 and 125,000 animals. By 2006, however, the Alaska population had fallen to an estimated 73,000 animals. A massive decline in sea otter populations in the Aleutian Islands accounts for most of the change; the cause of this decline is not known, although orca predation is suspected. The sea otter population in Prince William Sound was also hit hard by the Exxon Valdez oil spill, which killed thousands of sea otters in 1989.

British Columbia and Washington



John Weber's *Sea Otter*, c 1788

Along the North American coast south of Alaska, the sea otter's range is discontinuous. Between 1969 and 1972, 89 sea otters were flown or shipped from Alaska to the west coast of Vancouver Island, British Columbia. They established a healthy population, estimated to be over 3,000 as of 2004, and their range is now from Tofino to Cape Scott. In 1989, a separate colony was discovered in the central British Columbia coast. It is not known if this colony, which had a size of about 300 animals in 2004, was founded by transplanted otters or by survivors of the fur trade.

In 1969 and 1970, 59 sea otters were translocated from Amchitka Island to Washington. Annual surveys between 2000 and 2004 have recorded between 504 and 743 individuals, and their range is in the Olympic Peninsula from just south of Destruction Island to Pillar Point.

California has over 3,000 sea otters, descendants of approximately 50 individuals discovered in 1938.

In British Columbia and Washington, sea otters are found almost exclusively on the outer coasts. They can swim as close as 6 feet off shore along the Olympic coast. Reported sightings of sea otters in the San Juan Islands and Puget Sound almost always turn out to be northern river otters which are commonly seen along the seashore. However, biologists have confirmed isolated sightings of sea otters in these areas since the mid-1990s.

California

The spring 2007 sea otter survey counted 3,026 sea otters in the central Californian coast, down from an estimated pre-fur trade population of 16,000. California's sea otters are the descendants of a single colony of about 50 southern sea otters discovered near Big Sur in 1938; their principal range is now from just south of San Francisco to Santa Barbara County. In the late 1980s, the U.S. Fish and Wildlife Service relocated about 140 Californian sea otters to San Nicolas Island in southern California, in the hope of establishing a reserve population should the mainland be struck by an oil spill. To the surprise of biologists, the San Nicholas population initially shrank as the animals migrated back to the mainland, As of 2005, only 30 sea otters remained at San Nicholas, thriving on the abundant prey around the island. The plan that authorized the translocation program had predicted that carrying capacity would be reached within 5 to 10 years.

When the Fish and Wildlife Service implemented the translocation program, it also attempted to implement "zonal management" of the Californian population. To manage the competition between sea otters and fisheries, it declared an "otter-free zone"

stretching from Point Conception to the Mexican border. In this zone, only San Nicolas Island was designated as sea otter habitat, and sea otters found elsewhere in the area were supposed to be captured and relocated. These plans were abandoned after it proved impractical to capture the hundreds of otters which ignored regulations and swam into the zone. However, after engaging in a period of public commentary in 2005, the Fish and Wildlife Service has yet to release a formal decision on the issue.

Sea otter were once numerous in San Francisco Bay. Historical records reveal that the Russian-American Company snuck Aleuts into San Francisco Bay multiple times, despite the Spanish capturing or shooting them while hunting sea otters in the estuaries of San Jose, San Mateo, San Bruno and around Angel Island. The founder of Fort Ross, Ivan Kuskov, finding otter scarce on his second voyage to Bodega Bay in 1812, sent a party of Aleuts to San Francisco Bay where they met another Russian party and an American party, and caught 1,160 sea otter in three months. By 1817 sea otter in the area were practically eliminated and the Russians sought permission from the Spanish and the Mexican governments to hunt further and further south of San Francisco. Remnant sea otter populations may have survived in the Bay until 1840, when the Rancho Punta de Quentin was granted to Captain John B. R. Cooper, a sea captain from Boston, by Mexican Governor Juan Bautista Alvarado along with a license to hunt sea otter, reportedly then prevalent at the mouth of Corte Madera Creek.

Although the southern sea otter's range has continuously expanded from Big Sur since protection in 1911, in the last two years the otter population and its range has contracted. As of spring 2010 the northern boundary has moved from about Tunitas Creek to a point 2 km southeast of Pigeon Point, and the southern boundary has moved from approximately Coal Oil Point to Gaviota State Park. Recently a toxin called microcystin, produced by a type of cyanobacteria (*Microcystis*), seems to be concentrated in the shellfish that otter eat, poisoning them. Cyanobacteria are found in stagnant freshwater enriched with nitrogen and phosphorus from septic tank and agricultural fertilizer runoff, and may be flushed into the ocean when streamflows are high in the rainy season. A record number of sea otter carcasses were found on California's coastline in 2010, with increased shark attacks an increasing component of the mortality.

Oregon

The last native sea otter in Oregon was shot and killed in 1906. In 1970 and 1971, a total of 95 sea otters were transplanted from Amchitka Island, Alaska to the Southern Oregon coast. However, this translocation effort failed and otters soon again disappeared from the state.

In 2004 a lone male sea otter took up residence at Simpson Reef off of Cape Arago for six months. This male is thought to have originated from a colony in Washington, but disappeared after a coastal storm.

The most recent sighting of a sea otter off the Oregon coast took place 18 February 2009, in Depoe Bay, Oregon. The lone male sea otter could have traveled from either California or Washington.

Ecology

Diet

Sea otters keep kelp forests healthy by eating animals that graze on kelp.

Sea otters consume over 100 different prey species. In most of its range, the sea otter's diet consists almost exclusively of marine invertebrates, including sea urchins, a variety of bivalves such as clams and mussels, abalone, other mollusks, crustaceans, and snails. Its prey ranges in size from tiny limpets and crabs to giant octopuses. Where prey such as

sea urchins, clams, and abalone are present in a range of sizes, sea otters tend to select larger items over smaller ones of similar type. In California, it has been noted that sea otters ignore Pismo clams smaller than 3 inches (7 cm) across.

In a few northern areas, fish are also eaten. In studies performed at Amchitka Island in the 1960s, where the sea otter population was at carrying capacity, 50% of food found in sea otter stomachs was fish. The fish species were usually bottom-dwelling and sedentary or sluggish forms, such as *Hemilepidotus hemilepidotus* and family Tetraodontidae. However, south of Alaska on the North American coast, fish are a negligible or extremely minor part of the sea otter's diet. Contrary to popular depictions, sea otters rarely eat starfish, and any kelp that is consumed apparently passes through the sea otter's system undigested.

The individuals within a particular area often differ in their foraging methods and their prey types, and tend to follow the same patterns as their mothers. The diet of local populations also changes over time, as sea otters can significantly deplete populations of highly preferred prey such as large sea urchins, and prey availability is also affected by other factors such as fishing by humans. Sea otters can thoroughly remove abalone from an area except for specimens in deep rock crevices, however, they never completely wipe out a prey species from an area. A 2007 Californian study demonstrated that in areas where food was relatively scarce, a wider variety of prey was consumed. However, surprisingly, the diets of individuals were more specialized in these areas than in areas where food was plentiful.

As a keystone species

Sea otters are a classic example of a keystone species; their presence affects the ecosystem more profoundly than their size and numbers would suggest. Sea otters keep the population of certain benthic (sea floor) herbivores, particularly sea urchins, in check. Sea urchins graze on the lower stems of kelp, causing the kelp to drift away and die. Loss of the habitat and nutrients provided by kelp forests leads to profound cascade effects on the marine ecosystem. North Pacific areas that do not have sea otters often turn into urchin barrens, with abundant sea urchins and no kelp forest.

Remote areas of coastline, such as this area in California, sheltered the few remaining colonies of sea otters that survived the fur trade.

Reintroduction of sea otters to British Columbia has led to a dramatic improvement in the health of coastal ecosystems, and similar changes have been observed as sea otter populations recovered in the Aleutian and Commander Islands and the Big Sur coast of California However, some kelp forest ecosystems in California have also thrived without sea otters, with sea urchin populations apparently controlled by other factors. The role of sea otters in maintaining kelp forests has been observed to be more important in areas of open coast than in more protected bays and estuaries.

In addition to promoting growth of kelp forests, sea otters can also have a profound effect in rocky areas that tend to be dominated by mussel beds. They remove mussels from rocks, liberating space for competitive species and thereby increasing the diversity of species in the area.

Predators

Predators of sea otters include orcas and sea lions; bald eagles also prey on pups by snatching them from the water surface. In California, bites from sharks, particularly great white sharks, have been estimated to cause 10% of sea otter deaths and are one of the reasons the population has not expanded further north. Dead sea otters have been found

with injuries from shark bites, although there is no evidence that sharks actually eat them. An exhibit at the San Diego Natural History Museum states that cat feces from urban runoff carries parasites to the ocean and kills sea otters.

Relationship with humans

Fur trade

Aleut men in Unalaska in 1896. The waterproof kayak gear and garments were used to hunt sea otters.

Archaeological evidence indicates that for thousands of years, indigenous peoples have hunted sea otters for food and fur. Large-scale hunting, part of the Maritime Fur Trade, which would eventually kill approximately one million sea otters, began in the 18th century when hunters and traders began to arrive from all over the world to meet foreign demand for otter pelts, which were one of the world's most valuable types of fur.

In the early 18th century, Russians began to hunt sea otters in the Kuril Islands and sold them to China. Russia was also exploring the far northern Pacific at this time, and sent

Vitus Bering to map the Arctic coast and find routes from Siberia to North America. In 1741, on his second North Pacific voyage, Bering was shipwrecked off Bering Island in the Commander Islands, where Bering and many of his crew died. The surviving crew members, which included naturalist Georg Steller, discovered sea otters on the beaches of the island and spent the winter hunting sea otters and gambling with otter pelts. They returned to Siberia having killed nearly 1000 sea otters, and were able to command high prices for the pelts. Thus began what is sometimes called the "Great Hunt", which would continue for another hundred years.

Pelt sales (in thousands) in the London fur market. The drop beginning in the 1880s reflects dwindling sea otter populations.

Russian fur-hunting expeditions soon depleted the sea otter populations in the Commander Islands, and by 1745 they began to move on to the Aleutian Islands. The Russians initially traded with the Aleuts inhabitants of these islands for otter pelts, but later enslaved the Aleuts, taking women and children hostage and torturing and killing Aleut men to force them to hunt. Many Aleuts were either murdered by the Russians or died from diseases that the hunters had introduced. The Aleut population was reduced, by the Russians' own estimate, from 20,000 to 2,000. By the 1760s, the Russians had reached Alaska. In 1799, Emperor Paul I consolidated the rival fur hunting companies into the Russian-American Company, granting it an Imperial charter and protection, and a monopoly over trade rights and territorial acquisition. Under Aleksandr I the administration of the merchant-controlled Company was transferred to the Imperial Navy, largely due to the alarming reports by naval officers of native abuse, and in 1818 the indigenous peoples of Alaska were granted civil rights equivalent to a townsman status in the Russian Empire.

Other nations joined in the hunt in the south. Along the coasts of what is now Mexico and California, Spanish explorers bought sea otter pelts from Native Americans and sold them in Asia. In 1778, British explorer Captain James Cook reached Vancouver Island and bought sea otter furs from the First Nations people. When Cook's ship later stopped at a Chinese port, the pelts rapidly sold at high prices, and were soon known as "soft

gold". As word spread, people from all over Europe and North America began to arrive in the Pacific Northwest to trade for sea otter furs.

Russian hunting expanded to the south, initiated by American ship captains, who sub-contracted Russian supervisors and Aleut hunters in what is now Washington, Oregon, and California. Between 1803 and 1846, 72 American ships were involved in the otter hunt in California, harvesting an estimated 40,000 skins and tails, compared to only 13 ships of the Russian-American Company, which reported 5,696 otter skins taken between 1806-1846. In 1812 the Russians founded an agricultural settlement at what is now Fort Ross in northern California as their southern headquarters. Eventually, sea otter populations became so depleted that commercial hunting was no longer viable. In the Aleutian Islands, commercial hunting had stopped by 1808, as a conservation measure imposed by the Russian-American Company. Further restrictions were ordered by the Company in 1834. When Russia sold Alaska to the United States in 1867, the Alaska population had recovered to over 100,000, but Americans resumed hunting and quickly extirpated the sea otter again. Prices rose as the species became rare: During the 1880s, a pelt brought $105 to $165 in the London market, however by 1903 a pelt could be worth as much as $1,125. In 1911, Russia, Japan, Great Britain (for Canada) and the United States signed the Treaty for the Preservation and Protection of Fur Seals, imposing a moratorium on the harvesting of sea otters. So few remained, perhaps only 1,000–2,000 individuals in the wild, that many believed the species would become extinct.

Recovery and conservation

In the wake of the Exxon Valdez oil spill, heavy sheens of oil covered large areas of Prince William Sound.

During the 20th century, sea otter numbers rebounded in about two-thirds of their historic range, a recovery that is considered one of the greatest successes in marine conservation. However, the IUCN still lists the sea otter as an endangered species, and describes the significant threats to sea otters as oil pollution, predation by orcas, poaching, and conflicts with fisheries – sea otters can drown if entangled in fishing gear. The hunting of

sea otters is no longer legal except for limited harvests by indigenous peoples in the United States. Poaching was a serious concern in the Russian Far East immediately after the collapse of the Soviet Union in 1991, however it has declined significantly with stricter law enforcement and better economic conditions.

The most significant threat to sea otters is oil spills. Sea otters are particularly vulnerable, as they rely on their fur to keep warm. When their fur is soaked with oil, it loses its ability to retain air, and the animal quickly dies from hypothermia. The liver, kidneys, and lungs of sea otters also become damaged after they inhale oil or ingest it when grooming. The Exxon Valdez oil spill of 24 March 1989 killed thousands of sea otters in Prince William Sound, and as of 2006 the lingering oil in the area continues to affect the population. Describing the public sympathy for sea otters that developed from media coverage of the event, a U.S. Fish and Wildlife Service spokesperson wrote:

As a playful, photogenic, innocent bystander, the sea otter epitomized the role of victim ... cute and frolicsome sea otters suddenly in distress, oiled, frightened, and dying, in a losing battle with the oil.

The small geographic ranges of the sea otter populations in California, Washington, and British Columbia mean that a single major spill could be catastrophic for that state or province. Prevention of oil spills and preparation for the rescue of otters in the event of one are major areas of focus for conservation efforts. Increasing the size and the range of sea otter populations would also reduce the risk of an oil spill wiping out a population. However, because of the species' reputation for depleting shellfish resources, advocates for commercial, recreational, and subsistence shellfish harvesting have often opposed allowing the sea otter's range to increase, and there have even been instances of fishermen and others illegally killing them.

Sea otters in the Olympic Coast National Marine Sanctuary. Note the unusual shape of the hind feet, in which the outer toes are longest.

In the Aleutian Islands, a massive and unexpected disappearance of sea otters has occurred in recent decades. In the 1980s, the area was home to an estimated 55,000 to 100,000 sea otters, but the population fell to around 6,000 animals by 2000. The most widely accepted, but still controversial, hypothesis is that orcas have been eating the otters. The pattern of sea otter disappearances is consistent with a rise in orca predation, however there has been no direct evidence that orcas prey on sea otters to any significant extent.

Another area of concern is California, where recovery began to fluctuate or decline in the late 1990s. Unusually high mortality rates amongst adult and sub-adult otters, particularly females, have been reported. Necropsies of dead sea otters indicate that diseases, particularly *Toxoplasma gondii* infection and acanthocephalan parasite infection, are a major cause of sea otter mortality in California. The *Toxoplasma gondii* parasite, which is often fatal to sea otters, is carried by wild and domestic cats and by opossums, and may be transmitted by domestic cat droppings flushed into the ocean via the sewage system. Although it is clear that disease has contributed to the deaths of many of California's sea otters, it is not known why the Californian population is apparently more affected by disease than populations in other areas.

Sea otter habitat is preserved through several protected areas in the United States, Russia and Canada. In marine protected areas, polluting activities such as dumping of waste and oil drilling are typically prohibited. There are estimated to be more than 1,200 sea otters

within the Monterey Bay National Marine Sanctuary, and more than 500 within the Olympic Coast National Marine Sanctuary.

Economic impact

Some of the sea otter's preferred prey species, particularly abalone, clams, and crabs, are also food sources for humans. In some areas, massive declines in shellfish harvests have been blamed on the sea otter, and intense public debate has taken place over how to manage the competition between sea otters and humans for seafood.

Sea otters like this one near Moss Landing are a tourist attraction in the Monterey Bay area in California.

The debate is complicated by the fact that sea otters have sometimes been held responsible for declines of shellfish stocks that were more likely caused by overfishing by humans, disease, pollution, and seismic activity. Shellfish declines have also occurred in many parts of the North American Pacific coast that do not have sea otters, and conservationists sometimes note that the existence of large concentrations of shellfish on the coast is a recent development resulting from the fur trade's near-extirpation of the sea otter. Although many factors affect shellfish stocks, sea otter predation can deplete a fishery to the point that it is no longer commercially viable. There is a consensus among scientists that sea otters and abalone fisheries cannot co-exist in the same area, and the same is likely true for certain other types of shellfish as well.

There are many facets to the interaction between sea otters and the human economy that are not as immediately felt. Sea otters have been credited with contributing to the kelp harvesting industry via their well-known role in controlling sea urchin populations; kelp is used in the production of diverse food and pharmaceutical products. Although human divers harvest red sea urchins both for food and to protect the kelp, sea otters hunt more sea urchin species and are more consistently effective in controlling these populations. The health of the kelp forest ecosystem is significant in nurturing populations of fish, including commercially important fish species. In some areas, sea otters are a popular tourist attraction, bringing visitors to local hotels, restaurants, and sea otter-watching expeditions.

Role in human cultures

Left: Aleut sea otter amulet in the form of a mother with pup. **Above**: Aleut carving of a sea otter hunt on a whalebone spear. Both items are on display at the St. Petersburg Museum of Anthropology and Ethnography. Articles depicting sea otters were considered to have magical properties.

For many maritime indigenous cultures throughout the North Pacific, especially the Ainu in the Kuril Islands, the Koryaks and Itelmen of Kamchatka, the Aleut in the Aleutian Islands and a host of tribes on the Pacific coast of North America, the sea otter has played an important role as a cultural as well as material resource. In these cultures, many of which have strongly animist traditions full of legends and stories in which many aspects of the natural world are associated with spirits, the sea otter was considered particularly kin to humans. The Nuu-chah-nulth, Haida, and other First Nations of coastal British Columbia used the warm and luxurious pelts as chiefs' regalia. Sea otter pelts were given in potlatches to mark coming-of-age ceremonies, weddings, and funerals. The Aleuts carved sea otter bones for use as ornaments and in games, and used powdered sea otter baculum as a medicine for fever.

Sea otters at the Lisbon Oceanarium show their flexibility when grooming.

Among the Ainu, the otter is portrayed as an occasional messenger between humans and the creator. The sea otter is a recurring figure in Ainu folklore. A major Ainu epic, the *Kutune Shirka*, tells the tale of wars and struggles over a golden sea otter. Versions of a widespread Aleut legend tell of lovers or despairing women who plunge into the sea and become otters. These links have been associated with the many human-like behavioral features of the sea otter, including apparent playfulness, strong mother-pup bonds and tool use, yielding to ready anthropomorphism. The beginning of commercial exploitation had a great impact on the human as well as animal populations – the Ainu and Aleuts have been displaced or their numbers are dwindling, while the coastal tribes of North America, where the otter is in any case greatly depleted, no longer rely as intimately on sea mammals for survival.

Since the mid-1970s, the beauty and charisma of the species have gained wide appreciation, and the sea otter has become an icon of environmental conservation. The round, expressive face and soft furry body of the sea otter are depicted in a wide variety of souvenirs, postcards, clothing, and stuffed toys.

Aquariums and zoos

Sea otters can do well in captivity, and are featured in over 40 public aquariums and zoos. The Seattle Aquarium became the first institution to raise sea otters from conception to adulthood with the birth of Tichuk in 1979, followed by three more pups in the early

1980s. In 2007, a YouTube video of two sea otters holding paws drew 1.5 million viewers in two weeks, and currently has over 15 million views. Filmed five years previously at the Vancouver Aquarium, it was YouTube's most popular animal video at the time, although it has since been surpassed. The lighter-colored otter in the video is Nyac, a survivor of the 1989 *Exxon Valdez* oil spill. Nyac died in September 2008, at the age of 20.