Herbivorous Animals

Stepanie Bunch

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Chapter 1

Herbivore

A deer and two fawns feeding on some foliage

Herbivores are organisms that eat plants. Herbivory is a form of predation in which an organism principally consumes autotrophs such as plants, algae and photosynthesizing bacteria. More generally, organisms that feed on autotrophs in general are known as **primary consumers**. Comes from the Greek suffix "vora" (Greek -βόρα) meaning "which eat".

By strict interpretation of this definition, many fungi, some bacteria, many animals, some protists and a small number of parasitic plants might be considered herbivores. However, *herbivory* generally refers to animals eating plants. Fungi, bacteria and protists that feed on living plants are usually termed plant pathogens (plant diseases). Microbes that feed on dead plants are saprotrophs. Flowering plants that obtain nutrition from other living plants are usually termed parasitic plants.

Evolution of herbivory

A fossil *Viburnum lesquereuxii* leaf with evidence of insect herbivory; Dakota Sandstone (Cretaceous) of Ellsworth County, Kansas. Scale bar is 10 mm.

Our understanding of herbivory in geological time comes from three sources: fossilized plants, which may preserve evidence of defence (such as spines), or herbivory-related damage; the observation of plant debris in fossilised animal faeces; and the construction of herbivore mouthparts.

Long thought to be a Mesozoic phenomenon, evidence for herbivory is found almost as soon as fossils which could show it. Within under 20 million years of the first fossils of sporangia and stems towards the close of the Silurian, around 420 million years ago, there is evidence that plants were being consumed by insects. Insects fed on the spores of early Devonian plants, and the Rhynie chert also provides evidence that organisms fed on plants using a "pierce and suck" technique.

Herbivory among terrestrial vertebrates (tetrapods) came much later. Early tetrapods were large amphibious piscivores. While amphibians continued to feed on fish and later insects, reptiles began exploring two new food types, tetrapods (carnivory), and later, plants (herbivory). Carnivory was a natural transition from insectivory for medium and large tetrapods, requiring minimal adaptation. In contrast, a complex set of adaptations was necessary for feeding on highly fibrous plant materials).

During the ensuing 75 million years, plants evolved a range of more complex organs - from roots to seeds. There is no evidence for these being fed upon until the middle-late Mississippian, 326.4 million years ago. There was a gap of 50 to 100 million years between each organ evolving, and it being fed upon; this may be due to the low levels of oxygen during this period, which may have suppressed evolution. Further than their arthropod status, the identity of these early herbivores is uncertain. Hole feeding and skeletonisation are recorded in the early Permian, with surface fluid feeding evolving by the end of that period.

Arthropods have evolved herbivory in four phases, changing their approach to herbivory in response to changing plant communities.
Another stage of herbivore evolution is characterized by the evolution of tetrapod herbivores, with the first appearance in the fossil record near the Permio-Carboniferous boundary approximately 300 MYA. The earliest evidence of herbivory by tetrapod organisms is seen in fossils of jawbones where dental occlusion (process by which teeth from the upper jaw come in contact with those in the lower jaw) is present. The evolution of dental occlusion lead to a drastic increase in food processing associated with herbivory and provides direct evidence about feeding strategies based on tooth wear patterns. Examination of phylogenetic frameworks reveals that dental occlusion developed independently in several lineages through dental and mandibular morphologes, suggesting that the evolution and radiation of tetrapod herbivores occurred simultaneously within various lineages.

Food Chain

Leaf miners feed on leaf tissue between the epidermal layers, leaving visible trails

Herbivores form an important link in the food chain as they consume plants in order to receive the carbohydrates produced by a plant from photosynthesis. Carnivores in turn consume herbivores for the same reason, while omnivores can obtain their nutrients from either plants or herbivores. Due to an herbivore's ability to survive solely on tough and fibrous plant matter, they are termed the primary consumers in the food cycle(chain). Herbivory, carnivory, and omnivory and call be regarded as special cases of Consumer-Resource Systems.

Predator-prey Theory (herbivore-plant interactions)

According to the theory of predator-prey interactions, the relationship between herbivores and plants is cyclic. When prey (plants) are numerous their predators (herbivores) increase in numbers, reducing the prey population, which in turn causes predator number to decline. The prey population eventually recovers, starting a new cycle. This suggests that the population of the herbivore fluctuates around the carrying capacity of the food source, in this case the plant.

Several factors play into these fluctuating populations and help stabilize predator-prey dynamics. For example, spatial heterogeneity is maintained, which means there will always be pockets of plants not found by herbivores. This stabilizing dynamic plays an especially important role for specialist herbivores that feed on one species of plant and prevents these specialists from wiping out their food source. Prey defenses also help stabilize predator-prey dynamic. Eating a second prey type helps herbivores' populations

stabilize. Alternating between two or more plant types provides population stability for the herbivore, while the populations of the plants oscillate. This plays an important role for generalist herbivores that eat variety of plants. Keystone herbivores keep vegetation populations in check and allow for a greater diversity of both herbivores and plants. When an invasive herbivore or plant enters the system, the balance is thrown off and the diversity can collapse to a monotaxon system.

Feeding strategies

Herbivores are limited in their feeding ability by either time or resources. Animals that are time limited, meaning they have a limited amount of time to consume the food they need, use a feeding strategy of grazing and browsing, while those animals that are resource limited, meaning that they are limited in the type of food they eat, use a selective feeding strategy. Grazers/browsers tend to be either very large herbivores that need to consume a lot of food in order to maintain their metabolism, or herbivores that have a very short amount of time to eat as much as possible before reproducing, like many generalist insects. Several theories attempt to explain and quantify the relationship between animals and their food, such as Kleiber's law, Holling's disk equation and Marginal Value Theorem.

Kleiber's law explains the relationship between the size of the animal and the feeding strategy it uses. In essence, it says that larger animals need to eat less food, per unit weight, than smaller animals. Kleiber's law states that the metabolic rate (q_0) of an animal is the mass of the animal (M) raise to the 3/4th power:
$q_0=M^{3/4}$
Therefore, the mass of the animal increases at a faster rate then the metabolic rate.
There are many types of feeding strategies employed by herbivores. Many herbivores do not fall into one specific feeding strategy, but instead employ several strategies and eat a variety of plant parts.

Types of feeding strategies:

Feeding Strategy	Diet	Example
Frugivores	Fruit	Ruffed lemurs
Folivores	Leaves	Koalas
Nectarivores	Nectar	Honey Possum
Granivores	Seeds	Hawaiian Honeycreepers
Palynivores	Pollen	Bees
Mucivores	Plant fluids, i.e. sap	Aphids
Xylophages	Wood	Termites

Optimal Foraging Theory is a model for predicting animal behavior while looking for food or other resource, such as shelter or water. This model assesses both individual

movement, such as animal behavior while looking for food, and distribution within a habitat, such as dynamics at the population and community level. For example, the model would be used to look at the browsing behavior of a deer while looking for food, as well as that deer's specific location and movement within the forested habitat and its interaction with other deer while in that habitat.

This model can be controversial, where critics say that the theory is circular and untestable. Critics say that the theory uses examples that fit the theory, but that researchers do not use the theory when it does not fit the reality. Other critics point out that animals do not have the ability to assess and maximize their potential gains, therefore the optimal foraging theory is irrelevant and derived to explain trends that do not exist in nature.

Holling's disk equation models the efficiency at which predators consume prey. The model predicts that as the number of prey increases, the amount of time predators spend handling prey also increases and therefore the efficiency of the predator decreases. In 1959, S. Holling proposed an equation to model the rate of return for an optimal diet:
Rate (R) = Energy gained in foraging (Ef)/(time searching (Ts) + time handling (Th))
$R = Ef / (Ts + Th)$
Where s = cost of search per unit time f = rate of encounter with items, h = handling time, e = energy gained per encounter
In effect, this would indicate that an herbivore in a dense forest would spend more time getting handling (eating) the vegetation because there was so much vegetation around than an herbivore in a sparse forest, who could easily browse through the forest vegetation. Therefore, according to the Holling's disk equation, the herbivore in the sparse forest would be more efficient at eating than the herbivore in the dense forest

Marginal Value Theorem describes the balance between eating all the food in a patch for immediate energy, or moving to a new patch and leaving the plants in the first patch to regenerate for future use. The theory predicts that absent complicating factors, an animal should leave a resource patch when the rate of payoff (amount of food) falls below the average rate of payoff for the entire area. According to this theory, therefore, locus should move to a new patch of food when the patch they are currently feeding on requires more energy to obtain food than an average patch. Within this theory, two subsequent parameters emerge, the Giving Up Density (GUD) and the Giving Up Time (GUT). The Giving Up Density (GUD) quantifies the amount of food that remains in a patch when a forager moves to a new patch. The Giving Up Time (GUT) is used when an animal continuously assesses the patch quality.

Attacks and Counter-Attacks

Plant Defense

A plant defense is a trait that increases plant fitness when faced with herbivory. This is measured relative to another plant that lacks the defensive trait. Plant defenses increase

survival and/or reproduction (fitness) of plants under pressure of predation from herbivores.

Defense can be divided into two main categories, tolerance and resistance. Tolerance is the ability of a plant to withstand damage without a reduction in fitness. This can occur by diverting herbivory to non-essential plant parts or by rapid regrowth and recovery from herbivory. Resistance refers to the ability of a plant to reduce the amount of damage it receives from an herbivore. This can occur via avoidance in space or time, physical defenses, or chemical defenses. Defenses can either be constitutive, always present in the plant, or induced, produced or translocated by the plant following damage or stress.

Physical, or mechanical, defenses are barriers or structures designed to deter herbivores or reduce intake rates, lowering overall herbivory. thorns such as those found on roses or acacia trees are one example, as are the spines on a cactus. Smaller hairs known as trichomes may cover leaves or stems and are especially effective against invertebrate herbivores. In addition, some plants have waxes or resins that alter their texture, making them difficult to eat. Finally, some plants sequester silica inside their tissues. These are basically small pieces of glass that wear down the teeth of herbivores.

Chemical defenses are secondary metabolites produced by the plant that deter herbivory. There are a wide variety of these in nature and a single plant can have hundreds of different chemical defenses. Chemical defenses can be divided into two main groups, carbon-based defenses and nitrogen-based defenses.

Carbon-based defenses include terpenes and phenolics. Terpenes are derived from 5-carbon isoprene units and comprise essential oils, carotenoids, resins, and latex. They can have a number of functions that disrupt herbivores such as inhibiting adenosine triphosphate (ATP) formation, molting hormones, or the nervous system. Phenolics combine an aromatic carbon ring with a hydroxyl group. There are a number of different phenolics such as lignins, which are found in cell walls and are very indigestible except for specialized microorgamisms; tannins, which have a bitter taste and bind to proteins making them indigestible; and furanocumerins, which produce free radicals disrupting DNA, protein, and lipids, and can cause skin irritation.

Nitrogen-based defenses are synthesized from amino acids and primarily come in the form of alkaloids and cyanogens. Alkaloids include commonly recognized substances such as caffeine, nicotine, and morphine. These compounds are often bitter and can inhibit DNA or RNA synthesis or block nervous system signal transmission. Cyanogens get their name from the cyanide stored within their tissues. This is released when the plant is damaged and inhibits cellular respiration and electron transport.

Plants have also changed features that enhance the probability of attracting natural enemies to herbivores. Some emit semiochemicals, odors that attract natural enemies, while others provide food and housing to maintain the natural enemies' presence (e.g. ants that reduce herbivory). A given plant species often has many types of defensive

mechanisms, mechanical or chemical, constitutive or induced, which additively serve to protect the plant, and allow it to escape from herbivores.

Herbivore Offense

Aphids are fluid feeders on plant sap.

The myriad of defenses displayed by plants means that their herbivores need a variety of techniques to overcome these defenses and obtain food. These allow herbivores to increase their feeding and use of a host plant. Herbivores have three primary strategies for dealing with plant defenses: choice, herbivore modification, and plant modification.

Feeding choice involves which plants an herbivore chooses to consume. It has been suggested that many herbivores feed on a variety of plants to balance their nutrient uptake and to avoid consuming too much of any one type of defensive chemical. This involves a tradeoff however, between foraging on many plant species to avoid toxins or specializing on one type of plant that can be detoxified.

Herbivore modification is when various adaptations to body or digestive systems of the herbivore allow them to overcome plant defenses. This might include detoxifying secondary metabolites, sequestering toxins unaltered, or avoiding toxins, such as through the production of large amounts of saliva to reduce effectiveness of defenses. Herbivores may also utilize symbionts to evade plant defences. For example, some aphids use bacteria in their gut to provide essential amino acids lacking in their sap diet.

Plant modification occurs when herbivores manipulate their plant prey to increase feeding. For example, some caterpillars roll leaves to reduce the effectiveness of plant defenses activated by sunlight.

The Adaptation Dance

The back and forth relationship of plant defense and herbivore offense can be seen as a sort of "adaptation dance" in which one partner makes a move and the other counters it. This reciprocal change drives coevolution between many plants and herbivores, resulting in what has been referred to as a "coevolutionary arms race". The escape and radiation mechanisms for coevolution, presents the idea that adaptations in herbivores and their host plants, has been the driving force behind speciation.

It is important to remember that while much of the interaction of herbivory and plant defense is negative, with one individual reducing the fitness of the other, some is actually beneficial. This beneficial herbivory takes the form of mutualisms in which both partners benefit in some way from the interaction. Seed dispersal by herbivores and pollination are two forms of mutualistic herbivory in which the herbivore receives a food resource and the plant is aided in reproduction.

Impacts of Herbivores

The impact of herbivory can be seen in many areas ranging from economics to ecological, and sometimes affecting both. For example, environmental degradation from white-tailed deer (Odocoileus virginianus) in the U.S. alone has the potential to both change vegetative communities through over-browsing and cost forest restoration projects upwards of $750 million annually. Agricultural crop damage by the same species totals approximately $100 million every year. Insect crop damages also contribute largely to annual crop losses in the U.S. Another area in which herbivory greatly affects economics is through the revenue generated by recreational uses of herbivorous organisms, such as hunting and ecotourism. For example, the hunting of herbivorous game species such as white-tailed deer, cottontail rabbits, antelope, and elk in the U.S. contributes greatly to the billion-dollar annually hunting industry. Ecotourism is another major source of revenue, particularly in Africa, where many large mammalian herbivores such as elephants, zebras, and giraffes help to bring in the equivalent of millions of US dollars to various nations annually.

Chapter 2

Ruffed Lemur

Ruffed lemurs

Black-and-white ruffed lemur
(*Varecia variegata*)

Scientific classification	
Kingdom:	Animalia
Phylum:	Chordata
Class:	Mammalia
Order:	Primates
Family:	Lemuridae
Genus:	***Varecia*** Gray, 1863

Type species
Lemur varius É. Geoffroy

(= *Lemur macaco variegatus* Kerr, 1792)

Species

Varecia variegata
Varecia rubra

Distribution of *Varecia* spp.
red = *V. rubra*; orange = *V. v. subcincta*;
green = *V. v. variegata*; blue = *V. v. editorum*

The **ruffed lemurs** of the genus ***Varecia*** are strepsirrhine primates and the largest extant lemurs within the family Lemuridae. Like all living lemurs, they are found only on the island of Madagascar. Formerly considered to be a monotypic genus, two species are now recognized: the black-and-white ruffed lemur, with its three subspecies, and the red ruffed lemur.

Ruffed lemurs are diurnal and arboreal quadrupeds, often observed leaping through the upper canopy of the seasonal tropical rainforests in eastern Madagascar. They are also the most frugivorous of the Malagasy lemurs, and they are very sensitive to habitat disturbance. Ruffed lemurs live in multi-male/multi-female groups and have a complex and flexible social structure, described as fission-fusion. They are highly vocal, and have loud, raucous calls.

Ruffed lemurs are seasonal breeders and highly unusual in their reproductive strategy. They are considered an "evolutionary enigma" in that they are the largest of the extant species in Lemuridae, yet exhibit reproductive traits more common in small, nocturnal lemurs, such as short gestation periods (~102 days) and relatively large average litter sizes (~2–3). Ruffed lemurs also build nests for their newborns (the only primates that do so), carry them by mouth, and exhibit an absentee parental system by stashing them while

they forage. Infants are altricial, although they develop relatively quickly, traveling independently in the wild after 70 days and attaining full adult size by six months.

Threatened by habitat loss and hunting, ruffed lemurs are facing extinction in the wild. However, they reproduce readily in captivity, and have been gradually re-introduced into the wild since 1997. Organizations that are involved in ruffed lemur conservation include the Durrell Wildlife Conservation Trust, the Lemur Conservation Foundation (LCF), the Madagascar Fauna Group (MFG), Monkeyland Primate Sanctuary in South Africa, Wildlife Trust, and the Duke Lemur Center (DLC).

Evolutionary history

No mammalian fossil record exists for Madagascar until recent times. Consequently, little is known about the evolution of ruffed lemurs, let alone the entire order Lemuriformes, which comprises the endemic primate population of the island.

Although there is still much debate about the origins of lemurs on Madagascar, it is generally accepted that a single rafting event, similar to the one that brought New World monkeys to South America, occurred around 50–80 million years ago and allowed ancestral lemurs to cross the Mozambique Channel and colonize the island, which had already split from Africa (while it was joined to the Indian subcontinent), approximately 160 million years ago. The resulting founder effect and either non-existent or inferior competition resulted in speciation as the lemur ancestors radiated out to fill open or insufficiently guarded niches. Today, the endemic primate fauna of Madagascar contains over three-quarters of the extant species of the suborder Strepsirrhini, which had been abundant throughout Laurasia and Africa during the Eocene epoch.

Taxonomic classification

Color print of the two ruffed lemur species from Alfred Grandidier's *L'Histoire politique, physique et naturelle de Madagascar*. (1892)

The ruffed lemur genus, *Varecia*, is a member of the family Lemuridae. The extinct genus, *Pachylemur* most closely resembled the ruffed lemurs but died out after the arrival of humans. The genus *Varecia* contains two species, red ruffed lemurs and black-and-white ruffed lemurs, the latter having three subspecies.

- **Family Lemuridae**
  - Genus *Eulemur*: true lemurs
  - Genus *Hapalemur*: lesser bamboo lemurs
  - Genus *Lemur*: the ring-tailed lemur

- Genus †*Pachylemur*
- Genus *Prolemur*: the greater bamboo lemur
- **Genus *Varecia***: ruffed lemurs
  - black-and-white ruffed lemur, *Varecia variegata*
    - Variegated black-and-white ruffed lemur, *Varecia variegata variegata*
    - Southern black-and-white ruffed lemur, *Varecia variegata editorum*
    - Northern black-and-white ruffed lemur, *Varecia variegata subcincta*
  - red ruffed lemur, *Varecia rubra*

Changes in taxonomy

Ruffed lemurs, along with several species of brown lemur were once included in the genus *Lemur*. In 1962, the ruffed lemurs were reassigned to the genus *Varecia*.

The red ruffed lemur and the black-and-white ruffed lemur were formerly recognized as subspecies, *Varecia variegata rubra* and *Varecia variegata variegata* respectively. In 2001 both were elevated to species status, a decision that was later supported by genetic research. Three subspecies of black-and-white ruffed lemur, which had been published decades earlier, were also recognized as *variegata*, *editorum*, and *subcincta*, although studies have not been entirely conclusive.

Subfossil remains of two extinct lemur species were initially classified under the genus *Varecia*. Found at sites in central and southwestern Madagascar, *Varecia insignis* and *V. jullyi* were very similar to modern ruffed lemurs, but more robust and assumed to be more terrestrial, and thus more prone to predation by early human settlers. More recent studies have shown that these extinct species had a diet similar to that of modern ruffed lemurs, and that they were also arboreal in nature. Enough differences were demonstrated to merit a new genus, *Pachylemur*. These close relatives of ruffed lemurs are now named *Pachylemur insignis* and *P. jullyi*.

Anatomy and physiology

Profile of a typical ruffed lemur overbite

Ruffed lemurs are the largest extant members of the family Lemuridae, with an average head-body length between 43 to 57 cm (17 to 22 in) and a total length from 100 to 120 cm (39 to 47 in), while ranging in weight from 3.1 to 4.1 kg (6.8 to 9.0 lb). The thick, furry tail is longer than the body, averaging 60 and 65 cm (24 and 26 in) in length and is used primarily for balance while moving through the trees. Ruffed lemurs exhibit neither sexual dimorphism nor sexual dichromatism, and females have three pairs of mammary glands.

Foot of a ruffed lemur, showing the toilet-claw on the second toe

Ruffed lemurs are characterized by their long, canine-like muzzle, which includes a significant overbite. The face is mostly black, with furry "ruffs" running from the ears to the neck. Depending on the species, these ruffs are either white (*V. variegata*) or deep reddish (*V. rubra*). Likewise, the coloration of the fluffy fur also varies by species, while the coloration pattern varies by subspecies in the black-and-white ruffed lemur. There are also intermediates in color variation between the two species.

As with all lemurs, the ruffed lemur has special adaptations for grooming, including a toilet-claw on its second toe, and a toothcomb.

Locomotion

Ruffed lemurs are considered arboreal quadrupeds, with the most common type of movement being above-branch quadrupedalism. While in the canopy leaping, vertical clinging, and suspensory behavior, are also common, while bridging, bimanual movement, and bipedalism are infrequently seen. When moving from tree to tree, ruffed

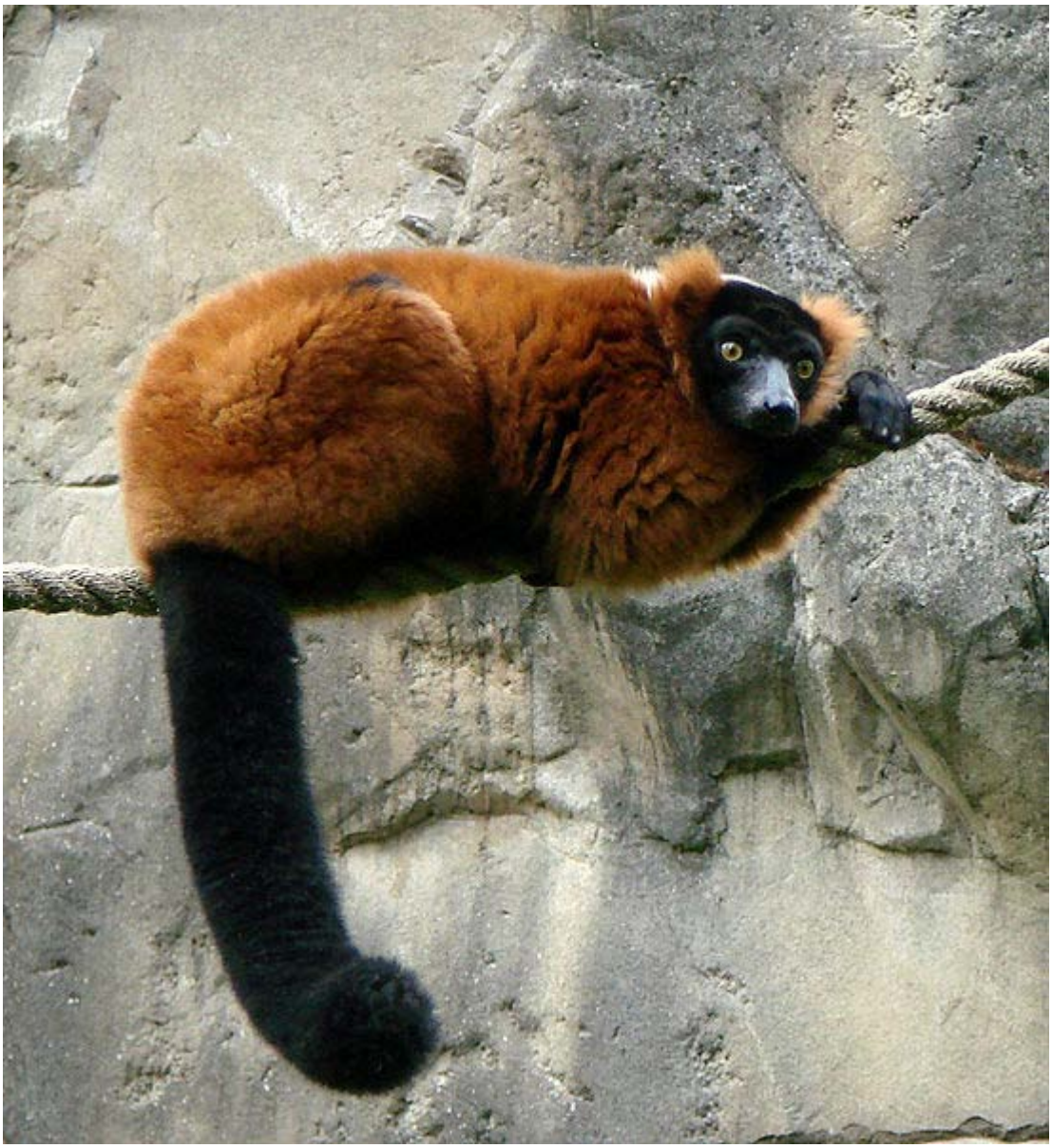
lemurs will look over the shoulder while clinging, launch themselves into the air, and twist mid-air so that their ventral surface lands on the new tree or limb. Suspensory behavior is more common in ruffed lemurs than in other lemur species. When ruffed lemurs come down to the ground, they continue to move quadrupedally, running with bounding hops and the tail held high.

Ecology

Being highly arboreal and the most frugivorous of the lemurs, they thrive only in primary forest with large fruiting trees, where they spend most of their time in the upper canopy. By spending the majority of their time in the crown of tall forest trees, they are relatively safe from predators such as the fossa.

Ruffed lemurs are active primarily during the day (diurnal), during which time they feed primarily on fruits and nectar, often utilizing suspensory postures while feeding. The seeds of the fruit they eat pass through their digestive tract and are propagated throughout the rainforests in their feces, helping to ensure new plant growth and a healthy forest ecosystem. These lemurs are also significant pollinators of the traveller's tree (*Ravenala madagascariensis*). Without destroying the inflorescence, they lick the nectar from deep inside the flower using their long muzzles and tongues, collecting and transferring pollen on their snouts and fur from plant to plant. This relationship is thought to be a result of co-evolution.

Geographic range and habitat



red ruffed lemur (*V. rubra*)

Like all lemurs, this genus is found only on the island of Madagascar off the southeastern coast of Africa. Confined to the island's seasonal eastern tropical rainforests, it is uncommon to rare throughout its range, which historically ran from the Masoala Peninsula in the northeast to the Mananara River in the south. Today, the black-and-white ruffed lemur has a much larger range than the red ruffed lemur, although it is very patchy, extending from slightly northwest of Maroantsetra, on Antongil Bay, in the north down the coast to the Mananara River near Vangaindrano in the south. Additionally, a concentrated population of black-and-white ruffed lemurs, of the subspecies *Varecia variegata subcincta*, can also be found on the island reserve of Nosy Mangabe in Antongil Bay. It is suspected that this population was introduced to the island in the

1930s. The red ruffed lemur, on the other hand, has a very restricted range on the Masoala Peninsula.

Historically, the confluence of the Vohimara and Antainambalana Rivers may have been a zone of hybridization between these two species, although no conclusive results have indicated current interbreeding. In general, the Antainambalana River appears to isolate the red ruffed lemurs from the neighboring subspecies of black-and-white ruffed lemur, *V. v. subcincta*. The subspecies *V. v. variegata* can be found further south, and *V. v. editorum* is the southernmost subspecies. The ranges of these two southern subspecies overlap and intermediate forms are reported to exist, although this has not been confirmed.

The rainforests in which these animals live are seasonal, with two primary seasons: the hot, wet season (November through April), and the cool, dry season (May through October). The primary habitat for both species, at any season, is in the crowns of trees, where they spend the majority of their time 15 and 25 m (49 and 82 ft) above ground. With the seasonal availability of resources being similar regardless of location, there is little to no difference in tree usage between species. From September through April, more fruit is available, so females prefer the lianas in the crowns of trees. Both sexes utilize the lower, major branches during the hot, rainy season. The tree crowns are predominantly used from May through August, when young leaves and flowers are in abundance.

Sympatric relations

The following lemur species can be found within the same geographic range as ruffed lemurs:

- Greater dwarf lemur (*Cheirogaleus major*)
- Eastern lesser bamboo lemur (*Hapalemur griseus griseus*)
- Weasel sportive lemur (*Lepilemur mustelinus*)
- Diademed sifaka (*Propithecus diadema*)
- Common brown lemur (*Eulemur fulvus*)
- Red-bellied lemur (*Eulemur rubriventer*)
- Eastern woolly lemur (*Avahi laniger*)
- Indri (*Indri indri*)
- Brown mouse lemur (*Microcebus rufus*)
- Aye-aye (*Daubentonia madagascariensis*)
- White-headed lemur (*Eulemur albifrons*)

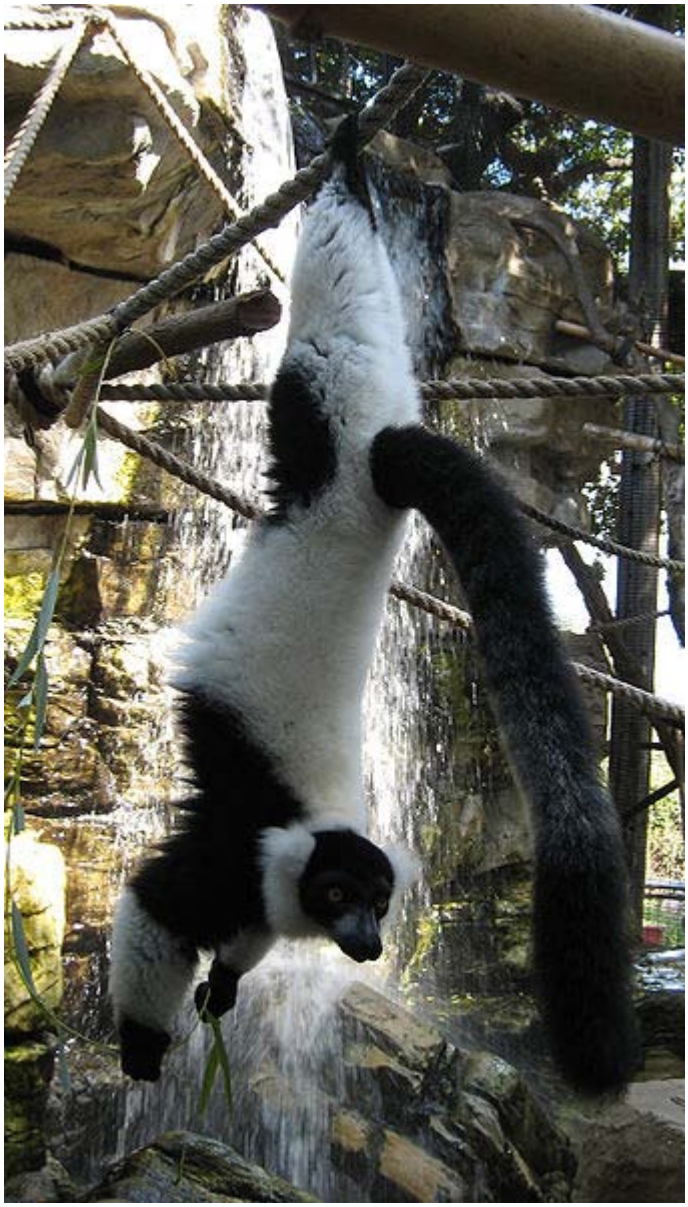
Ruffed lemurs either demonstrate feeding dominance or divide resources by using different forest strata. They are dominant over red-bellied lemurs, while eastern lesser bamboo lemurs avoid encountering them all together. White-headed lemurs, on the other hand, utilize the understory and lower canopy, below 15 m (49 ft), while the ruffed lemurs utilize the upper canopy, above 15 m (49 ft). Play has even been observed between infant ruffed lemurs and White-headed Lemurs.

Behavior

Ruffed lemurs, on average, spend 28% of the day feeding, 53% resting, and 19% traveling, although differences in resting and feeding durations have been observed between males and females, with females resting less and feeding more. They are diurnal; although peak activity occurs during the early morning and late afternoon or evening, resting usually occurs around midday. When resting, ruffed lemurs often sit hunched or upright. They are also frequently seen lying prone over a branch or sunbathing in a supine position with the limbs outstretched. When feeding, they will often hang upside-down by their hind feet, a type of suspensory behavior, which allows them to reach fruits and flowers.

Being highly arboreal, they spend the majority of their time in the high canopy throughout the day. Ruffed lemurs spend the majority of their time between 15 to 20 m (49 to 66 ft) above the forest floor, followed by 20 to 25 metres (66 to 82 ft) up, and are least frequently seen at 10 to 15 metres (33 to 49 ft). During the hot season, they will relocate to the lower canopy to help regulate their body temperature. In the cold season, ruffed lemurs are least active and may dedicate 2% of their resting time to sunbathing in order to warm up.

Long-term field research has shown that range size, group size, social systems, and territorial behavior vary widely, and may be greatly affected by food distribution and quality. It is generally agreed that the ruffed lemur social system is multi-male/multi-female with a fission-fusion society, although some populations of black-and-white ruffed lemur have been reported as monogamous. This social flexibility is suspected to improve survivability despite an inflexible feeding ecology.



Suspensory feeding by a black-and-white ruffed lemur

Diet

Being the most frugivorous members of the family Lemuridae, consuming an average of 74–90% fruit, ruffed lemurs also consume nectar (4–21%), and supplement the rest of their diet with young leaves (3–6%), mature leaves (1%), flowers (3–6%), and some seeds. Ruffed lemurs have also been reported to come to the ground to eat fungi and exhibit geophagy.

The majority of their diet is made up of relatively few common plant species, with a few species providing more than 50% of the diet. Fig species of the genus *Ficus*, for example, account for 78% of the fruit consumed by red ruffed lemurs on the Masoala Peninsula.

Although plant species and diets vary by location, the most common food plants reported from the field include the following:

- *Canarium*
- *Cryptocarya*
- *Ocotea*
- *Ravensara* (family Lauraceae)
- *Ficus*
- *Eugenia*/*Syzygium*
- *Grewia*

Fruit trees do not appear to be selected by species, but by availability and accessibility of edible fruit. And despite predominance of a few plant species in the ruffed lemur diet, the remainder of their diet consists of between 80 and 132 other species from 36 plant families.

The availability of food reflects the seasonal nature of the forests in which they live. During the hot season, fruit, flowers, and young leaves are more abundant, whereas the cold, wet season offers more young leaves and flowers. Despite this, the diet changes little between seasons, except that females will consume more high-protein, low-fiber items, such as young leaves and flowers, during pregnancy and lactation in order to offset the energy costs of reproduction. Nectar is only available sporadically, yet constitutes a major food source when the flowers bloom. The nectar of the traveller's palm (*Ravenala madagascariensis*) is a favorite among ruffed lemurs.

Social systems

The social organization of ruffed lemurs is widely variable in both group organization and group composition, although no notable difference can be seen between the two species. Ruffed lemurs are typically described as multi-male groups with a fission-fusion social structure, although this can vary by season and locality.

In a study done at Masoala Peninsula on red ruffed lemurs three levels of organization were identified and defined: communities, core groups, and subgroups. Communities are individuals that affiliated regularly with each other, but rarely with conspecifics outside of the community. Although the entire multi-male/multi-female community lives within a discrete home range, all individuals are never seen in the same location at the same time. Instead, individuals form dispersed social networks, known as core groups, within the community. Core groups are individuals that shared the same core area within a community territory throughout the year. Core groups typically consist of two reproductive females, as well as reproductive males and subadults, ranging in size from two individuals to nine. Females within the groups are cooperative, but male encounters are often agonistic. Subgroups, on the other hand, vary daily in size, composition, and duration, and consist of associated individuals from either the same core group or different core groups, depending on the season. It is from the consistent, daily changes in these subgroups that occur throughout the year, as well as the seasonal formations of core

groups in core areas, that demonstrate the fission-fusion nature of ruffed lemur social structure.

Ruffed lemur sunning position

In another study done at Nosy Mangabe on black-and-white ruffed lemurs a fourth level or organization was defined: affiliates. Affiliates were individuals with more persistent social bonds and more frequent interactions, usually within a core group, but sometimes also between core groups within a subgroup. Adult females typically had many affiliates, whereas adult males rarely interacted with conspecifics, living a more solitary existence.

Past studies have reported other social organizations in ruffed lemurs including monogamous pair bonding. This may have been due to the use of short-term, seasonal

field studies instead of yearlong studies that take into consideration the effects that changing seasons have on ruffed lemur communities. For instance, during the cold, rainy season, which corresponds with the breeding season, interactions between core groups within a community are significantly reduced. During this time small subgroups form consisting of a mature female, a mature male, and sometimes offspring. This can be misinterpreted as monogamous pair bonding.

Ranging behavior can also exhibit seasonal variability. During the hot, wet season, females range widely, either alone or in groups of up to six individuals. In the cool, dry season, smaller core groups stabilize in order to occupy concentrated areas. Therefore, during seasons when fruit is abundant, subgroups are larger while scarcity is met with more solitary behavior. This suggests that although their feeding ecology is inflexible, being tied to widely distributed, patchy, and sometimes scarce fruit, ruffed lemurs instead adapt the social system in order to survive.

In terms of dominance, the ruffed lemur's social structure is not as clear-cut as other lemur societies where female dominance is the norm. Although it is historically reported that "males were subordinate to females," especially with captive and free-ranging ruffed lemur populations demonstrating this, wild populations cannot be definitively labeled as matriarchal due to inter-group variation.

There are also social differences between males and females. Females typically have many affiliates and bond strongly with other females both within and outside their core areas, but do not affiliate with individuals outside the community range, except during mating season. Males, on the other hand, are more solitary, interact with only a couple of conspecifics, have weak social bonds with other males, and rarely associate with others outside their core group. Furthermore, field studies suggest that only females play a role in communal home range defense. Males may scent-mark and remain relatively silent, but otherwise show little involvement during disputes.

Community range or territory size can vary widely, from 16 to 197 ha (0.16 to 2.0 km^2; 0.062 to 0.76 sq mi) while group size can range from a single pair to 31 individuals. Population density is also noticeably variable. These wide ranges can be attributed to differing levels of protection and degree of environmental degradation, with better protection and a less degraded environment resulting in higher population density and more moderately sized community ranges. (The duration and seasonality of the studies involved may also have contributed to low group size estimates and community ranges. A study at the Betampona Reserve, for instance, observed monogamous pairs with two to five infants maintaining ranges of 16 to 43 ha (0.16 to 0.43 km^2; 0.062 to 0.17 sq mi).) Core areas at Ambatonikonilahy constituted approximately 10% of the overall community range and showed a close relationship with the location of the largest fruiting trees.

The average daily traveling distance for ruffed lemurs varies between 436 to 2,250 metres (1,430 to 7,380 ft), averaging 1,129 metres (3,704 ft) per day. Activity patterns within the community range vary by gender and season. Males generally stay within a core area all

year, whereas females only confine themselves to a core area during the cold wet season, then expand their range throughout the community range during the hot, rainy season. Females expand their traveling range slightly after giving birth, still staying within the core area, but gradually range further in December when they begin stashing their infants with other community members while they look for food. Females range the furthest later during the hot, rainy season. Both activity level and reproductive activity can be summarized in the following table.

Seasonal behavior

Season	Months	Stage	Reproductive cycle	Females activity	Male activity
hot, rainy season	November – April	early	Infant rearing	Expanding travel & infant stashing	Remains in core area
		late	Infant rearing	Expands travel throughout community range	Remains in core area
cool, dry season	May – October	early	Mating season	Remains in core area	Remains in core area
		late	Gestation and birth	Remains in core area & nest building	Remains in core area

Although males demonstrate little involvement in territorial disputes between neighboring communities, and ruffed lemur communities lack cohesiveness, females communally defend the community range against females of other communities. These disputes occur mostly during the hot, rainy season, when resources are more abundant and occur near the boundaries of community ranges. Spacing is maintained by scent marking and vocal communication. Ruffed lemurs are known for their loud, raucous calls that are answered by neighboring communities and subgroups within the same community.

During agonistic encounters between communities, chasing, scent-marking, calling, and occasional physical contact can be seen. Other social behaviors appear to vary between wild and captive ruffed lemurs, as illustrated by the following table.

Behavioral differences: captive vs. wild

	Wild behaviors	Captive behaviors
Aggressive/Agonistic behaviors	• attacks • cuffs • grapples • chases	• stare • charge • chase • lunge • cuff • feint-to-cuff • bipedal hop • pounce on

		• push down • bite
Submissive behaviors	• chatter vocalizations	• chatter vocalizations • displacement • head turning/eye aversion • cowering/flinching • grimacing • backing away • fleeing • jumping away
Affiliate/Affinitive behaviors	• female greeting behavior (intertwining and scent marking) • play • social grooming • squeal approach / anogenital inspections (males, mating season only)	• group movement • huddling together with bodily contact • greeting by sniffing • play (wrestling, grappling, chasing, fleeing and solitary play) • social grooming

Some affiliative behaviors are seasonal or gender-specific, such as the male squeal approach and anogenital inspections performed during the mating season. Another example is the female greeting behavior, where two females will use their anogenital scent glands to mark each other's backs, jump over one another, writhe together, and emit squealing vocalizations. This behavior is not seen during the end of the cool, dry season or around gestation. The frequency of other affiliative behaviors can be affected by age. All ruffed lemurs over five months of age allogroom, and, in captivity, subadults participate in play more frequently than adults.

Cognitive abilities

Historically, relatively few studies of learning and cognition have been performed on strepsirrhine primates, including ruffed lemurs. However, a study at the Myakka City Lemur Reserve demonstrated that ruffed lemurs, along with several other members of the family Lemuridae, could understand the outcome of simple arithmetic operations.

Communication

Olfactory communication

As with all prosimian primates, olfactory communication is used extensively by ruffed lemurs – scent marking in territorial defense and disputes, as well as female greeting displays. The scents communicate the sex, location, and identity of their owner.

Females predominantly scent mark with their anogenital scent glands, by squatting to rub their anogenital region along horizontal surfaces, such as tree limbs. Males, on the other hand, favor using the glands on their neck, muzzle, and chest, by embracing horizontal and vertical surfaces and rubbing themselves over them. Both sexes will occasionally scent mark in ways characteristic of the opposite sex.

In greeting displays, female ruffed lemurs will leap over one another, scent marking the other individual's back in the process.

Auditory communication

Ruffed lemurs are highly vocal, with an extensive vocal repertoire with calls being used in multiple contexts. Calls can also vary seasonally. During the hot, rainy season, the loud, raucous calls that are a hallmark of ruffed lemurs allow groups to remain in contact and maintain spacing. These loud calls can be heard up to 1 kilometre (0.6 mi) away.

Ruffed lemurs utilize alarm calls that differentiate between ground and aerial predators. For instance an *abrupt roar* or *huff* alerts the group to an avian predator, and a *pulsed squawk* or *growl-snort* communicates the existence of a mammalian ground predator. When sounding these calls, such as the pulsed squawk, adults direct them at the predator after moving to a safe position. Once the alarm call is sounded by one individual, the resulting chorus can even reach the furthest ranging community members.

In captivity, ruffed lemur vocalizations have been studied and divided into three general groups: high-, medium-, and low-amplitude calls.

High-amplitude calls

Call	Inferred Function
Roar/shriek chorus	• Intergroup communication and spacing • Intragroup communication (unspecified social functions)
Abrupt roar	• Signals disturbances • Promotes intergroup spacing • Avian predator alert
Pulsed squawk	• Mammalian predator alert • Indicates high arousal

	• Call group together
Wail (*V. variegata* only)	• Signals end of disturbance • Calls group together
Bray	• May serve a mating function (males only)
Quack	• May serve a mating function (males only)

The well-known *roar/shriek chorus* is spontaneous, occurring most often during period of high activity, as well as being contagious, involving communal participation including infants three to four months old. *Abrupt roars* are also more common during high activity and aside from alerting group members to the presence of an avian predator, they probably also help maintain contact with individuals outside of visual range or indicate an aggressive/defensive response to a disturbance. In the wild, both of these calls are emitted more during the hot, rainy season due to heighten activity. All high-amplitude calls are delivered with from a "taut" body posture.

Medium-amplitude calls

Call	Inferred Function
Growl	• Alerts group to low-level disturbance • Announces individual's approach
Growl-snort	• Alerts group to mammalian predator or other startling context
Chatter	• Signals submission • Signals subordinate status
Whine • **sample 1** • **sample 2**	• Behavioral frustration • Signals submission • Signals appeasement during mating season (males only)

Medium-amplitude calls operate over a shorter range or often involve moderately arousing situations, such as frustration or submission. Low-amplitude calls also generally operate over a short range, yet also cover a wider range of aggravation levels.

Whines are highly variable between individual ruffed lemurs. *Cough*, *grumble*, *squeak*, and *squeal* have only been observed and researched in the wild.

Low-amplitude calls

Call	Inferred Function
Grunt	• Indicates mild aggravation
Huff • **2 huffs** • **3 huffs**	• Indicates intense aggravation or high level arousal • Aggravation when avian predator is present
Mew • **sample 1** • **sample 2**	• Contact call between mother and infant • Occasionally used for coordination between individuals while traveling
Cough	• Aggression between a female and male during mating/birth seasons
Grumble	• Advertises the presence of a male to another
Squeak	• Infant distress signal
Squeal	• Female affiliation

The calls of ruffed lemurs vary only slightly between the two species. In fact, in captivity, it has been documented that red ruffed lemurs understand and even join in the alarm calls of black-and-white ruffed lemurs. One minor difference between the vocal repertoires of these two species is in the pulse rate and frequency of the *pulsed squawk*, which is much faster and higher in red ruffed lemurs than in black-and-white ruffed lemurs. The difference in this vocalization is only interspecific, showing no signs of significant sexual dimorphism within each species.

Red ruffed lemurs do not appear to produce a bona fide *wail* vocalization. In black-and-white ruffed lemurs, *pulsed squawks* sometimes slow down as the group calms down, and integrate with the *wail*, creating *pulsed squawk-wail intermediates*. red ruffed lemurs also produce *pulsed squawk-wail intermediate* sounds, but they do not exhibit long, drawn-out *wails* like the black-and-white ruffed lemurs.

Breeding and reproduction

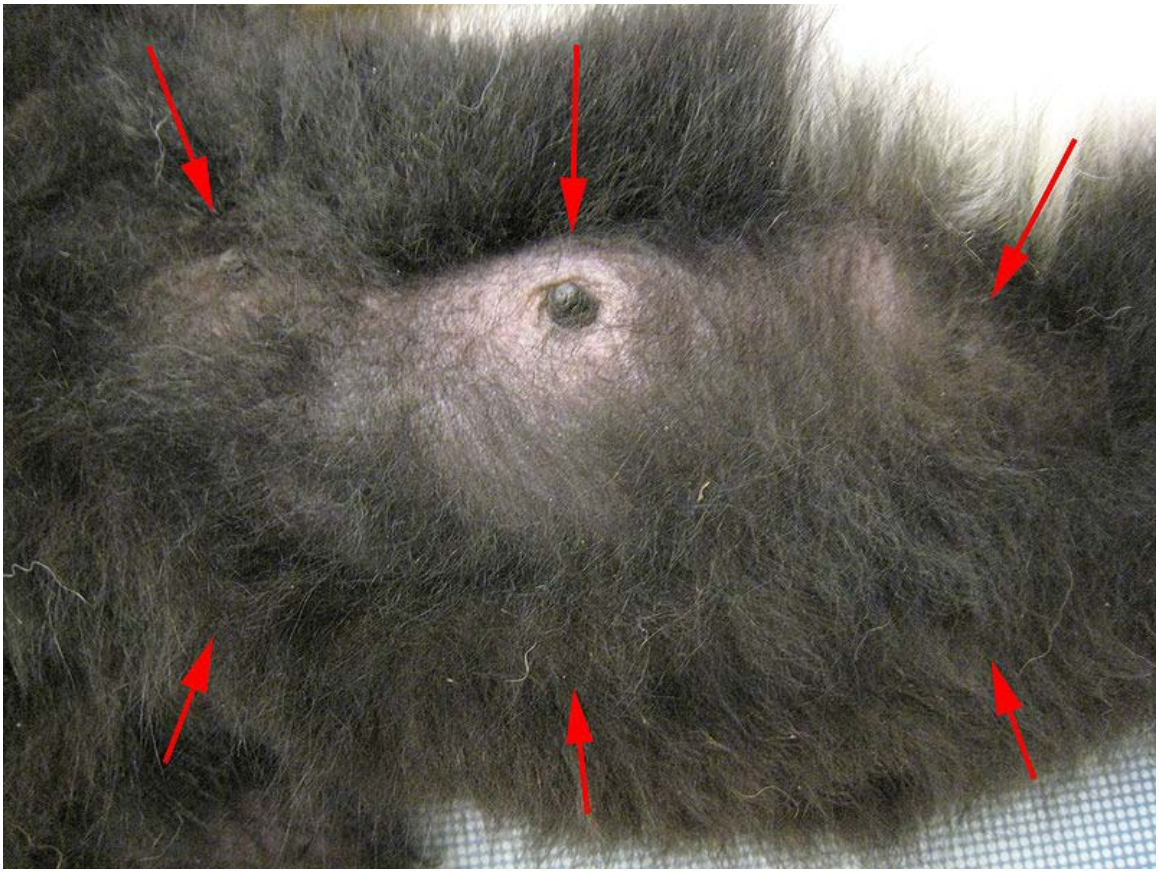
Contrary to initial reports of monogamy, ruffed lemurs in the wild exhibit seasonal polygamous breeding behavior, with both males and females mating with more than one partner within a single season. Mating is not restricted to just community members, but

also involves members of neighboring communities. Females mate primarily with males with whom they had affiliative relations prior to mating season, although some matings occurred with roaming males from other communities.

Shortly before mating season begins, females exhibit swelling of the sex skin, which reaches its peak around the middle of their 14.8 day estrous cycle. Male sexual physiology also undergoes its own change, with testicular volume increasing during mating season, peaking around the time of breeding. Aggression also increases during the mating season, both between members of the same sex and by females towards the male attempting to mate with her. Females have been observed grappling, cuffing, and biting the male during copulation. Either sex may approach the other when the female is in estrus. Initially they may *roar-shriek* with each other. When a male approaches a female he often lowers his head and squeals, inspecting the female's genitalia by licking or sniffing, scent-marking, and offering a submissive chattering vocalization. When a female approaches a male, she may posture herself for mounting. Mating pairs often copulate many times during the course of a mating bout.

The mating season lasts from May through July, during the cold, rainy season, resulting in birth and peak lactation coinciding with the time that fruit is the most plentiful. The gestation period of ruffed lemurs is the shortest of the family Lemuridae, averaging 102 days (with a range of 90 to 106 days). Gestation in the wild last slightly longer than in captivity, averaging 106 days. Just like the mating season, parturition is also seasonal, synchronized to the end of the cold, dry season and the start of the productive hot, rainy season.

In addition to an abnormally short gestation period, ruffed lemurs share another feature with small, nocturnal lemurs by producing the largest litters of the family Lemuridae. Litters typically include two or three infants, although up to five have been reported. Birth weights in captivity average between 83 to 101.7 g (2.9 to 3.59 oz) and range from 70 to 140 grams (2.5 to 4.9 oz). Ruffed lemur infants are altricial, and are born with their eyes open and a full coat of fur.



Female ruffed lemurs have three pairs of mammary glands for feeding their large litters

Ruffed lemurs are the only known primates to build arboreal nests, used exclusively for birth and for the first week or two of life. Starting three weeks prior to birth, females begin constructing the nest from twigs, branches, leaves, and vines, locating it within her core area and 10 to 25 metres (33 to 82 ft) above ground. The nests have only one apparent entry point, and are shallow and dish-shaped. During the first couple of weeks, the mother is mostly solitary and does not travel far from the nest, spending as much as 70–90% of her time with the newborns (in captivity). In order to find food, she will leave the infants alone in the nest or, after the first couple of weeks, will carry them in her mouth and stash them in concealed locations in the canopy while she forages. Since this early developmental period corresponds with the end of the cold, dry season, which offers the least amount of fruit, energy is conserved for lactation while travel is limited. As the hot, rainy season begins, fruit availability rises, lactation demands rise as well, and females increase their travel distance in search of food.

Unlike other diurnal primates, which usually carry their infants with them, ruffed lemur mothers will stash their young by concealing them in the canopy foliage, leaving them to rest and sit quietly for several hours while she forages and performs other activities. Mothers continue to transport their offspring by mouth, moving them one at a time by grasping the infant's belly crosswise. This form of transport usually stops around 2.5 months of age when the infants become too heavy to carry.

Ruffed lemurs are cooperative breeders, with parental care being shared by all community members. For example, mothers will stash their offspring with other mothers or leave them to be guarded by other community members, including non-breeding individuals of both genders. While the mother is away, community members will not only care for and guard them, but also sound alarm calls if danger is detected or if leaving the infant alone. They will also respond to alarm calls by others. These coordinated vigilance displays further involve communal transmission of the alarm call, with nearby community members repeating the alarm call, potentially summoning the mother back to her offspring. Infant transport by other members of the community has also been recorded. Females have been observed nursing infants of their close relatives, while close kin have adopted rejected infants, acting as foster parents.

Male care for infants has been documented in ruffed lemur societies. During early development, adult males may guard the nests of multiple core group females, as well as help care for the infants that were likely fathered by other males. During the season when females practice infant stashing, males effectively lighten the reproductive burden of up to several mothers by guarding, huddling, grooming, travelling, playing with and feeding the young.

Female ruffed lemurs produce relatively rich milk compared to other lemurs, and consequently, their young develop faster than those of other lemurs. Infants develop rapidly, attaining approximately 70–75% adult weight by the age of four months. They begin climbing and clinging at one month of age, advancing to the point of independently following their mother and group members through the canopy at heights of 50 to 100 metres (160 to 330 ft) by two to three months. Full adult mobility is attained at three to four months of age. Socially, they begin exchanging contact calls with their mother at three weeks, and select their mother as their play partner 75–80% of the time during the first three months. Participation in greeting displays and utilization of more extensive vocalizations commences around four months, while scent marking does not start until six months of age. Infants begin testing solid food starting around 40 days to two months with weaning occurring between four to six months in the wild, although some individuals have continued to nurse until seven to eight months.

Infant mortality is often high among ruffed lemurs, but can also be highly variable. In some seasons, as many as 65% are unable to reach three months of age, possibly due to falls and related injuries, although in some seasons infant mortality is as low as 0%. For those that do survive to adulthood, sexual maturity is attained at 18 to 20 months in females and 32 to 48 months in males. Sexual maturity may take longer to reach in the wild compared to captivity. For females, the inter-birth interval, or time between successive offspring, is typically one year, and in captivity, females can remain reproductively active until the age of 23. The life expectancy for both species of ruffed lemur is estimated at 36 years in captivity, although it is likely to be considerably less in the wild.

Conservation status

In a land where approximately 90% of the original island forest has been destroyed, ruffed lemurs cling to only a small fraction of their original range. Completely dependent upon large fruiting trees, neither species appears to be flexible with its habitat choice, with selective logging resulting in significantly lower population densities. Although they can survive in very disturbed habitats with lower population densities, they are still especially vulnerable to habitat disturbance. Decreased genetic diversity, in tandem with hunting, natural disasters, predation, and disease, can easily wipe out small populations.

The black-and-white ruffed lemur was elevated by the IUCN to Critically Endangered (A2cd) status from Endangered status in 2008. They cite that "the species is believed to have undergone a decline of 80% over a period of 27 years, due primarily to a decline in area and quality of habitat within the known range of the species and due to levels of exploitation." The total area of all known localities in which black-and-white ruffed lemurs exist is estimated at less than 8,000 km^2 (3,100 sq mi), while the total wild population is estimated between 1,000 and 10,000.

The red ruffed lemur was downgraded to Endangered status from Critically Endangered status by the IUCN in 2008. The justification given includes its limited range, its restriction to only the Masoala Peninsula, and its risk from ongoing habitat loss and hunting. This species occupies a range of no more than 4,000 km^2 (1,500 sq mi), while the total wild population is estimated between 29,000 and 52,000 individuals. Red ruffed lemurs are only protected within the boundaries of the Masoala National Park. Historically, this species has been considered more threatened due to its highly restricted range, compared to the widely distributed black-and-white ruffed lemur. However, its protection within the island's largest national park has slightly improved its chances at survival.

There are several organizations involved in ruffed lemur conservation, including the Durrell Wildlife Conservation Trust, the Lemur Conservation Foundation (LCF), the Madagascar Fauna Group (MFG), Monkeyland Primate Sanctuary in South Africa, Wildlife Trust, and the Duke Lemur Center (DLC). To conservation organizations, the ruffed lemurs are considered indicator, umbrella, and flagship species.

Threats in the wild

As with other primates, one of the principal threats to both ruffed lemur species is habitat loss due to slash-and-burn agriculture, logging, and mining. Both species appear to be very sensitive to logging, and are thought to be the most vulnerable of rainforest lemurs. The hardwoods that are favored for construction materials and selectively logged are also preferred by ruffed lemurs for their fruits and potentially affect their travel routes through the canopy. Deforestation, on the other hand, is a result of the need to provide firewood and to support subsistence agriculture and cash crops. For red ruffed lemurs, Slash-and-burn agriculture, known locally as *tavy*, is practiced seasonally on the Masoala peninsula between October and December, and its practice is expanding. Additionally, cattle are

sometimes allowed to free-range over these former agricultural clearings, preventing forest re-growth.

Another principal threat to the survival of ruffed lemurs is hunting. Local human populations still hunt and trap ruffed lemurs with traditional weapons, using them as a source of subsistence. Studies from villages in the Makira Forest have revealed that ruffed lemur meat is not only a desired food, but is being hunted unsustainably. On the Masoala peninsula, the calls of red ruffed lemurs help hunters locate them. On this peninsula, firearms are used in addition to traditional traps, known as *laly*, which involve a 5 metres (16 ft) strip of cleared forest with snares set on the few remaining branches that allow the lemurs to cross. Although hunting is illegal, the laws are generally not enforced and the local inhabitants show little concern about their hunting practices, which occur mostly from May to September. Hunting is the biggest concern in the Masoala peninsula because it is likely to continue, whereas logging and slash-and-burn agriculture could be curtailed. In other regions, hunters can scare away ruffed lemurs from their favorite food sources, even if they are hunting other prey. Lastly, these animals are taken from their natural habitats to display for tourists or are sold as exotic pets.

Frequent cyclones also pose a threat, particularly to concentrated or small populations. In late January 1997, cyclone Gretelle destroyed 80% of the Manombo forest canopy. With their habitat, including most of their food resources, effectively destroyed, the ruffed lemurs of the forest broadened their diet, remaining surprisingly frugivorous. Their body weights dropped and no births were reported for four years, but they managed to stave off starvation. This event demonstrated not only their flexibility in the face of natural disasters, which may highlight the evolutionary reasons behind their reproductive capacity and litter size, but also the threat faced by already stressed populations.

Predation in the wild appears to be very rare for ruffed lemurs, probably because living in the high canopy makes them challenging to catch. Evidence of predation by raptors, such as the Henst's Goshawk (*Accipiter henstii*) suggests it occurs at a low rate. The Fossa (*Cryptoprocta ferox*) could present a potential risk if it found an individual lower in the forest canopy, but no confirmation has been presented to indicate that they prey upon ruffed lemurs. Instead, only re-introduced, captive-bred ruffed lemurs have been killed by Fossa, likely due to their inexperience with predators. Nesting behavior poses the biggest risk of predation, making them susceptible to carnivorous mammals, such as the Ring-tailed Mongoose (*Galidia elegans*) and Brown-tailed Mongoose (*Salanoia concolor*).

Captive breeding and reintroductions

Captive populations of both ruffed lemur species exist in American and European zoos, representing a safeguard against extinction. In the United States, captive breeding is managed by the Species Survival Plan (SSP), a program developed by the Association of Zoos and Aquariums (AZA). Although the populations are very limited in their genetic diversity, these species thrive in captivity, making them an ideal candidate for reintroduction into protected habitat, if it is available. Although reintroduction is seen as a last resort among conservationists, a combination of in situ conservation efforts, such as

legal protection, public education, the spread of sustainable livelihoods, and reforestation offer hope for ruffed lemurs. In the meantime, reintroductions offer conservation research opportunities and allow the limited genetic diversity maintained by the SSP to improve the genetic diversity of dwindling Malagasy ruffed lemur populations.

A captive release first occurred in November 1997, when five black-and-white ruffed lemurs (*Varecia variegata variegata*) born in the United States were returned to Madagascar for release in the Betampona Strict Nature Reserve in eastern Madagascar. Popularly known as the *Carolina Five*, these individuals had lived their entire lives in the Natural Habitat Enclosures at the Duke Lemur Center (DLC). Since then, two more groups totaling 13 captive-born ruffed lemurs have been reintroduced into the same reserve, once in November 1998 and again in January 2001. These latter two groups also received "boot camp training" in the DLC forested free-range enclosures prior to release. So far, the results have shown some success, with 10 surviving longer than one year, 3 individuals integrating into wild groups, and 4 offspring have been born to or sired by released lemurs, all of which were parent-raised. Saraph, a male released with the first group, was reported to be doing well seven years post-release, living in a social group with a wild female and their offspring. Research has been ongoing since the initial release, as illustrated in the 1998 BBC documentary *In the Wild: Operation Lemur with John Cleese*. The research has provided useful information about their adaptation to life in the wild.

Chapter 3

Koala

Koala

female

male

Conservation status

Least Concern (IUCN 3.1)

Scientific classification

Kingdom:	Animalia
Phylum:	Chordata
Class:	Mammalia
Infraclass:	Marsupialia
Order:	Diprotodontia
Family:	Phascolarctidae
Genus:	*Phascolarctos*
Species:	***P. cinereus***

Binomial name

Phascolarctos cinereus
(Goldfuss, 1817)

Koala range
(brown — native, red — introduced)

The **koala** *(Phascolarctos cinereus)* is an arboreal herbivorous marsupial native to Australia, and the only extant representative of the family Phascolarctidae.

The koala is found in coastal regions of eastern and southern Australia, from Adelaide to the southern part of Cape York Peninsula. Populations also extend for considerable distances inland in regions with enough moisture to support suitable woodlands. The koalas of South Australia were largely exterminated during the early part of the 20th century, but the state has since been repopulated with Victorian stock. The koala is not found in Tasmania or Western Australia.

Names

The word *koala* comes from the Dharuk *gula*. Although the vowel /u/ was originally written in the Latin alphabet as "oo" (in spellings such as *coola* or *koolah*), it was changed to "oa" possibly due to an error. The word is erroneously said to mean "doesn't drink".

The scientific name of the koala's genus, *Phascolarctos*, is derived from Greek *phaskolos* "pouch" and *arktos* "bear". Its species name, *cinereus*, is Latin and means "ash-coloured".

Although the koala is not a bear, English-speaking settlers from the late 18th century first called it *koala bear* due to its similarity in appearance to bears. Although taxonomically incorrect, the name *koala bear* is still in use today outside Australia — its use is discouraged because of the inaccuracy in the name. Other descriptive English names based on "bear" have included *monkey bear*, *native bear*, and *tree-bear*.

Variation

A Southern koala on Kangaroo Island, not native to the island

Although three subspecies have been described, these are arbitrary selections from a cline and are not generally accepted as valid. Following Bergmann's Rule, individuals from the southern cooler climates are larger.

A typical Victorian koala (formerly *P. cinereus victor*) has longer, thicker fur, is a darker, softer grey, often with chocolate-brown highlights on the back and forearms, and has a more prominently light-coloured ventral side and fluffy white ear tufts. Typical and New South Wales koala weights are 12 kg (26 lb) for males and 8.5 kg (19 lb) for females. In tropical and sub-tropical Queensland, however, the koala is smaller (at around 6.5 kg (14 lb) for an average male and just over 5 kg (11 lb) for an average female), a lighter often rather scruffy grey in colour, and has shorter, thinner fur. In Queensland, the koala was previously classified as the subspecies *P. cinereus adustus*, and the intermediate forms in New South Wales as *P. cinereus cinereus*. A fourth variation, though not technically a subspecies, is *Phascolarctos cinereus aurum*, or in English "golden koala", which has a slight golden tinge to the fur as a result of an absence of the melanin pigment that produces albinism in most other mammalian species. The variation from one form to another is continuous and there are substantial differences between individual koalas in any given region such as hair colour. Koalas may also have white fur in rare cases due to a recessive gene.

The origins of the koala are unclear, although almost certainly they descended from terrestrial wombat-like animals. Koala fossils are quite rare, but some have been found in northern Australia dating to 20 million years ago. During this time, the northern half of Australia was rainforest. The koala did not specialise in a diet of eucalyptus until the climate cooled and eucalypt forests grew in the place of rainforests. The fossil record indicates that before 50,000 years ago, giant koalas inhabited the southern regions of Australia. The koala fills the same ecological role as the sloths of South America.

Physical description

Female

Koalas have a slow metabolism and sleep for most of the day

The koala is broadly similar in appearance to the wombat (its closest living relative), but has a thicker coat, much larger ears, and longer limbs. The koala has large, sharp claws to assist with climbing tree trunks. Weight varies from about 14 kg (31 lb) for a large southern male, to about 5 kg (11 lb) for a small northern female. The koala's five fingers include two opposable thumbs, providing better gripping ability. The first two fingers are positioned in apposition on the front paws, and the first three fingers for the hind paws. The koala is one of the few mammals (other than primates) that has fingerprints. Koala fingerprints are similar to human fingerprints; even with an electron microscope, it can be quite difficult to distinguish between the two.

A Koala Skeleton

The teeth of the koala are adapted to their herbivorous diet, and are similar to those of other diprotodont marsupials, such as kangaroos and wombats. They have sharp incisors to clip leaves at the front of the mouth, separated from the grinding cheek teeth by a wide diastema. The dental formula for koalas is:

Dentition

3.1.1.4

1.0.1.4

The male koala, like many marsupials, has a bifurcated penis. The female has two lateral vaginas and two separate uteri, which is common to all marsupials.

Koalas walk on all four legs when walking on the ground, joey clinging to the back

The brain in the ancestors of the modern koala once filled the whole cranial cavity, but has become drastically reduced in the present species, a degeneration scientists suspect is an adaptation to a diet low in energy. One of the smallest in marsupials with no more than 0.2% of its body weight, about 40% of the cranial cavity is filled with cerebrospinal fluid, while the brain's two cerebral hemispheres are like "a pair of shrivelled walnut halves on top of the brain stem, in contact neither with each other nor the bones of the skull. It is the only animal on Earth with such a strangely reduced brain."

It is generally a silent animal, but males have a very loud advertising call that can be heard from almost a kilometre away during the breeding season. Females glean clues regarding a male's suitability as a mate from these calls, showing a preference for larger males. When under stress, koalas may issue a loud cry, which has been reported as similar to that of a human baby. There is little reliable information about the lifespan of the koala, but in captivity they have been observed to reach the age of 18 years.

Life cycle

A young joey, preserved at Port Macquarie Koala Hospital

Baby koala on a mothers back

Baby koala at Currumbin Wildlife Sanctuary

Females reach maturity at 2 to 3 years of age, males at 3 to 4 years. A healthy female koala can produce one young each year for about 12 years. Gestation is 35 days. Twins are very rare; the world's first confirmed identical twin koalas, named "*Euca*" and "*Lyptus*", were born at the University of Queensland in April 1999. Mating normally occurs between December and March, the Southern Hemisphere's summer.

A baby koala is referred to as a joey and is hairless, blind, and earless. At birth the joey, only a quarter of an inch long, crawls into the downward-facing pouch on the mother's belly (which is closed by a drawstring-like muscle that the mother can tighten at will) and attaches itself to one of the two teats.

Young remain hidden in the pouch for about six months, only feeding on milk. During this time they grow ears, eyes, and fur. The joey then begins to explore outside of the pouch. At about this stage it begins to consume small quantities of the mother's "pap" (formerly thought to be excrement, but now thought to come from the mother's cecum) in

order to inoculate its gut with the microbes necessary to digest eucalypt leaves. The joey will remain with its mother for another six months or so, riding on her back, and feeding on both milk and eucalypt leaves until weaning is complete at about 12 months of age. Young females disperse to nearby areas at that time; young males often stay in the mother's home range until they are two or three years old.

Diet and behaviour

Koala with joey in pouch

Koala dozing during the day

The koala lives almost entirely on eucalypt leaves. This is likely to be an evolutionary adaptation that takes advantage of an otherwise unfilled ecological niche, since eucalypt leaves are low in protein, high in indigestible substances, and contain phenolic and terpene compounds that are toxic to most species. Like wombats and sloths, the koala has a very low metabolic rate for a mammal and rests motionless for about 16 to 18 hours a day, sleeping most of that time. Koalas can be aggressive towards each other, throwing a foreleg around their opponent and biting, though most aggressive behavior is brief squabbles. Handling koalas may cause them stress, and the issue of aggression and stress from handling is a political issue in Australia.

Koalas spend about three of their five active hours eating. Feeding occurs at any time of day, but usually at night. Koalas eat an average of 500 g (18 oz) of eucalypt leaves each day, chewing them with powerful jaws to a very fine paste before swallowing. The liver deactivates the toxic components ready for excretion, and the hind gut (especially the cecum) is greatly enlarged to extract the maximum amount of nutrient from the poor quality diet. Much of this is done through bacterial fermentation: while young are being weaned, the mother passes these essential digestive aids on to her offspring.

A koala eating eucalyptus

Koala in tree, scratching & grooming

The koala will eat the leaves of a wide range of eucalypts, and occasionally even some non-eucalypt species such as *Acacia*, *Leptospermum*, and *Melaleuca*. It has firm preferences for particular varieties of eucalypt and these preferences vary from one region to another: in the south Manna Gum, Blue Gum, and Swamp Gum are favoured; Grey Gum and Tallowwood are important in the north, and the ubiquitous River Red Gum of the isolated seasonal swamps and watercourses that meander across the dry inland plains allows the koala to live in surprisingly arid areas. Many factors determine which of the 680 species of eucalypt trees the koala eats. Among trees of their favourite species, however, the major factor that determines which individual trees the koala chooses is the concentration of a group of phenolic toxins called formylated phloroglucinol compounds. Researches on koalas by keepers at 13 wildlife parks and zoos in New South Wales show that the most preferred group of Eucalyptus foliage had the lowest content of condensed tannins.

Conservation status

A Koala, Victoria, Australia.

The Australian government currently lists the koala as a priority species for conservation status assessment. Government estimates of the national koala population numbers in the hundreds of thousands, although other studies have estimated as few as 80,000 koalas left in the wild. The Australian Koala Foundation estimates there are around 100,000 koalas left in the wild.

As with most native Australian animals, the koala cannot legally be kept as a pet in Australia or anywhere else. The only people who are permitted to keep koalas are wildlife carers and, occasionally, research scientists. These individuals are issued with special permits to care for koalas, but have to return them to the wild when they are either well enough or, in the case of joeys, old enough.

The IUCN lists the species as "Least Concern". The Australian government does not consider the species to be threatened, although the US government has declared the koala a threatened species.

The koala inhabits four Australian states. Under state legislation, the species is listed as:

- Queensland — Common, or "Least Concern Wildlife" throughout the state, except in the South East Queensland bioregion, where it is listed as *vulnerable*.

- New South Wales — listed at a state scale as *vulnerable*, but varying regionally from *secure* to *locally extinct*.
- South Australia — classified as *rare*.
- Victoria — The koala population in Victoria was considered *large and thriving*, according to an article which was last reviewed on 29 October 2007.

The koala was hunted almost to extinction in the early 20th century, largely for its fur. Millions of furs were traded to Europe and the United States, and the population has not fully recovered from such decimations. Extensive cullings occurred in Queensland in 1915, 1917, and again in 1919 when over one million koalas were killed with guns, poisons, and nooses. The public outcry over the cullings was most likely the first wide-scale environmental issue that rallied Australians. Despite the growing movement to protect native species, the poverty brought about by the drought of 1926–28 led to another 600,000 koalas being killed during a one-month open season in August 1927.

Today, habitat loss and the impacts of urbanisation (such as dog attacks and traffic accidents) are the leading threats to the survival of the koala. In recent years, some colonies have been hard hit by disease, especially chlamydia. The koala requires large areas of healthy, connected forest and will travel long distances along tree corridors in search of new territory and mates. The increasing human population of the coastal parts of the continent continues to cut these corridors by agricultural and residential development, forestry, and road-building, marooning koala colonies in decreasing areas of bush. The long term viability of the koala is therefore threatened by genetic weakness. The Australian Koala Foundation is the principal organisation dedicated to the conservation of the koala and its habitat, mapping 40,000 km^2 (15,000 sq mi) of land for koala habitat and claiming strong evidence that wild koala populations are in serious decline throughout the species' natural range. Local councils in growing urban areas with koala populations that have established or are in the process of establishing planning overlays and controls to preserve habitat for koalas include the Victorian councils of City of Ballarat, Macedon Ranges Shire and Glenelg Hopkins Catchment Management Authority as well as the Queensland councils of Moreton Bay Regional Council, Redland Shire Council.

Although the species covers a large area, only 'pieces' of koala habitat remain. Presently, many habitats are lost to weeds, clearance for agriculture, or carved up by developers. Other threats come from logging, poor management, attacks from feral and domestic animals, diseases, and roads.

Pest status

A koala at Healesville Sanctuary

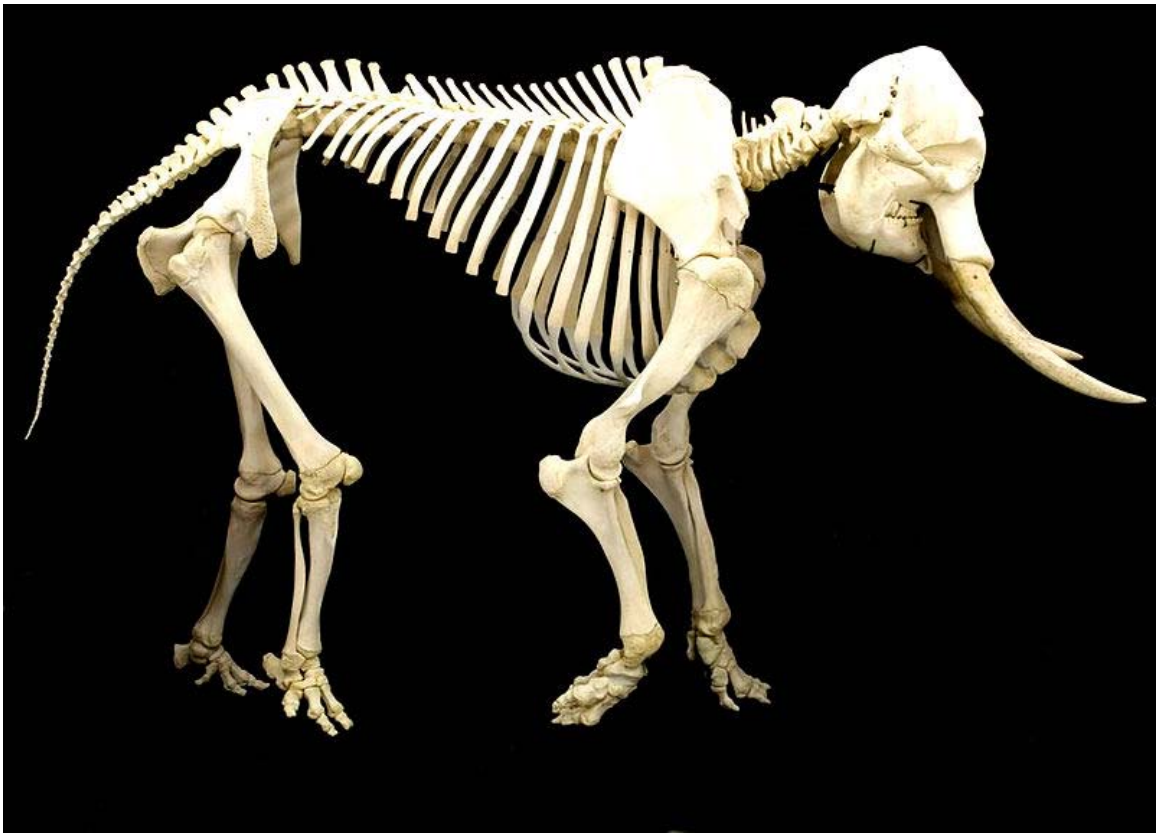
In contrast to the situation on much of the mainland, where populations are declining, koalas, like many other species, can overrun smaller islands or isolated regions where they have been introduced. On Kangaroo Island in South Australia, koalas introduced some 90 years ago have thrived in the absence of predators and competition. Combined with an inability to migrate to new areas, this has caused the koala populations to become unsustainable and threaten the island's unique ecology. In particular, species of Manna Gum, native to the island, are being stripped by koalas at a rate faster than they can regenerate, endangering local birds and invertebrates that rely on them, and causing the extinction of at least one isolated population of manna. Koala numbers are estimated at over 30,000, with ecologists suggesting that the island can sustain 10,000 at most.

Although culling has been suggested as a means to reduce koala numbers, with the South Australian government seriously considering such in 1996, this has met with fierce opposition both domestically and internationally, and the species remains protected. The popularity of the koala has made the possibility of a cull politically improbable, with any negative perception likely to impact tourism and a government's electability. In place of a cull, sterilization and relocation programs have had only limited success in reducing numbers thus far, and remain expensive. There is evidence that koalas relocated to the mainland have difficulty establishing themselves in the different circumstances. A mooted alternative to the complex sterilization method, wherein the animal must first be captured, are hormonal implants that can be injected via darts.

Chapter 4

Elephant

African bush elephant



African elephant skeleton

Asian (*Elephas maximus*) and African (*Loxodonta*) elephants.

Elephants are large land mammals in two genera of the family Elephantidae: *Elephas* and *Loxodonta*. Three species of elephant are living today: the African bush elephant, the African forest elephant and the Asian elephant (also known as the Indian elephant). All other species and genera of Elephantidae are extinct, some since the last ice age although dwarf forms of mammoths may have survived as late as 2,000 BCE. Elephants and other Elephantidae were once classified with other thick-skinned animals in a now invalid order, Pachydermata.

Elephants are the largest land animals now living. The elephant's gestation period is 22 months, the longest of any land animal. At birth it is common for an elephant calf to weigh 120 kilograms (260 lb). They typically live for 50 to 70 years, but the oldest recorded elephant lived for 82 years. The largest elephant ever recorded was shot in Angola in 1956. This male weighed about 24,000 lb (11,000 kg), with a shoulder height of 3.96 metres (13.0 ft), a metre (yard) taller than the average male African elephant. The smallest elephants, about the size of a calf or a large pig, were a prehistoric species that lived on the island of Crete during the Pleistocene epoch.

Elephants are a symbol of wisdom in Asian cultures and are famed for their memory and intelligence, where their intelligence level is thought to be equal to that of dolphins and primates. Aristotle once said the elephant was "the beast which passeth all others in wit and mind." The word "elephant" has its origins in the Greek ἐλέφας, meaning "ivory" or "elephant".

According to observations, healthy adult elephants have no natural predators, although lions may take calves or weak individuals. They are, however, threatened by human intrusion and poaching.

Etymology

Olifant and its variations (ex. *oliphant*, *olyphant*) are archaic spellings of *elephant*. Aside from elephants, the word has been used to refer to ivory, elephant tusks, musical horns made of elephant tusks, or a musical instrument resembling such horns.

It appears in Middle English as *olifant* or *olifaunt*, and was borrowed from Medieval French *olifanz*. The French word owes something to both Old High German *olbenta* "camel", and to Latin *elephantus* "elephant", a word of Greek origin. OHG *olbenta* is a word of old Germanic origin; cf. Gothic *ulbandus* also meaning "camel". But the form of the OHG and Gothic words suggests it is also a borrowing, perhaps indeed directly or indirectly from Greek "ἐλέφας" (*elephas*), which in Homer only meant "ivory" but from Herodotus and on the word also referred to the animal. The earliest attested form of the word is the Mycenaean Greek *e-re-pa-to*, written in Linear B syllabic script.

Taxonomy and evolution

Physical difference between an Asian (left) and African (right) elephant.

The African elephant genus contains two or, arguably, three living species; whereas the Asian elephant species is the only surviving member of the Asian elephant genus, but can be divided into four subspecies. The African and the Asian elephant diverged from a common ancestor some 7.6 million years ago.

African elephant

Elephant crossing a river, Kenya.

African bush (savanna) elephant in Etosha National Park, Namibia.

elephants in the wild

The Elephants of the genus *Loxodonta*, known collectively as African elephants, are currently found in 37 countries in Africa.

African elephants are distinguished from Asian elephants in several ways, the most noticeable being their much larger ears. Also, the African elephant is typically larger than the Asian elephant and has a concave back. In Asian elephants, only males have tusks, but both males and females of African elephants have tusks and are usually less hairy than their Asian cousins.

African elephants have traditionally been classified as a single species comprising two distinct subspecies, namely the savanna elephant (*Loxodonta africana africana*) and the forest elephant (*Loxodonta africana cyclotis*), but recent DNA analysis suggests that these may actually constitute distinct species. This split is not universally accepted by experts. A third species of African elephant has also been proposed.

The authors of an analysis of nuclear DNA extracted from "African savanna elephant, African forest elephant, Asian elephant, the extinct American mastodon, and the woolly mammoth" concluded in 2010 that African savanna and forest elephants are indeed separate species:

We unequivocally establish that the Asian elephant is the sister species to the woolly mammoth. A surprising finding from our study is that the divergence of African savanna and forest elephants—which some have argued to be two populations of the same species—is about as ancient as the divergence of Asian elephants and mammoths. Given their ancient divergence, we conclude that African savanna and forest elephants should be classified as two distinct species.

This reclassification has implications for conservation. If there are two separate species, each will be less abundant (particularly the rarer) and could be more endangered than a more numerous and wide-ranging single species. There is also a potential danger that if the forest elephant is not explicitly listed as an endangered species, poachers and smugglers might be able to evade the law forbidding trade in endangered animals and their products.

The forest elephant and the savanna elephant can hybridize (interbreed), though their preferences for different terrains reduce such opportunities. As the African elephant has only recently been recognized to comprise two separate species, groups of captive elephants have not been comprehensively classified and some could well be hybrids.

Under the new two species classification, *Loxodonta africana* refers specifically to the savanna elephant, the largest of all elephants. It is the largest land animal, with males standing 3.2 metres (10 ft) to 4 metres (13 ft) at the shoulder and weighing 3,500 kilograms (7,700 lb) up to a reported 12,000 kilograms (26,000 lb). The female is smaller, standing about 3 metres (9.8 ft) at the shoulder. Most often, savanna elephants are found in open grasslands, marshes, and lakeshores. They range over much of the savanna zone south of the Sahara.

The other putative species, the forest elephant (*Loxodonta cyclotis*), is usually smaller and rounder, and its tusks thinner and straighter compared with the savanna elephant. The

forest elephant can weigh up to 4,500 kilograms (9,900 lb) and stand about 3 metres (10 ft) tall. Much less is known about these animals than their savanna cousins, because environmental and political obstacles make them difficult to study. Normally, they inhabit the dense African rain forests of central and western Africa, although occasionally they roam the edges of forests, thus overlapping the savanna elephant home ranges and hybridizing. In 1979, Iain Douglas-Hamilton estimated the continental population of African elephants at around 1.3 million animals. This estimate is controversial and is believed to be a gross overestimate,, but it is very widely cited and has become a *de facto* baseline that continues to be incorrectly used to quantify downward population trends in the species. Through the 1980s, *Loxodonta* received worldwide attention due to the dwindling numbers of major populations in East Africa, largely as a result of poaching. According to IUCN's African Elephant Status Report 2007, there are between 470,000 and 690,000 African elephants in the wild. Although this estimate only covers about half of the total elephant range, experts do not believe the true figure to be much higher, as it is unlikely that large populations remain to be discovered. By far, the largest populations are now found in southern and eastern Africa, which together account for the majority of the continental population. According to a recent analysis by IUCN experts, most major populations in eastern and southern Africa are stable or have been steadily increasing since the mid-1990s, at an average rate of 4.5% per year.

Elephant populations in West Africa, on the other hand, are generally small and fragmented, and only account for a small proportion of the continental total. Much uncertainty remains as to the size of the elephant population in central Africa, where the prevalence of forest makes population surveys difficult, but poaching for ivory and bushmeat is believed to be intense through much of the region. South African elephant population more than doubled, rising from 8,000 to over 20,000, in the thirteen years after a 1995 ban on the trade in elephant ivory. The ban on the ivory trade in southern Africa (but not elsewhere) was lifted in February 2008, sparking controversy among environmental groups.

Asian elephant

A temple elephant in Kerala, India.

The Asian elephant, *Elephas maximus*, is smaller than the African. It has smaller ears, and typically, only the males have large external tusks.

The world population of Asian elephants—also called Indian elephants—is estimated to be around 60,000, about a tenth of the number of African elephants. More precisely, it is estimated that there are between 38,000 and 53,000 wild elephants and between 14,500 and 15,300 domesticated elephants in Asia, with perhaps another 1,000 scattered around zoos in the rest of the world. The Asian elephants' decline has possibly been more gradual than the African and caused primarily by poaching and habitat destruction by human encroachment.

A decorated Indian elephant in Jaipur, India.

Elephant orphanage in Sri Lanka

Several subspecies of *Elephas maximus* have been identified, using morphometric data and molecular markers. *Elephas maximus maximus* (Sri Lankan elephant) is found only on the island of Sri Lanka. It is the largest of the Asians. There are an estimated 3,000–4,500 members of this subspecies left today in the wild, although no accurate census has been carried out recently. Large males can weigh upward to 5,400 kg (12,000 lb) and stand over 3.4 m (11 ft) tall. Sri Lankan males have very large cranial bulges, and both sexes have more areas of depigmentation than other Asians. Typically, their ears, face, trunk, and belly have large concentrations of pink-speckled skin. There is an orphanage for elephants in Pinnawala, Sri Lanka, which plays a large role in protecting the Sri Lankan elephant from extinction.

Elephas maximus indicus (Indian elephant) makes up the bulk of the Asian elephant population. Numbering approximately 36,000, these elephants are lighter grey in colour, with depigmentation only on the ears and trunk. Large males will ordinarily weigh only about 5,000 kg (11,000 lb), but are as tall as the Sri Lankan. The mainland Asian can be found in 11 Asian countries, from India to Indonesia. They prefer forested areas and transitional zones, between forests and grasslands, where greater food variety is available.

The Sumatran elephant, *Elephas maximus sumatranus*, found only on Sumatra, is smaller than the Indian elephant. Population estimates for this group range from 2,100 to 3,000 individuals. It is very light grey in colour and has less depigmentation than the other Asians, with pink spots only on the ears. Mature Sumatrans will usually only measure 1.7–2.6 m (5.6–8.5 ft) at the shoulder and weigh less than 3,000 kg (6,600 lb). It is

considerably smaller than its other Asian (and African) cousins and exists only on the island of Sumatra, usually in forested regions and partially wooded habitats.

In 2003, a further subspecies was identified on Borneo. Named the Borneo pygmy elephant, it is smaller and tamer than any other Asian elephants. It also has relatively larger ears, longer tail and straighter tusks.

Physical characteristics

Trunk

Trunk of African (left) and Asian (right) elephant.

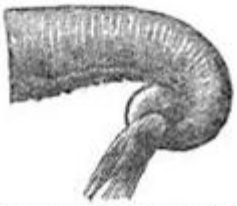
Anterior termination of elephant's trunk (profile).

Anterior extremities of the trunks of male (A) and female elephants (B).

Action of anterior extremity of proboscis in gathering long herbage.

Mode of holding herbage when gathered.

Mode of holding a root till enough is collected for a mouthful.



Curled action, when a powerful grasp and much force is required.

Articulation of elephant trunk.

An elephant can use its trunk for a variety of purposes. This one is wiping its eye.

Eye of an Asian elephant.

The proboscis, or trunk, is a fusion of the nose and upper lip, elongated and specialized to become the elephant's most important and versatile appendage. African elephants are equipped with two fingerlike projections at the tip of their trunk, while Asians have only one. The elephant's trunk is sensitive enough to pick up a single blade of grass, yet strong enough to rip the branches off a tree.

Most herbivores (plant eaters, like the elephant) possess teeth adapted for cutting and tearing off plant materials. However, except for the very young or infirm, elephants always use their trunks to tear up their food and then place it in their mouths. They will graze on grass or reach up into trees to grasp leaves, fruit, or entire branches. If the desired food item is too high up, the elephant will wrap its trunk around the tree or branch and shake its food loose or sometimes simply knock the tree down altogether.

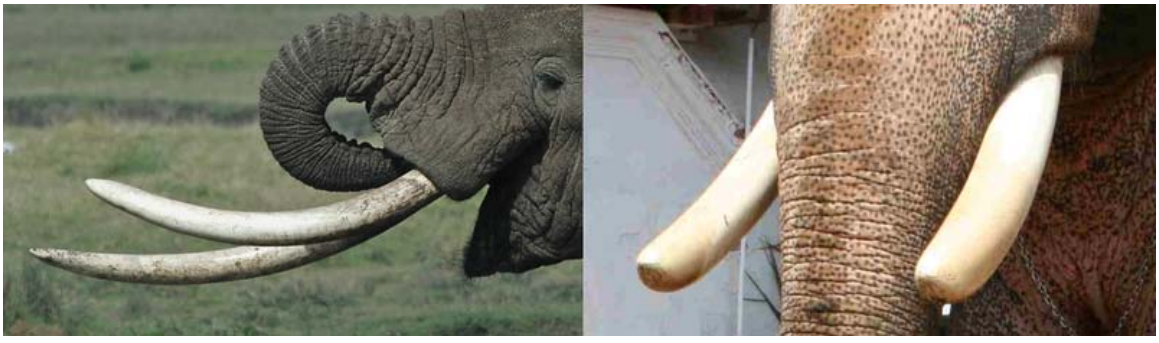
The trunk is also used for drinking. Elephants suck water up into the trunk—up to 14 litres (15 quarts) at a time—and then blow it into their mouths. Elephants also suck up water to spray on their bodies during bathing. On top of this watery coating, the animals will then spray dirt and mud, which dries and acts as a protective sunscreen. When swimming, the trunk makes an excellent snorkel.

This appendage also plays a key role in many social interactions. Familiar elephants will greet each other by entwining their trunks, much like a handshake. They also use them while play-wrestling, caressing during courtship and mother-child interactions, and for dominance displays; a raised trunk can be a warning or threat, while a lowered trunk can be a sign of submission. Elephants can defend themselves very well by flailing their trunks at unwanted intruders or by grasping and flinging them.

An elephant also relies on its trunk for its highly developed sense of smell. By raising the trunk up in the air and swiveling it from side to side, like a periscope, it can determine the location of friends, enemies, and food sources.

Some elephants have been afflicted by floppy trunk syndrome.

Tusks



Tusks of African and Asian elephants.

The tusks of an elephant are its second upper incisors. Tusks grow continuously; an adult male's tusks grow about 18 cm (7 in) a year. Tusks are used to dig for water, salt, and roots; to debark trees to eat the bark; to dig into baobab trees to get at the pulp inside; and to move trees and branches when clearing a path. In addition, they are used for marking trees to establish territory, and occasionally as weapons.

Like humans who are typically right- or left-handed, elephants are usually right- or left-tusked. The dominant tusk, called the master tusk, is generally shorter and more rounded at the tip from wear. Both male and female African elephants have large tusks that can reach over 3 m (10 ft) in length and weigh over 90 kg (200 lb). In the Asian species, only the males have large tusks. Female Asians have tusks which are very small or absent altogether. Asian males can have tusks as long as the much larger Africans, but they are usually much slimmer and lighter; the heaviest recorded is 39 kg (86 lb). The tusk of both species is mostly made of calcium phosphate in the form of apatite. As a piece of living tissue, it is relatively soft (compared with other minerals such as rock), and the tusk, also known as ivory, is strongly favoured by artists for its carvability. The desire for elephant ivory has been one of the major factors in the reduction of the world's elephant population.

Some extinct relatives of elephants had tusks in their lower jaws in addition to their upper jaws, such as *Gomphotherium*, or only in their lower jaws, such as *Deinotherium*.

Teeth

Elephants' teeth are very different from those of most other mammals. Over their lives they usually have 28 teeth. These are:

- The two upper second incisors: these are the tusks.
- The milk precursors of the tusks.
- 12 premolars, 3 in each side of each jaw.
- 12 molars, 3 in each side of each jaw.

Replica of an Asian elephant's molar, showing upper side.

This gives elephants a dental formula of: $\frac{1.0.3.3}{0.0.3.3}$

Unlike most mammals, which grow baby teeth and then replace them with a permanent set of adult teeth, elephants have cycles of tooth rotation throughout their entire lives. The tusks have milk precursors, which fall out quickly and the adult tusks are in place by one year of age, but the chewing teeth are replaced five or, very rarely, six times in an elephant's lifetime.

Only four chewing teeth (premolars and/or molars), one on each side of each jaw, are in primary use at any given time (or two, as one replaces the other at each location). Adult teeth do not replace milk teeth by emerging from the jaws vertically as human teeth do. Instead, new teeth grow in at the back of the mouth, pushing older teeth toward the front, where the latter break off in pieces until they are gone. In African elephants, the first two sets of chewing teeth (premolars) are in place when an elephant is born. The first chewing tooth on each side in each jaw falls out when the elephant is about two years old. The second set of chewing teeth falls out when the elephant is about six years old. The third set is lost at 13 to 15 years of age, and set four lasts to approximately 28 years of age. The fifth set of chewing teeth (molars) lasts until the elephant is in its early 40s. The sixth (and usually final) set must last the elephant the rest of its life. If an elephant lives to more than 60 years of age, the last set of molars is worn to stumps, and it can no longer feed properly. Moss reports a female elephant in its sixties whose final set of molars were worn smooth and about one-quarter of their original size and who survived "with extra chewing and longer feeding bouts." Abscesses of chewing teeth, as well as of tusks and jaws, are common in elephants, and may lead to premature death.

Tusks in the lower jaw are also second incisors. These grew out large in *Deinotherium* and some mastodons, but in modern elephants they disappear early without erupting.

Skin

Skin of an African (left) and Asian (right) elephant.

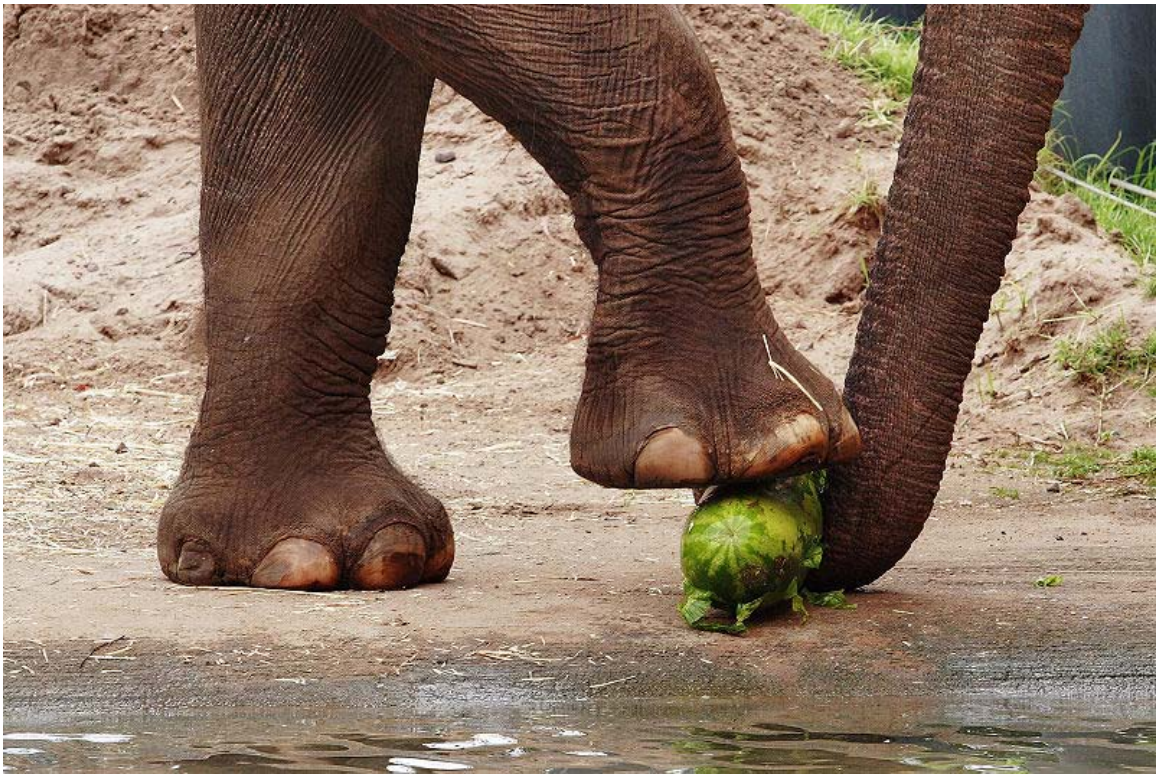
African elephant bathing

Elephants are colloquially called *pachyderms* (from their original scientific classification), which means thick-skinned animals. An elephant's skin is extremely tough around most parts of its body and measures about 2.5 centimetres (1.0 in) thick. However, the skin around the mouth and inside of the ear is considerably thinner. Normally, the skin of an Asian is covered with more hair than its African counterpart. This is most noticeable in the young. Asian calves are usually covered with a thick coat of brownish red fuzz. As they get older, this hair darkens and becomes more sparse, but it will always remain on their heads and tails.

The species of elephants are typically greyish in colour, but the Africans very often appear brown or reddish from wallowing in mud holes of colored soil. Wallowing is an important behaviour in elephant society. Not only is it important for socialization, but the mud acts as a sunscreen, protecting its skin from harsh ultraviolet radiation. Although tough, an elephant's skin is very sensitive. Without regular mud baths to protect it from burning, as well as from insect bites and moisture loss, an elephant's skin would suffer serious damage. After bathing, the elephant will usually use its trunk to blow soil on its body to help dry and bake on its new protective coat. As elephants are limited to smaller and smaller areas, there is less water available, and local herds will often come too close over the right to use these limited resources.

Wallowing also aids the skin in regulating body temperatures. Elephants have difficulty in releasing heat through the skin because, in proportion to their body size, they have very little of it. The ratio of an elephant's mass to the surface area of its skin is many times that of a human. Elephants have even been observed lifting up their legs to expose the soles of their feet, presumably in an effort to expose more skin to the air. Since wild elephants live in very hot climates, they must have other means of getting rid of excess heat.

Legs and feet



Elephant using its feet to crush a watermelon before eating it.

An elephant's legs are roughly shaped like columns or pillars, as they must be to support its bulk. The elephant needs less muscular power to stand because of its straight legs and large padded feet. For this reason, an elephant can stand for very long periods of time without tiring. In fact, African elephants rarely lie down unless they are sick or wounded. Indian elephants, in contrast, lie down frequently.

The feet of an elephant are nearly round. African elephants have three nails on each hind foot, and four on each front foot. Indian elephants have four nails on each hind foot and five on each front foot. Beneath the bones of the foot is a tough, gelatinous material that acts as a cushion or shock absorber. Under the elephant's weight, the foot swells, but it gets smaller when the weight is removed. An elephant can sink deep into mud, but can pull its legs out readily because its feet become smaller when they are lifted.

Elephants swim well, but cannot trot, jump, or gallop. They do have two gaits: a walk and a faster gait that is similar to running.

In walking, the legs act as pendulums, with the hips and shoulders rising and falling while the foot is planted on the ground. With no "aerial phase", the faster gait does not meet all the criteria of running, as elephants always have at least one foot on the ground. However, an elephant moving fast uses its legs much like other running animals, with the hips and shoulders falling and then rising while the feet are on the ground. In this gait, an elephant will have three feet off the ground at one time. As both of the hind feet and both of the front feet are off the ground at the same time, this gait has been likened to the hind legs and the front legs taking turns running. Tests at the Thai Elephant Conservation Centre are reported to show that fast-moving elephants 'run' with their front legs, but 'walk' with their hind legs.

Although they start this "run" at only 8 km/h, elephants have been reported to reach speeds up to 40 km/h (25 mph), all the while using the same gait. In tests at the Thai Elephant Conservation Centre, the fastest elephants reached a top speed of 18 km/h (11 mph). At this speed, most other four-legged creatures are well into a gallop, even accounting for leg length. Spring-like kinetics could explain the difference between the motion of elephants and other animals.

Ears

Difference between Asian (left) and African (right) elephant ears.

The large flapping ears of an elephant are also very important for temperature regulation. Elephant ears are made of a very thin layer of skin stretched over cartilage and a rich network of blood vessels. On hot days, elephants will flap their ears constantly, creating a slight breeze. This breeze cools the surface blood vessels, and then the cooler blood gets circulated to the rest of the animal's body. The hot blood entering the ears can be cooled as much as 10 °F (6 °C) before returning to the body. Differences in the ear sizes of African and Asian elephants can be explained, in part, by their geographical distribution. Africans originated and stayed near the equator, where it is warmer. Therefore, they have bigger ears. Asians live farther north, in slightly cooler climates, and thus have smaller ears.

The ears are also used in certain displays of aggression and during the males' mating period. If an elephant wants to intimidate a predator or rival, it will spread its ears out wide to make itself look more massive and imposing. During the breeding season, males give off an odor from the musth gland located behind their eyes. Joyce Poole, a well-known elephant researcher, has theorized that the males will fan their ears in an effort to help propel this "elephant cologne" great distances.

Biology and behavior

The skeleton of a dwarf elephant from the island of Crete. Dwarf elephants were present on some Mediterranean islands until about 10,000 years ago.

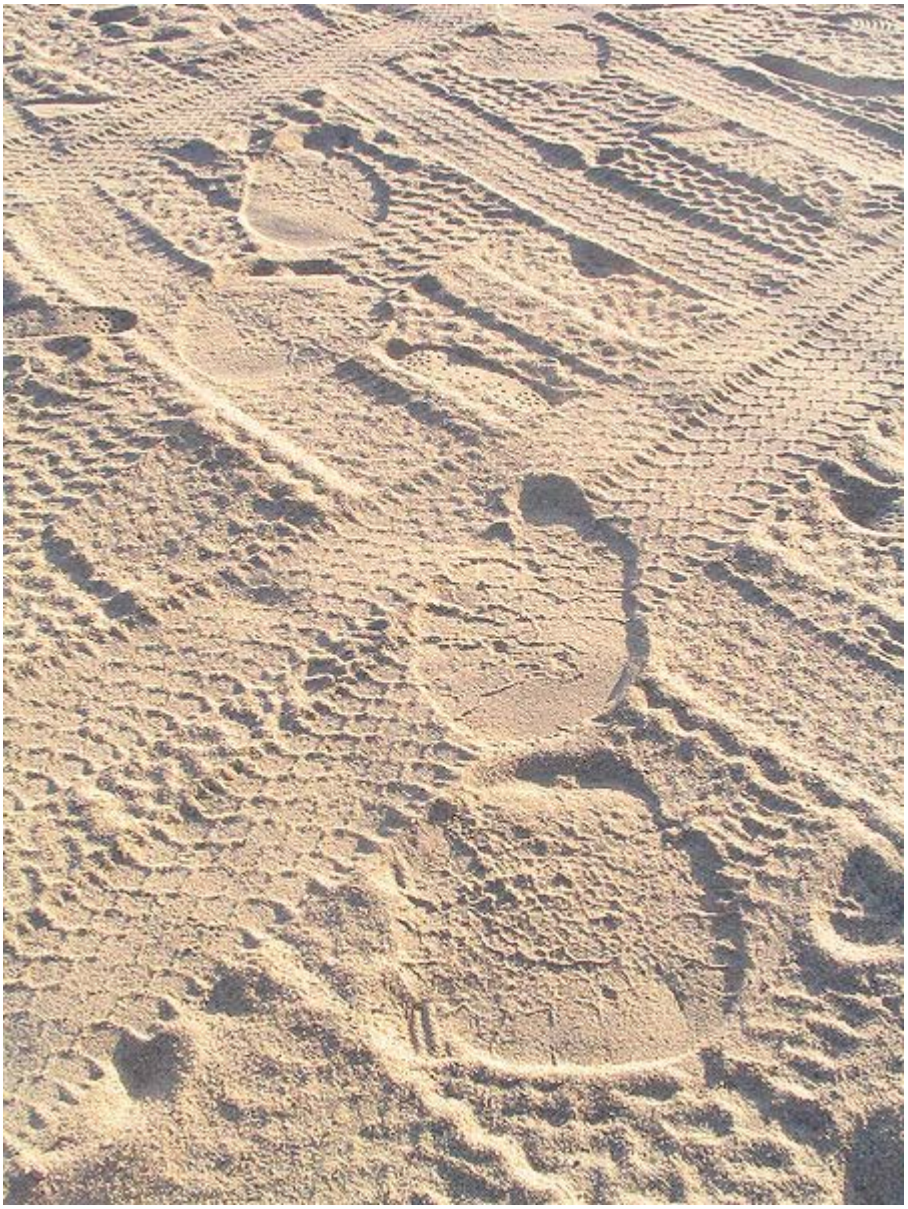
Evolution

The earliest known ancestors of modern-day elephants evolved about 60 million years ago. The ancestor of the elephants from 37 million years ago was aquatic and had a similar lifestyle to a hippopotamus.

Social behavior

Elephants live in a structured social order. The social lives of male and female elephants are very different. The females spend their entire lives in tightly knit family groups made up of mothers, daughters, sisters, and aunts. These groups are led by the eldest female, or matriarch. Adult males, on the other hand, live mostly solitary lives.

The social circle of the female elephant does not end with the small family unit. In addition to encountering the local males that live on the fringes of one or more groups, the female's life also involves interaction with other families, clans, and subpopulations. Most immediate family groups range from five to fifteen adults, as well as a number of immature males and females. When a group gets too big, a few of the elder daughters will break off and form their own small group. They remain very aware of which local herds are relatives and which are not.



Elephant footprints (tire tracks for scale)

The life of the adult male is very different. As he gets older, he begins to spend more time at the edge of the herd, gradually going off on his own for hours or days at a time. Eventually, days become weeks, and somewhere around the age of fourteen, the mature male, or bull, sets out from his natal group for good. While males do live primarily solitary lives, they will occasionally form loose associations with other males. These groups are called bachelor herds. The males spend much more time than the females fighting for dominance with each other. Only the most dominant males will be permitted to breed with cycling females. The less dominant ones must wait their turns. It is usually the older bulls, forty to fifty years old, that do most of the breeding.

The dominance battles between males can look very fierce, but typically they inflict very little injury. Most of the bouts are in the form of aggressive displays and bluffs. Ordinarily, the smaller, younger, and less confident animal will back off before any real damage can be done. However, during the breeding season, the battles can get extremely aggressive, and the occasional elephant is injured. During this season, known as musth, a bull will fight with almost any other male it encounters, and it will spend most of its time hovering around the female herds, trying to find a receptive mate.

Mating behavior

Elephant mating behaviour.

Elephant mating behaviour (2)

The mating season is short and females are only able to conceive for a few days each year. She will detach herself from the herd. The scent of the female (cow) elephant in heat (or estrus) attracts the male and she also uses audible signals to attract the male. As the female can usually outrun the male, she does not have to mate with every male that approaches her.

The male initiates the courtship and the female ignores him for several minutes. He then stops and starts again. Elephants display a range of affectionate interactions, such as nuzzling, trunk intertwining, and placing their trunks in each other's mouths (image 2).

In a rarely observed display of his affection, he may drape his trunk outside of his tusks during the ritual (image 1). The interactions may last for 20–30 minutes and do not necessarily result in the male mounting the female, though he may demonstrate arousal during the ritual.

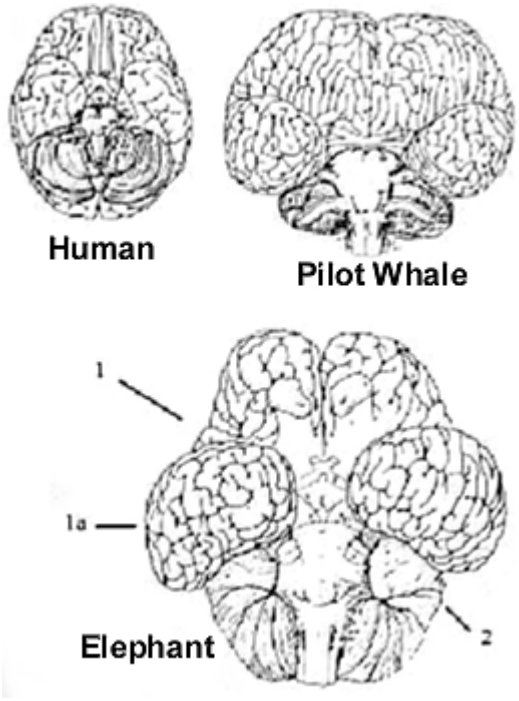
The female elephant is not passive in the ritual and uses the same techniques as the male.

African as well as Asiatic males will engage in same-sex bonding and mounting. The encounters are analogous to heterosexual bouts, one male often extending his trunk along the other's back and pushing forward with his tusks to signify his intention to mount. Unlike heterosexual relations, which are always of a fleeting nature, those between males result in a "companionship", consisting of an older individual and one or two younger,

attendant males. Same-sex relations are common and frequent in both sexes, with Asiatic elephants in captivity devoting roughly 46% of sexual encounters to same-sex activity.

Rogue elephant is a term for a lone, violently aggressive wild elephant. It is a calque of the Sinhala term *hora aliya*. Its introduction to English has been attributed by the Oxford English Dictionary to Sir James Emerson Tennent, but this usage may have been predated by William Sirr.

Intelligence



Human, pilot whale and elephant brains up to scale. (1)-cerebrum (1a)-temporal lobe and (2)-cerebellum.

With a mass just over 5 kg (11 lb), elephant brains are larger than those of any other land animal. A wide variety of behaviours associated with intelligence have been attributed to elephants, including those associated with grief, making music, art, altruism, allomothering, play, use of tools, compassion and self-awareness. Elephants are believed to rank equally in terms of intelligence with cetaceans and nonhuman primates. The elephant's brain is similar to that of humans in terms of structure and complexity; the elephant brain exhibits a gyral pattern more complex and with more numerous convolutes, or brain folds, than that of humans, primates or carnivores, but less complex than cetaceans. However, the cortex of the elephant brain is "thicker than that of cetaceans" and is believed to have as many cortical neurons (nerve cells) and cortical synapses as that of humans, which exceeds that of cetaceans.

Senses

Elephants have well innervated trunks, and an exceptional sense of hearing and smell. The hearing receptors reside not only in ears, but also in trunks that are sensitive to vibrations, and most significantly feet, which have special receptors for low frequency sound and are exceptionally well innervated. Elephants communicate by sound over large distances of several kilometers partly through the ground, which is important for their social lives. Elephants are observed listening by putting trunks on the ground and carefully positioning their feet.

The eyesight of elephants is relatively poor.

Self-awareness

Mirror self recognition is a test of self-awareness and cognition used in animal studies. A mirror was provided and visible marks were made on the elephant. The elephants investigated these marks, which were visible only via the mirror. The tests also included invisible marks to rule out the possibility of their using other senses to detect these marks. This shows that elephants recognize the fact that the image in the mirror is their own self, and such abilities are considered the basis for empathy, altruism and higher social interactions. This ability has also been demonstrated in humans, apes, bottlenose dolphins, and magpies.

A young elephant in Zimbabwe.

Communication

Elephants make a number of sounds when communicating. Elephants are famous for their trumpet calls, which are made when the animal blows through its nostrils. Trumpeting is usually made during excitement. Its use varies from startlement to a cry of help to rage. Elephants also make rumbling growls when greeting each other. The growl becomes a bellow when the mouth is open and a bellow becomes a moan when prolonged. This can escalate with a roar when threatening another elephant or another animal.

Elephants can communicate over long distances by producing and receiving low-frequency sound (infrasound), a sub-sonic rumbling, which can travel in the air and through the ground much farther than higher frequencies. These calls range in frequency from 15–35 Hz and can be as loud as 117 dB, allowing communication for many kilometres, with a possible maximum range of around 10 km. This sound can be felt by the sensitive skin of an elephant's feet and trunk, which pick up the resonant vibrations much as the flat skin on the head of a drum. To listen attentively, every member of the herd will lift one foreleg from the ground, and face the source of the sound, or often lay its trunk on the ground. The lifting presumably increases the ground contact and sensitivity of the remaining legs. This ability is thought also to aid their navigation by use of external sources of infrasound. Discovery of this new aspect of elephant social communication and perception came with breakthroughs in audio technology, which can pick up frequencies outside the range of the human ear. Pioneering research in elephant infrasound communication was done by Katy Payne, of the Elephant Listening Project, and is detailed in her book *Silent Thunder*. Though this research is still in its infancy, it is helping to solve many mysteries, such as how elephants can find distant potential mates, and how social groups are able to coordinate their movements over extensive range. Joyce Poole has also begun decoding elephant utterances that have been recorded over many years of observation, hoping to create a lexicon based on a systematic catalogue of elephant sounds.

Diet

Elephants are herbivores, and spend up to 16 hours a day eating plants. Their diets are highly variable, both seasonally and across habitats and regions. Elephants are primarily browsers, feeding on the leaves, bark, and fruits of trees and shrubs, but they may also eat considerable grasses and herbs. As is true for other nonruminant unglulates, elephants only digest approximately 40% of what they eat. They make up for their digestive systems' lack of efficiency in volume. An adult elephant consumes 140–270 kg (300–600 lb) of food a day.

Reproduction and life cycle

Elephant calves

Female elephant social life revolves around breeding and raising of the calves. A female will usually be ready to breed around the age of thirteen, when she comes into estrus, a

short phase of receptiveness lasting a couple of days, for the first time. Females announce their estrus with smell signals and special calls.

Female African elephant with calf, in Kenya.

Females prefer bigger, stronger, and, most importantly, older males. Such a reproductive strategy tends to increase their offspring's chances of survival.

After a twenty-two-month pregnancy, the mother gives birth to a calf that weighs about 115 kg (250 lb) and stands over 75 cm (2.5 ft) tall. Elephants have a very long development. As is common with more intelligent species, they are born with fewer survival instincts than many other animals. Instead, they rely on their elders to teach them what they need to know. Today, however, the pressures humans have put on the wild elephant populations, from poaching to habitat destruction, mean that the elderly often die at a younger age, leaving fewer teachers for the young. The consequences of this for the next generation are not known.

A new calf is usually the center of attention for herd members. Adults and most of the other young will gather around the newborn, touching and caressing it with their trunks.

The baby is born nearly blind and at first relies almost completely on its trunk to discover the world around it.

Elephants within a herd are usually related, and all members of the tightly-knit female group participate in the care and protection of the young. After the initial excitement, the mother will usually select several full-time baby-sitters, or "allomothers", from her group. An elephant is considered an allomother when she is not able to have her own calf. The more allomothers, the better the calf's chances of survival. A benefit of being an allomother is she can gain experience or receive assistance when caring for her own calf. According to Cynthia Moss, a well known researcher, these allomothers will help in all aspects of raising the calf. They walk with the young as the herd travels, helping the calves along if they fall or get stuck in the mud. The more allomothers a calf has, the more free time its mother has to feed herself. Providing a calf with nutritious milk means the mother has to eat more nutritious food herself.

Effect on the environment

Elephants can have profound impacts on the ecosystems they occupy, and both positive and negative effects on other species especially with their foraging activities. By pulling down trees to eat leaves, breaking branches, and pulling out roots, they reduce woody cover, creating clearings in forests, converting forests to savannas, and converting savannas to grasslands. These changes tend to benefit grazers at the expense of browsers.

Dung beetles and termites both eat elephant feces. During the dry season, elephants use their tusks to dig into river beds to reach underground sources of water. These holes may then become essential sources of water for other species. Elephants make paths through their environment that are used by other animals. Some of these pathways have apparently been used by several generations of elephants, used by humans and eventually even been converted to roads.

Chapter 5

Bee

Bees

Osmia ribifloris

Scientific classification	
Kingdom:	Animalia
Phylum:	Arthropoda
Class:	Insecta
Order:	Hymenoptera
Suborder:	Apocrita
Superfamily:	Apoidea
(unranked):	**Anthophila**

Families
Andrenidae
Apidae
Colletidae
Dasypodaidae
Halictidae
Megachilidae
Meganomiidae
Melittidae
Stenotritidae

Synonyms
Apiformes

Bees are flying insects closely related to wasps and ants, and are known for their role in pollination and for producing honey and beeswax. Bees are a monophyletic lineage within the superfamily **Apoidea**, presently classified by the unranked taxon name **Anthophila**. There are nearly 20,000 known species of bees in seven to nine recognized families, though many are undescribed and the actual number is probably higher. They are found on every continent except Antarctica, in every habitat on the planet that contains insect-pollinated flowering plants.

Bees are adapted for feeding on nectar and pollen, the former primarily as an energy source and the latter primarily for protein and other nutrients. Most pollen is used as food for larvae.

Bees have a long proboscis (a complex "tongue") that enables them to obtain the nectar from flowers. They have antennae almost universally made up of 13 segments in males and 12 in females, as is typical for the superfamily. Bees all have two pairs of wings, the hind pair being the smaller of the two; in a very few species, one sex or caste has relatively short wings that make flight difficult or impossible, but none are wingless.

The smallest bee is *Trigona minima*, a stingless bee whose workers are about 2.1 mm (5/64") long. The largest bee in the world is *Megachile pluto*, a leafcutter bee whose females can attain a length of 39 mm (1.5"). Members of the family Halictidae, or sweat bees, are the most common type of bee in the Northern Hemisphere, though they are small and often mistaken for wasps or flies.

The best-known bee species is the European honey bee, which, as its name suggests, produces honey, as do a few other types of bee. Human management of this species is known as beekeeping or apiculture.

Bees are the favorite meal of *Merops apiaster*, the bee-eater bird. Other common predators are kingbirds, mockingbirds, beewolves, and dragonflies.

Pollination

Bees play an important role in pollinating flowering plants, and are the major type of pollinator in ecosystems that contain flowering plants. Bees either focus on gathering nectar or on gathering pollen depending on demand, especially in social species. Bees gathering nectar may accomplish pollination, but bees that are deliberately gathering pollen are more efficient pollinators. It is estimated that one third of the human food supply depends on insect pollination, most of which is accomplished by bees, especially the domesticated European honey bee. Contract pollination has overtaken the role of honey production for beekeepers in many countries. Monoculture and the massive decline of many bee species (both wild and domesticated) have increasingly caused honey bee keepers to become migratory so that bees can be concentrated in seasonally varying high-demand areas of pollination.

Honey bee (*Apis mellifera*) collecting pollen

Most bees are fuzzy and carry an electrostatic charge, which aids in the adherence of pollen. Female bees periodically stop foraging and groom themselves to pack the pollen into the scopa, which is on the legs in most bees, and on the ventral abdomen on others, and modified into specialized pollen baskets on the legs of honey bees and their relatives. Many bees are opportunistic foragers, and will gather pollen from a variety of plants, while others are oligolectic, gathering pollen from only one or a few types of plant. A small number of plants produce nutritious floral oils rather than pollen, which are gathered and used by oligolectic bees. One small subgroup of stingless bees, called "vulture bees," is specialized to feed on carrion, and these are the only bees that do not use plant products as food. Pollen and nectar are usually combined together to form a "provision mass", which is often soupy, but can be firm. It is formed into various shapes (typically spheroid), and stored in a small chamber (a "cell"), with the egg deposited on the mass. The cell is typically sealed after the egg is laid, and the adult and larva never interact directly (a system called "mass provisioning").

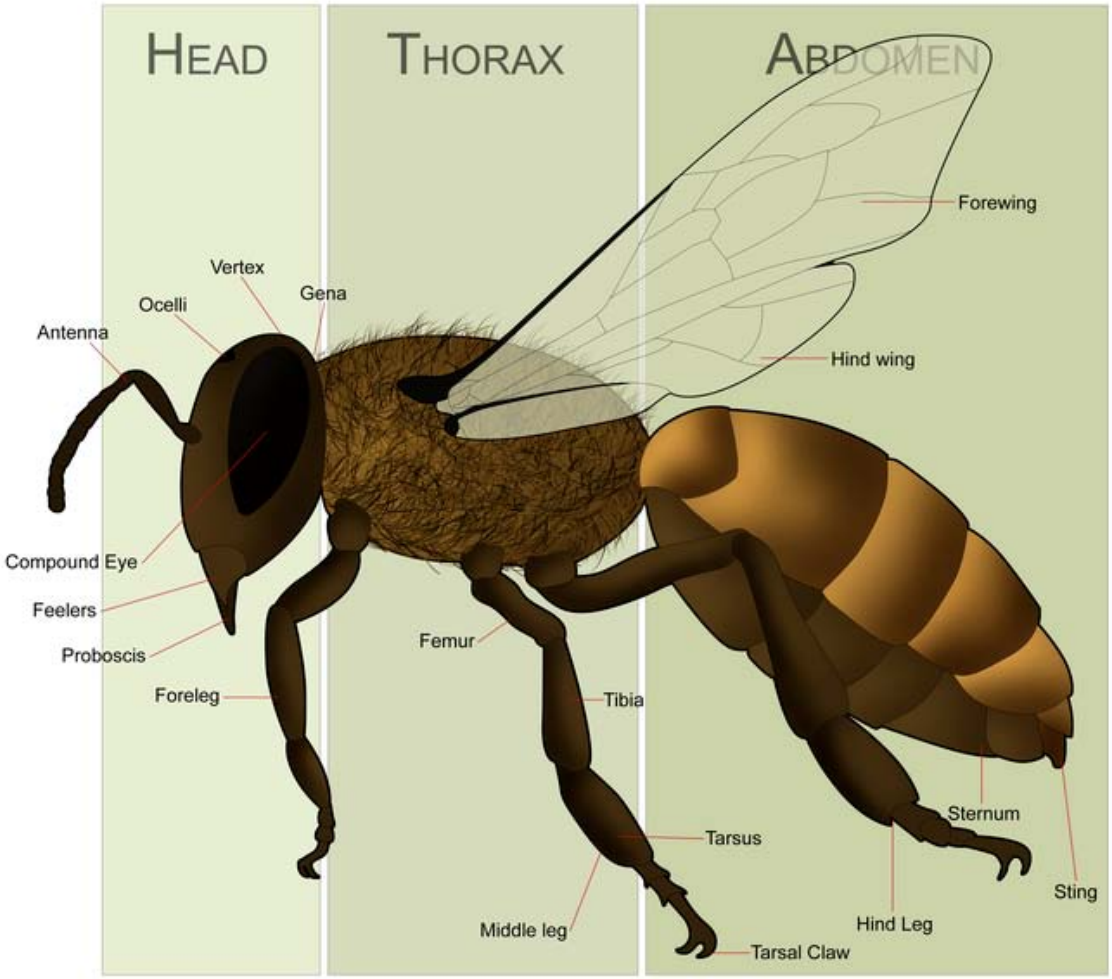
In New Zealand scientists discovered that three genera of native bees have evolved to open flower buds of the native mistletoe *Peraxilla tetrapetala*. The buds cannot open themselves but are visited by birds such as the tui and bellbird which twist the top of the ripe bud. That action releases a mechanism which causes the petals to suddenly spring open, giving access to the nectar and pollen. However, when observing the native bees in

the Canterbury province in the South Island, the scientists were astonished to see the bees biting the top off the buds, then pushing with their legs, occasionally popping open the buds to allow the bees to harvest the nectar and pollen, and therefore aid in the pollination of the mistletoe which is in decline in New Zealand. Nowhere else in the world have bees demonstrated ability to open explosive bird-adapted flowers.

Visiting flowers can be a dangerous occupation. Many assassin bugs and crab spiders hide in flowers to capture unwary bees. Other bees are lost to birds in flight. Insecticides used on blooming plants kill many bees, both by direct poisoning and by contamination of their food supply. A honey bee queen may lay 2000 eggs per day during spring buildup, but she also must lay 1000 to 1500 eggs per day during the foraging season, mostly to replace daily casualties, most of which are workers dying of old age. Among solitary and primitively social bees, however, lifetime reproduction is among the lowest of all insects, as it is common for females of such species to produce fewer than 25 offspring.

The population value of bees depends partly on the individual efficiency of the bees, but also on the population itself. Thus while bumblebees have been found to be about ten times more efficient pollinators on cucurbits, the total efficiency of a colony of honey bees is much greater due to greater numbers. Likewise during early spring orchard blossoms, bumblebee populations are limited to only a few queens, and thus are not significant pollinators of early fruit.

Pollinator decline



Morphology of a female honey bee

From 1972 to 2006, there was a dramatic reduction in the number of feral honey bees in the US, which are now almost absent. At the same time there was a significant though somewhat gradual decline in the number of colonies maintained by beekeepers. This decline includes the cumulative losses from all factors, such as urbanization, pesticide use, tracheal and *Varroa* mites, and commercial beekeepers' retiring and going out of business. However, in late 2006 and early 2007 the rate of attrition reached new proportions, and the term colony collapse disorder was coined to describe the sudden disappearances. After several years of research and concern, a team of scientists headed by Jerry Bromenshenk published a paper in October 2010 saying that a new DNA-based virus, invertebrate iridescent virus or IIV6, and the fungus *Nosema ceranae* were found in every killed colony the group studied. In their study they found that neither agent alone seemed deadly, but a combination of the virus and *Nosema ceraneae* was always 100% fatal. Bromenshenk said it is not yet clear whether one condition weakens the bees enough to be finished off by the second, or whether they somehow compound the other's

destructive power. "They're co-factors, that's all we can say at the moment. They're both present in all these collapsed colonies." Investigations into the phenomenon had occurred amidst great concern over the nature and extent of the losses. In 2009 some reports from the US suggested that 1/3 of the honey bee colonies did not survive the winter, though normal winter losses are known to be around 25%.

Apart from colony collapse disorder, many of the losses outside the US have also been attributed to other causes. Pesticides used to treat seeds, such as Clothianidin and Imidacloprid, have been considered prime suspects. Other species of bees such as mason bees are increasingly cultured and used to meet the agricultural pollination need.

Native pollinators include bumblebees and solitary bees, which often survive in refuges in wild areas away from agricultural spraying, but may still be poisoned in massive spray programs for mosquitoes, gypsy moths, or other insect pests. Although pesticide use remains a concern, the major problem for wild pollinator populations is the loss of the flower-rich habitat on which they depend for food. Throughout the northern hemisphere, the last 70 or so years have seen an intensification of agricultural systems, which has decreased the abundance and diversity of wild flowers.

Legislation such as the UK's Bees Act 1980 is designed to stop the decline of bees.

Evolution

Bees, like ants, are a specialized form of wasp. The ancestors of bees were wasps in the family Crabronidae, and therefore predators of other insects. The switch from insect prey to pollen may have resulted from the consumption of prey insects which were flower visitors and were partially covered with pollen when they were fed to the wasp larvae. This same evolutionary scenario has also occurred within the vespoid wasps, where the group known as "pollen wasps" also evolved from predatory ancestors. Up until recently, the oldest non-compression bee fossil had been *Cretotrigona prisca* in New Jersey amber and of Cretaceous age, a meliponine. A recently reported bee fossil, of the genus *Melittosphex*, is considered *"an extinct lineage of pollen-collecting Apoidea sister to the modern bees"*, and dates from the early Cretaceous (~100 mya). Derived features of its morphology ("apomorphies") place it clearly within the bees, but it retains two unmodified ancestral traits ("plesiomorphies") of the legs (two mid-tibial spurs, and a slender hind basitarsus), indicative of its transitional status.

The earliest animal-pollinated flowers were pollinated by insects such as beetles, so the syndrome of insect pollination was well established before bees first appeared. The novelty is that bees are *specialized* as pollination agents, with behavioral and physical modifications that specifically enhance pollination, and are generally more efficient at the task than any other pollinating insect such as beetles, flies, butterflies and pollen wasps. The appearance of such floral specialists is believed to have driven the adaptive radiation of the angiosperms, and, in turn, the bees themselves.

Among living bee groups, the "short-tongued" bee family Colletidae has traditionally been considered the most "primitive", and sister taxon to the remainder of the bees. In the 21st century, however, some researchers have claimed that the Dasypodaidae is the basal group, the short, wasp-like mouthparts of colletids being the result of convergent evolution, rather than indicative of a plesiomorphic condition. This subject is still under debate, and the phylogenetic relationships among bee families are poorly understood.

Eusocial and semisocial bees

A honey bee swarm

Bees may be solitary or may live in various types of communities. The most advanced of these are eusocial colonies found among the honey bees, bumblebees, and stingless bees.

Sociality, of several different types, is believed to have evolved separately many times within the bees.

In some species, groups of cohabiting females may be sisters, and if there is a division of labor within the group, then they are considered semisocial.

If, in addition to a division of labor, the group consists of a mother and her daughters, then the group is called eusocial. The mother is considered the "queen" and the daughters are "workers". These castes may be purely behavioral alternatives, in which case the system is considered "primitively eusocial" (similar to many paper wasps), and if the castes are morphologically discrete, then the system is "highly eusocial".

There are many more species of primitively eusocial bees than highly eusocial bees, but they have rarely been studied. The biology of most such species is almost completely unknown. The vast majority are in the family Halictidae, or "sweat bees". Colonies are typically small, with a dozen or fewer workers, on average. The only physical difference between queens and workers is average size, if they differ at all. Most species have a single season colony cycle, even in the tropics, and only mated females (future queens, or "gynes") hibernate (called diapause). A few species have long active seasons and attain colony sizes in the hundreds. The orchid bees include a number of primitively eusocial species with similar biology. Certain species of allodapine bees (relatives of carpenter bees) also have primitively eusocial colonies, with unusual levels of interaction between the adult bees and the developing brood. This is "progressive provisioning"; a larva's food is supplied gradually as it develops. This system is also seen in honey bees and some bumblebees.

Highly eusocial bees live in colonies. Each colony has a single queen, many workers and, at certain stages in the colony cycle, drones. When humans provide the nest, it is called a hive. Honey bee hives can contain up to 40,000 bees at their annual peak, which occurs in the spring, but usually have fewer.

Bumblebees

Bumblebees (*Bombus terrestris*, *Bombus pratorum*, et al.) are eusocial in a manner quite similar to the eusocial Vespidae such as hornets. The queen initiates a nest on her own (unlike queens of honey bees and stingless bees which start nests via swarms in the company of a large worker force). Bumblebee colonies typically have from 50 to 200 bees at peak population, which occurs in mid to late summer. Nest architecture is simple, limited by the size of the nest cavity (pre-existing), and colonies are rarely perennial. Bumblebee queens sometimes seek winter safety in honey bee hives, where they are sometimes found dead in the spring by beekeepers, presumably stung to death by the honey bees. It is unknown whether any survive winter in such an environment.

Bumblebees are one of the more important wild pollinators, but have declined significantly in recent decades. In the UK, 2 species have become nationally extinct during the last 75 years while others have been placed on the UK Biodiversity Action

Plan as priority species in recognition of the need for conservation action. In 2006 a new charity, the Bumblebee Conservation Trust, was established in order to coordinate efforts to conserve remaining populations through conservation and education.

Stingless bees

Stingless bees are very diverse in behavior, but all are highly eusocial. They practise mass provisioning, complex nest architecture, and perennial colonies.

Honey bees

A European honey bee extracts nectar from an *Aster* flower

The true honey bees (genus *Apis*) have arguably the most complex social behavior among the bees. The European (or Western) honey bee, *Apis mellifera*, is the best known bee species and one of the best known of all insects.

Africanized honey bee

Africanized bees, also called killer bees, are a hybrid strain of *Apis mellifera* derived from experiments by Warwick Estevam Kerr to cross European and African honey bees.

Several queen bees escaped from his laboratory in South America and have spread throughout the Americas. Africanized honey bees are more defensive than European honey bees.

Solitary and communal bees

Most other bees, including familiar species of bee such as the Eastern carpenter bee (*Xylocopa virginica*), alfalfa leafcutter bee (*Megachile rotundata*), orchard mason bee (*Osmia lignaria*) and the hornfaced bee (*Osmia cornifrons*) are solitary in the sense that every female is fertile, and typically inhabits a nest she constructs herself. There are no *worker* bees for these species. Solitary bees typically produce neither honey nor beeswax. They are immune from acarine and *Varroa* mites, but have their own unique parasites, pests and diseases.

Solitary bees are important pollinators, and pollen is gathered for provisioning the nest with food for their brood. Often it is mixed with nectar to form a paste-like consistency. Some solitary bees have very advanced types of pollen-carrying structures on their bodies. A very few species of solitary bees are being increasingly cultured for commercial pollination.

A solitary bee, *Anthidium florentinum* (family Megachilidae), visiting *Lantana*

Solitary bees are often oligoleges, in that they only gather pollen from one or a few species/genera of plants (unlike honey bees and bumblebees which are generalists). No known bees are nectar specialists; many oligolectic bees will visit multiple plants for nectar, but there are no bees which visit only one plant for nectar while also gathering pollen from many different sources. Specialist pollinators also include bee species which gather floral oils instead of pollen, and male orchid bees, which gather aromatic compounds from orchids (one of the only cases where male bees are effective pollinators). In a very few cases only one species of bee can effectively pollinate a plant species, and some plants are endangered at least in part because their pollinator is dying off. There is, however, a pronounced tendency for oligolectic bees to be associated with common, widespread plants which are visited by multiple pollinators (e.g., there are some 40 oligoleges associated with creosote bush in the US desert southwest, and a similar pattern is seen in sunflowers, asters, mesquite, etc.)

Solitary bees create nests in hollow reeds or twigs, holes in wood, or, most commonly, in tunnels in the ground. The female typically creates a compartment (a "cell") with an egg and some provisions for the resulting larva, then seals it off. A nest may consist of numerous cells. When the nest is in wood, usually the last (those closer to the entrance) contain eggs that will become males. The adult does not provide care for the brood once the egg is laid, and usually dies after making one or more nests. The males typically emerge first and are ready for mating when the females emerge. Providing nest boxes for solitary bees is increasingly popular for gardeners. Solitary bees are either stingless or very unlikely to sting (only in self defense, if ever).

While solitary females each make individual nests, some species are gregarious, preferring to make nests near others of the same species, giving the appearance to the casual observer that they are social. Large groups of solitary bee nests are called *aggregations*, to distinguish them from colonies.

In some species, multiple females share a common nest, but each makes and provisions her own cells independently. This type of group is called "communal" and is not uncommon. The primary advantage appears to be that a nest entrance is easier to defend from predators and parasites when there are multiple females using that same entrance on a regular basis.

Cleptoparasitic bees

Bombus vestalis, a cuckoo bee parasite of the bumblebee Bombus terrestris

Cleptoparasitic bees, commonly called "cuckoo bees" because their behavior is similar to cuckoo birds, occur in several bee families, though the name is technically best applied to the apid subfamily Nomadinae. Females of these bees lack pollen collecting structures (the scopa) and do not construct their own nests. They typically enter the nests of pollen collecting species, and lay their eggs in cells provisioned by the host bee. When the cuckoo bee larva hatches it consumes the host larva's pollen ball, and if the female cleptoparasite has not already done so, kills and eats the host larva. In a few cases where the hosts are social species, the cleptoparasite remains in the host nest and lays many eggs, sometimes even killing the host queen and replacing her.

Many cleptoparasitic bees are closely related to, and resemble, their hosts in looks and size, (i.e., the *Bombus* subgenus *Psithyrus*, which are parasitic bumblebees that infiltrate

nests of species in other subgenera of *Bombus*). This common pattern gave rise to the ecological principle known as "Emery's Rule". Others parasitize bees in different families, like *Townsendiella*, a nomadine apid, one species of which is a cleptoparasite of the dasypodaid genus *Hesperapis*, while the other species in the same genus attack halictid bees.

Nocturnal bees

Four bee families (Andrenidae, Colletidae, Halictidae, and Apidae) contain some species that are crepuscular (these may be either the vespertine or matinal type). These bees have greatly enlarged ocelli, which are extremely sensitive to light and dark, though incapable of forming images. Many are pollinators of flowers that themselves are crepuscular, such as evening primroses, and some live in desert habitats where daytime temperatures are extremely high.

Flight

Bee in mid air flight carrying pollen in pollen basket

In his 1934 French book *Le vol des insectes*, M. Magnan wrote that he and a M. Saint-Lague had applied the equations of air resistance to bumblebees and found that their flight could not be explained by fixed-wing calculations, but that "One shouldn't be surprised that the results of the calculations don't square with reality". This has led to a common misconception that bees "violate aerodynamic theory", but in fact it merely

confirms that bees do not engage in fixed-wing flight, and that their flight is explained by other mechanics, such as those used by helicopters.

In 1996 Charlie Ellington at Cambridge University showed that vortices created by many insects' wings and non-linear effects were a vital source of lift; vortices and non-linear phenomena are notoriously difficult areas of hydrodynamics, which has made for slow progress in theoretical understanding of insect flight.

In 2005, Michael Dickinson and his Caltech colleagues studied honey bee flight with the assistance of high-speed cinematography and a giant robotic mock-up of a bee wing. Their analysis revealed that sufficient lift was generated by "the unconventional combination of short, choppy wing strokes, a rapid rotation of the wing as it flops over and reverses direction, and a very fast wing-beat frequency". Wing-beat frequency normally increases as size decreases, but as the bee's wing beat covers such a small arc, it flaps approximately 230 times per second, faster than a fruitfly (200 times per second) which is 80 times smaller.

Bees and humans

Bee larvae as food in Java

Bees figure prominently in mythology and have been used by political theorists as a model for human society. Journalist Bee Wilson states that the image of a community of honey bees "occurs from ancient to modern times, in Aristotle and Plato; in Virgil and

Seneca; in Erasmus and Shakespeare; Tolstoy, as well as by social theorists Bernard Mandeville and Karl Marx."

Despite the honey bee's painful sting and the stereotype of insects as pests, bees are generally held in high regard. This is most likely due to their usefulness as pollinators and as producers of honey, their social nature, and their reputation for diligence. Bees are one of the few insects regularly used on advertisements, being used to illustrate honey and foods made with honey (such as Honey Nut Cheerios).

In ancient Egypt, the bee was seen to symbolize the lands of Lower Egypt, with the Pharaoh being referred to as "He of Sedge and Bee" (the sedge representing Upper Egypt).

In North America, yellowjackets and hornets, especially when encountered as flying pests, are often misidentified as bees, despite numerous differences between them.

Although a bee sting can be deadly to those with allergies, virtually all bee species are non-aggressive if undisturbed and many cannot sting at all. Humans are often a greater danger to bees, as bees can be affected or even harmed by encounters with toxic chemicals in the environment.

In Indonesia bee larvae are eaten as a companion to rice, after being mixed with shredded coconut "meat", wrapped in banana leaves, and steamed.

Chapter 6

Cattle

Cattle

A Swiss Braunvieh cow wearing a cowbell
Conservation status
Domesticated
Scientific classification
Kingdom: Animalia
Phylum: Chordata
Class: Mammalia
Subclass: Theria

Infraclass:	Eutheria
Order:	Artiodactyla
Family:	Bovidae
Subfamily:	Bovinae
Genus:	*Bos*
Species:	*B. primigenius*
Subspecies:	*B. p. taurus*, *B. p. indicus*

Binomial name
Bos primigenius Bojanus, 1827
Trinomial name
Bos primigenius taurus*,** ***Bos primigenius indicus
Synonyms
Bos taurus, *Bos indicus*

Cattle (colloquially **cows**) are the most common type of large domesticated ungulates. They are a prominent modern member of the subfamily Bovinae, are the most widespread species of the genus *Bos*, and are most commonly classified collectively as ***Bos primigenius***. Cattle are raised as livestock for meat (beef and veal), as dairy animals for milk and other dairy products, and as draft animals (pulling carts, plows and the like). Other products include leather and dung for manure or fuel. In some countries, such as India, cattle are sacred. It is estimated that there are 1.3 billion cattle in the world today. In 2009, cattle became the first livestock animal to have its genome mapped.

Species of cattle

Cattle were originally identified as three separate species. These were *Bos taurus*, the European or "taurine" cattle (including similar types from Africa and Asia); *Bos indicus*, the zebu; and the extinct *Bos primigenius*, the aurochs. The aurochs is ancestral to both zebu and taurine cattle. Recently these three have increasingly been grouped as one species, with *Bos primigenius taurus*, *Bos primigenius indicus* and *Bos primigenius primigenius* as the subspecies.

Zubron, a cross between Wisent and cattle.

Complicating the matter is the ability of cattle to interbreed with other closely related species. Hybrid individuals and even breeds exist, not only between taurine cattle and zebu (including the sanga cattle breeds, *Bos taurus africanus*) but also between one or both of these and some other members of the genus *Bos*: yak (called a dzo or "yattle"), banteng and gaur. Hybrids (such as the beefalo breed) can also occur between taurine cattle and either species of bison, which some authors consider to be in the genus *Bos* as well. The hybrid origin of some types may not be obvious – for example, genetic testing of the Dwarf Lulu breed, the only taurine-type cattle in Nepal, found them to be a mix of taurine cattle, zebu and yak. Cattle cannot successfully be hybridized with more distantly related bovines such as water buffalo or African buffalo.

The aurochs originally ranged throughout Europe, North Africa, and much of Asia. In historical times its range became restricted to Europe, and the last known individual died in Masovia, Poland, in about 1627. Breeders have attempted to recreate cattle of similar appearance to aurochs by crossing traditional types of domesticated cattle, creating the Heck cattle breed.

Word origin

Cattle did not originate as the term for bovine animals. It was borrowed from Old French *catel*, itself from Latin *caput*, head, and originally meant movable personal property, especially livestock of any kind, as opposed to real property (the land, to also include wild or small free-roaming animals such as chickens, which would be sold as part of the land). The word is closely related to "chattel" (a unit of personal property) and "capital" in the economic sense. The term replaced earlier Old English *feoh* "cattle, property" (cf. German: *Vieh*, Gothic: faihu).

The word *cow* came via Anglo-Saxon *cū* (plural *cȳ*), from Common Indo-European *gʷōus* (genitive *gʷowes*) = "a bovine animal", compare Persian *Gâv*, Sanskrit *go*, Welsh *buwch*.

In older English sources such as the King James Version of the Bible, "cattle" refers to livestock, as opposed to "deer" which refers to wildlife. "Wild cattle" may refer to feral cattle or to undomesticated species of the genus *Bos*. Today, when used without any other qualifier, the modern meaning of "cattle" is usually restricted to domesticated bovines.

Terminology

A Hereford bull

Cattle exhibit at Louisiana State Exhibit Museum in Shreveport

In general, the same words are used in different parts of the world but with minor differences in the definitions. The terminology described here contrasts the differences in definition between the United Kingdom and other British influenced parts of world such as Canada, Australia, New Zealand, Ireland, and the United States.

- An *intact* (i.e., not castrated) adult male is called a *bull*. A wild, young, unmarked bull is known as a *micky* in Australia. An unbranded bovine of either sex is called a "maverick" in the USA and Canada.
- An adult female that has had a calf (or two, depending on regional usage) is a *cow*. A young female before she has had a calf of her own and is under three years of age is called a *heifer*. A young female that has had only one calf is occasionally called a *first-calf heifer*.
- Young cattle of both sexes are called *calves* until they are weaned, then *weaners* until they are a year old in some areas; in other areas, particularly with male beef cattle, they may be known as *feeder-calves* or simply *feeders*. After that, they are referred to as *yearlings* or *stirks* if between one and two years of age.
- A castrated male is called a *steer* in the United States; older steers are often called *bullocks* in other parts of the world but in North America this term refers to a young bull. *Piker bullocks* are micky bulls that were caught, castrated and then later lost. In Australia, the term "Japanese ox" is used for grain fed steers in the

weight range of 500 to 650 kg that are destined for the Japanese meat trade. In North America, draft cattle under four years old are called *working steers*. Improper or late castration on a bull results in it becoming a coarse steer known as a *stag* in Australia, Canada and New Zealand. In some countries an incompletely castrated male is known also as a *rig*.

- A castrated male (occasionally a female or in some areas a bull) kept for draft purposes is called an *ox* (plural *oxen*); "ox" may also be used to refer to some carcase products from any adult cattle, such as *ox-hide*, *ox-blood* or *ox-liver*.
- A *springer* is a cow or heifer close to calving.
- In all cattle species, a female that is the twin of a bull usually becomes an infertile partial intersex, and is a *freemartin*.
- *Neat* (horned oxen, from which neatsfoot oil is derived), *beef* (young ox) and *beefing* (young animal fit for slaughtering) are obsolete terms, although *poll*, *pollard* or *polled cattle* are still terms in use for naturally hornless animals, or in some areas also for those that have been disbudded.
- Cattle raised for human consumption are called *beef cattle*. Within the beef cattle industry in parts of the United States, the older term *beef* (plural *beeves*) is still used to refer to an animal of either gender. Some Australian, Canadian, New Zealand and British people use the term *beast*, especially for single animals when the gender is unknown.
- Cattle of certain breeds bred specifically for milk production are called *milking* or *dairy cattle*.; a cow kept to provide milk for one family may be called a *house cow* or *milker*.
- The adjective applying to cattle in general is usually *bovine*. The terms "bull", "cow" and "calf" are also used by extension to denote the gender or age of other large animals, including whales, hippopotamuses, camels, elk and elephants

Singular terminology issue

A herd of Cattle

Cattle can only be used in the plural and not in the singular: it is a plurale tantum. Thus one may refer to "three cattle" or "some cattle", but not "one cattle". There is no universally used singular form in modern English of "cattle", other than the sex- and age-specific terms such as cow, bull, steer and heifer. Historically, "ox" was a non-gender-specific term for adult cattle, but generally this is now used only for draft cattle, especially adult castrated males. The term is also incorporated into the names of other species such as the musk ox and "grunting ox" (yak), and is used in some areas to describe certain cattle products such as ox-hide and ox-tail.

A Brahman calf

"Cow" is in general use as a singular for the collective "cattle", despite the objections by those who insist it to be a female-specific term. Although the phrase "that cow is a bull" is absurd from a lexicographic standpoint, the word "cow" is easy to use when a singular is needed and the sex is unknown or irrelevant - when "there is a cow in the road", for example. Further, any herd of fully mature cattle in or near a pasture is statistically likely to consist mostly of cows, so the term is probably accurate even in the restrictive sense. Other than the few bulls needed for breeding, the vast majority of male cattle are castrated as calves and slaughtered for meat before the age of three years. Thus, in a pastured herd, any calves or herd bulls usually are clearly distinguishable from the cows due to distinctively different sizes and clear anatomical differences. Merriam-Webster, a U.S. dictionary, recognizes the non-sex-specific use of "cow" as an alternate definition, whereas Collins, a UK dictionary, does not.

Colloquially, more general non-specific terms may denote cattle when a singular form is needed. Australian, New Zealand and British farmers use the term "beast" or "cattle beast". "Bovine" is also used in Britain. The term "critter" is common in the western United States and Canada, particularly when referring to young cattle. In some areas of the American South (particularly the Appalachian region), where both dairy and beef cattle are present, an individual animal was once called a "beef critter", though that term is becoming archaic.

Other terminology

Cattle raised for human consumption are called "beef cattle". Within the beef cattle industry in parts of the United States, the term "beef" (plural "beeves") is still used in its archaic sense to refer to an animal of either gender. Cows of certain breeds that are kept for the milk they give are called "dairy cows" or "milking cows" (formerly "milch cows" – "milch" was pronounced as "milk"). Most young male offspring of dairy cows are sold for veal, and may be referred to as *veal calves*.

The term "dogies" is used to describe orphaned calves in the context of ranch work in the American west, as in "Keep them dogies moving". In some places, a cow kept to provide milk for one family is called a "house cow". Other obsolete terms for cattle include "neat" (this use survives in "neatsfoot oil", extracted from the feet and legs of cattle), and "beefing" (young animal fit for slaughter).

An onomatopoeic term for one of the commonest sounds made by cattle is "moo", and this sound is also called *lowing*. There are a number of other sounds made by cattle, including calves *bawling*, and bulls *bellowing*. The bullroarer makes a sound similar to a territorial call made by bulls.

Anatomy

Cattle have one stomach with four compartments. They are the rumen, reticulum, omasum, and abomasum, with the rumen being the largest compartment. The reticulum, the smallest compartment, is known as the "honeycomb". Cattle sometimes consume metal objects which are deposited in the reticulum and irritation from the metal objects causes hardware disease. The omasum's main function is to absorb water and nutrients from the digestible feed. The omasum is known as the "many plies". The abomasum is like the human stomach; this is why it is known as the "true stomach".

Dairy farming and the milking of cattle - once performed largely by hand, but now usually replaced by machine – exploits the cow's ruminant biology.

Cattle are ruminants, meaning that they have a digestive system that allows use of otherwise indigestible foods by regurgitating and rechewing them as "cud". The cud is then reswallowed and further digested by specialised microorganisms in the rumen. These microbes are primarily responsible for decomposing cellulose and other carbohydrates into volatile fatty acids that cattle use as their primary metabolic fuel. The microbes inside the rumen are also able to synthesize amino acids from non-protein nitrogenous sources, such as urea and ammonia. As these microbes reproduce in the rumen, older generations die and their carcasses continue on through the digestive tract. These carcasses are then partially digested by the cattle, allowing them to gain a high

quality protein source. These features allow cattle to thrive on grasses and other vegetation.

The gestation period for a cow is nine months. A newborn calf weighs 25 to 45 kilograms (55 to 99 lb). The world record for the heaviest bull was 1,740 kilograms (3,840 lb), a Chianina named Donetto, when he was exhibited at the Arezzo show in 1955. The heaviest steer was eight year old ‘Old Ben’, a Shorthorn/Hereford cross weighing in at 2,140 kilograms (4,720 lb) in 1910. Steers are generally killed before reaching 750 kilograms (1,650 lb). Breeding stock usually live to about 15 years (occasionally as much as 25 years). The oldest recorded cow, Big Bertha, died at the age of 48 in 1993.

A common misconception about cattle (particularly bulls) is that they are enraged by the color red (something provocative is often said to be "like a red flag to a bull"). This is incorrect, as cattle are red-green color-blind. The myth arose from the use of red capes in the sport of bullfighting; in fact, two different capes are used. The capote is a large, flowing cape that is magenta and yellow. The more famous muleta is the smaller, red cape, used exclusively for the final, fatal segment of the fight. It is not the color of the cape that angers the bull, but rather the movement of the fabric that irritates the bull and incites it to charge.

Although cattle cannot distinguish red from green, they do have two kinds of color receptors in the cone cells in their retinas. Thus they are dichromatic, the same as most other mammals (including dogs, cats, horses and up to ten percent of male humans). They are able to distinguish some colors, particularly blue from yellow, in the same way as most other non-primate land mammals.

Cattle genome

In the April 24, 2009 edition of the journal *Science*, it was reported that a team of researchers led by the National Institutes of Health and the U.S. Department of Agriculture has mapped the bovine genome. The scientists found that cattle have approximately 22,000 genes, and 80 percent of their genes are shared with humans, and they have approximately 1,000 genes they share with dogs and rodents, but are not found in humans. Using this bovine "HapMap", researchers can track the differences between the breeds that affect the quality of meat and milk yields.

Domestication and husbandry

Texas Longhorns are a U.S. breed

Cattle occupy a unique role in human history, domesticated since at least the early Neolithic. They are raised for meat (beef cattle), dairy products and hides. They are also used as draft animals and in certain sports. Some consider cattle the oldest form of wealth, and cattle raiding consequently one of the earliest forms of theft.

A hereford being inspected for ticks; cattle are often restrained or confined in Cattle crushes when given medical attention.

Cattle are often raised by allowing herds to graze on the grasses of large tracts of rangeland. Raising cattle in this manner allows the use of land that might be unsuitable for growing crops. The most common interactions with cattle involve daily feeding,

cleaning and milking. Many routine husbandry practices involve ear tagging, dehorning, loading, medical operations, vaccinations and hoof care, as well as training for agricultural shows and preparations. There are also some cultural differences in working with cattle- the cattle husbandry of Fulani men rests on behavioural techniques, whereas in Europe cattle are controlled primarily by physical means like fences. Breeders use cattle husbandry to reduce M. bovis infection susceptibility by selective breeding and maintaining herd health to avoid concurrent disease.

Cattle are farmed for beef, veal, dairy, leather and they are less commonly used for conservation grazing, simply to maintain grassland for wildlife – for example, in Epping Forest, England. They are often used in some of the most wild places for livestock. Depending on the breed, cattle can survive on hill grazing, heaths, marshes, moors and semi desert. Modern cows are more commercial than older breeds and, having become more specialized, are less versatile. For this reason many smaller farmers still favor old breeds, like the dairy breed of cattle Jersey.

In Portugal, Spain, Southern France and some Latin American countries, bulls are used in the activity of bullfighting; a similar activity, Jallikattu, is seen in South India; in many other countries this is illegal. Other activities such as bull riding are seen as part of a rodeo, especially in North America. Bull-leaping, a central ritual in Bronze Age Minoan culture, still exists in southwestern France. In modern times, cattle are also entered into agricultural competitions. These competitions can involve live cattle or cattle carcases in hoof and hook events.

In terms of food intake by humans, consumption of cattle is less efficient than of grain or vegetables with regard to land use, and hence cattle grazing consumes more area than such other agricultural production when raised on grains. Nonetheless, cattle and other forms of domesticated animals can sometimes help to use plant resources in areas not easily amenable to other forms of agriculture.

Economy

Holstein cattle are the primary dairy breed, bred for high milk production.

Cattle today are the basis of a multi-billion dollar industry worldwide. The international trade in beef for 2000 was over $30 billion and represented only 23 percent of world beef production. (Clay 2004). The production of milk, which is also made into cheese, butter, yogurt, and other dairy products, is comparable in economic size to beef production and provides an important part of the food supply for many of the world's people. Cattle hides, used for leather to make shoes, couches and clothing, are another widespread product. Cattle remain broadly used as draft animals in many developing countries, such as India.

Environmental impact

Cattle — especially when kept on enormous feedlots such as this one — have been named as a contributing factor in the rise in greenhouse gas emissions.

A 400-page United Nations report from the Food and Agriculture Organization (FAO) states that cattle farming is "responsible for 18% of greenhouse gases". The production of cattle to feed and clothe humans stresses ecosystems around the world, and is assessed to be one of the top three environmental problems in the world on a local to global scale.

The report, entitled *Livestock's Long Shadow*, also surveys the environmental damage from sheep, chickens, pigs and goats. But in almost every case, the world's 1.5 billion cattle are cited as the greatest adverse impact with respect to climate change as well as species extinction. The report concludes that, unless changes are made, the massive damage reckoned to be due to livestock may more than double by 2050, as demand for meat increases. One of the cited changes suggests that intensification of the livestock industry may be suggested, since intensification leads to less land for a given level of production.

Some microbes respire in the cattle gut by an anaerobic process known as methanogenesis (producing the gas methane). Cattle emit a large volume of methane, 95% of it through eructation or burping, not flatulence. As the carbon in the methane comes from the digestion of vegetation produced by photosynthesis, its release into the air by this process would normally be considered harmless, because there is no net increase in carbon in the atmosphere — it's removed as carbon dioxide from the air by photosynthesis and returned to it as methane. Methane is a more potent greenhouse gas

than carbon dioxide, having a warming effect 23 to 50 times greater, and according to Takahashi and Young "even a small increase in methane concentration in the atmosphere exerts a potentially significant contribution to global warming". Further analysis of the methane gas produced by livestock as a contributor to the increase in greenhouse gases is provided by Weart. Research is underway on methods of reducing this source of methane, by the use of dietary supplements, or treatments to reduce the proportion of methanogenetic microbes, perhaps by vaccination. In 2010, a diet was proposed to reduce the emissions of greenhouse gases by cattle. The diet was conceived by Alexander Hristov of the Pennstate University.

Cattle are fed a concentrated high-corn diet which produces rapid weight gain, but this has side effects which include increased acidity in the digestive system. When improperly handled, manure and other byproducts of concentrated agriculture also have environmental consequences.

Grazing by cattle at low intensities can create a favourable environment for native herbs and forbs; however, in most world regions cattle are reducing biodiversity due to overgrazing driven by food demands by an expanding human population.

Health

Cow urine is commonly used in India for medical purposes. It is distilled and then consumed by patients seeking treatment for a wide variety of illness. At present, there is no conclusive medical evidence that this has any effect.

Oxen

Draft Zebus in Mumbai, Maharashtra, India

Oxen (singular **ox**) are large and heavyset breeds of *Bos taurus* cattle trained as draft animals. Often they are adult, castrated males. Usually an ox is over four years old due to the need for training and to allow it to grow to full size. Oxen are used for plowing, transport, hauling cargo, grain-grinding by trampling or by powering machines, irrigation by powering pumps, and wagon drawing. Oxen were commonly used to skid logs in forests, and sometimes still are, in low-impact select-cut logging. Oxen are most often used in teams of two, paired, for light work such as carting. In the past, teams might have been larger, with some teams exceeding twenty animals when used for logging.

An ox is a mature bovine who has learned to respond appropriately to a teamster's signals. These signals are given by verbal commands or by noise (whip cracks). In North America, the commands are (1) *get up*, (2) *whoa*, (3) *back up*, (4) *gee* (turn right) and (5) *haw* (turn left). U.S. ox trainers favored larger males for their ability to work.

Riding an ox in Hova, Sweden.

Oxen can pull harder and longer than horses. Though not as fast as horses, they are less prone to injury because they are more sure-footed.

Many oxen are used worldwide, especially in developing countries.

Oxen are also used as food products, including their blood, livers, kidneys, hearts, hides, and tails.

Chapter 7

Goat

Domestic Goat

Conservation status
Domesticated
Scientific classification

Kingdom:	Animalia
Phylum:	Chordata
Class:	Mammalia
Order:	Artiodactyla
Family:	Bovidae
Subfamily:	Caprinae
Genus:	*Capra*
Species:	*C. aegagrus*
Subspecies:	***C. a. hircus***

Trinomial name
Capra aegagrus hircus (Linnaeus, 1758)
Synonyms
Capra hircus

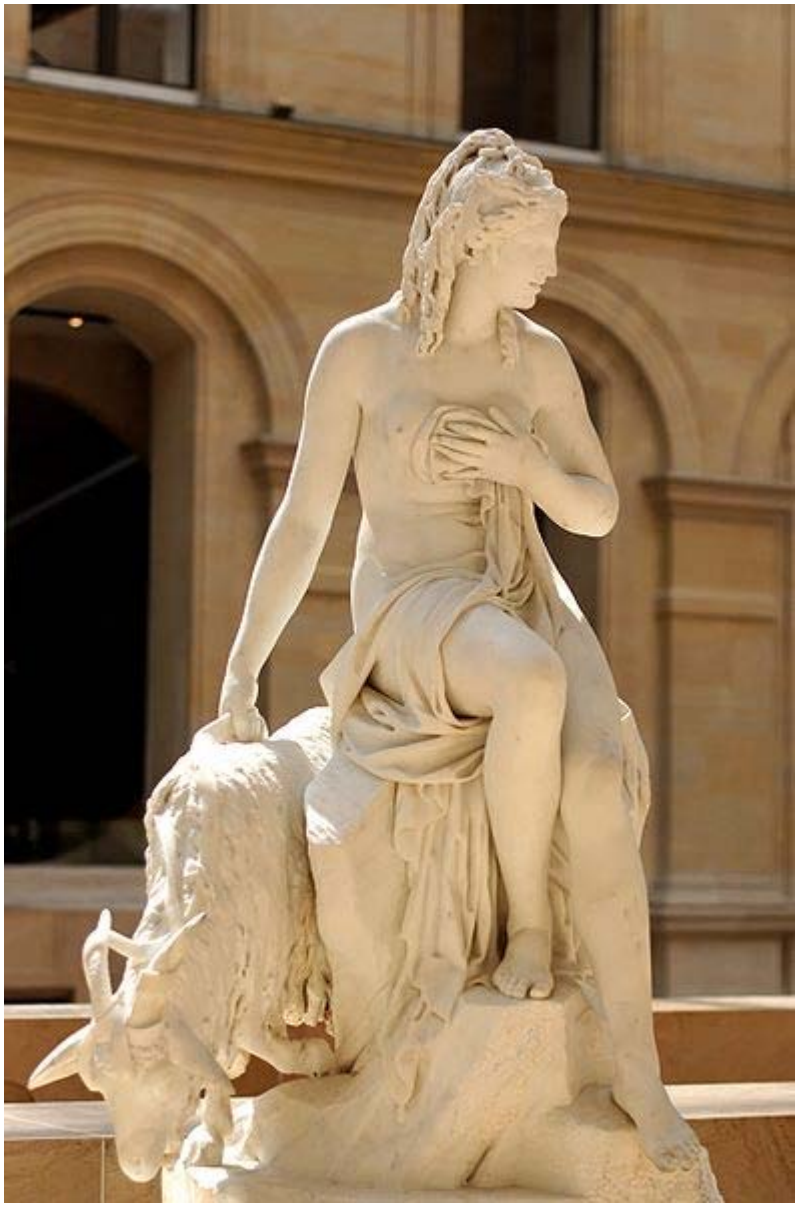
The **domestic goat** (*Capra aegagrus hircus*) is a subspecies of goat domesticated from the wild goat of southwest Asia and Eastern Europe. The goat is a member of the Bovidae family and is closely related to the sheep as both are in the goat-antelope subfamily Caprinae. There are over three hundred distinct breeds of goat.

Goats are one of the oldest domesticated species. Goats have been used for their milk, meat, hair, and skins over much of the world. In the twentieth century they also gained in popularity as pets.

Female goats are referred to as *does* or *nannies*, intact males as *bucks* or *billies*; their offspring are *kids*. Note that many goat breeders prefer the terms "buck" and "doe" to "billy" and "nanny". Castrated males are *wethers*. Goat meat from younger animals is called *kid* or *cabrito*, and from older animals is sometimes called *chevon*, or in some areas “mutton”.

Etymology

The Modern English word *goat* comes from the Old English *gāt* which meant "she-goat", and this in turn derived from Proto-Germanic **gaitaz* (cf. Old Norse and Dutch *geit* "goat", German *Geiß* "she-goat", and Gothic *gaits* "goat"), ultimately from Proto-Indo-European **ghaidos* meaning "young goat" (cf. Latin *haedus* "kid"), itself perhaps from a root meaning "jump" (assuming that Old Church Slavonic *zajęcĭ* "hare", Sanskrit *jihīte* "he moves" are related). To refer to the male of the species, Old English used *bucca* (which survives as "buck") until a shift to *he-goat* (and *she-goat*) occurred in the late 12th century. "Nanny goat" originated in the 18th century and "billy goat" in the 19th.



Amalthée et la chèvre de Jupiter (Amalthea and Jupiter's goat) Commissioned by the Queen of France in 1787 for the royal dairy at Rambouillet

History

Goats are among the earliest animals domesticated by humans. The most recent genetic analysis confirms the archaeological evidence that the Anatolian Zagros are the likely origin of almost all domestic goats today. Another major genetic source of modern goats is the Bezoar goat, distributed from the mountainous regions of Asia Minor across the Middle East to Sind.

Neolithic farmers began to keep goats for access to milk and meat, primarily, as well as for their dung, which was used as fuel and their bones, hair, and sinew for clothing,

building, and tools. The earliest remnants of domesticated goats dating 10,000 years before present are found in Ganj Dareh in Iran. Goat remains have been found at archaeological sites in Jericho, Choga, Mami, Djeitun and Cayonu, dating the domestication of goats in western Asia at between 8000 and 9000 years ago.

Historically, goat hide has been used for water and wine bottles in both traveling and transporting wine for sale. It has also been used to produce parchment.

Anatomy and health

Most goats naturally have two horns, of various shapes and sizes depending on the breed. All goats have horns unless they are "polled" meaning they have one parent with a dominant polled gene. There have been incidents of polycerate goats (having as many as eight horns), although this is a genetic rarity thought to be inherited. Their horns are made of living bone surrounded by keratin and other proteins, and are used for defense, dominance, and territoriality.

Goats are ruminants. They have a four-chambered stomach consisting of the rumen, the reticulum, the omasum, and the abomasum. As with other mammal ruminants, they are even-toed ungulates. The females have an udder consisting of two teats, in contrast to cattle, which have four teats.

Goats have horizontal slit-shaped pupils, an adaptation which increases peripheral depth perception. Because goats' irises are usually pale, the pupils are much more visible than in animals with horizontal pupils, but very dark irises, such as cattle, deer, most horses and many sheep.

Both male and female goats have beards, and many types of goat (most commonly dairy goats, dairy-cross boers, and pygmy goats) may have wattles, one dangling from each side of the neck.

Some breeds of sheep and goats look similar, but they can usually be told apart because goat tails are short and point up, whereas sheep tails hang down and are usually longer and bigger – though some (like those of Northern European short-tailed sheep) are short, and longer ones are often docked.

Reproduction

A 2 month old goat kid in a field of capeweed.

Goats reach puberty between 3 and 15 months of age, depending on breed and nutrition status. Many breeders prefer to postpone breeding until the doe has reached 70% of the adult weight. However, this separation is rarely possible in extensively managed, open range herds.

In temperate climates and among the Swiss breeds, the breeding season commences as the day length shortens, and ends in early spring or before. In equatorial regions, goats are able to breed at any time of the year. Successful breeding in these regions depends more on available forage than on day length. Does of any breed or region come into heat every 21 days for 2 to 48 hours. A doe in heat typically flags (vigorously wags) her tail often, stays near the buck if one is present, becomes more vocal, and may also show a decrease in appetite and milk production for the duration of the heat.

Bucks (intact males) of Swiss and northern breeds come into rut in the fall as with the doe's heat cycles. Bucks of equatorial breeds may show seasonal reduced fertility but, as with the does, are capable of breeding at all times. Rut is characterized by a decrease in appetite and obsessive interest in the does. A buck in rut will display flehmen lip curling and will urinate on his forelegs and face. Sebaceous scent glands at the base of the horns add to the male goat's odor, which is important to make him attractive to the female. Some does will not mate with a buck which has been de-scented.

In addition to natural mating, artificial insemination has gained popularity among goat breeders, as it allows easy access to a wide variety of bloodlines.

Suckling

Gestation length is approximately 150 days. Twins are the usual result, with single and triplet births also common. Less frequent are litters of quadruplet, quintuplet, and even sextuplet kids. Birthing, known as *kidding*, generally occurs uneventfully. Just before kidding, the doe will have a sunken area around the tail and hip, as well as heavy breathing. She may have a worried look, become restless and display great affection for her keeper. The mother often eats the placenta, which gives her much needed nutrients, helps stanch her bleeding, and parallels the behavior of wild herbivores such as deer to reduce the lure of the birth scent for predators.

Freshening (coming into milk production) occurs at kidding. Milk production varies with the breed, age, quality, and diet of the doe; dairy goats generally produce between 660 to 1,800 L (1,500 and 4,000 lb) of milk per 305 day lactation. On average, a good quality dairy doe will give at least 6 lb (2.7 l) of milk per day while she is in milk. A first time milker may produce less, or as much as 16 lb (7.3 l), or more of milk in exceptional cases. After the 305 day lactation, the doe will "dry off", typically after she has been bred. Occasionally, goats that have not been bred and are continuously milked will

continue lactation beyond the typical 305 days. Meat, fibre, and pet breeds are not usually milked and simply produce enough for the kids until weaning.

Western European-origin goats without horns (polled) frequently produce intersex offspring. These are generally female animals with male characteristics, and are infertile.

Male lactation is also known to occur in goats.

Diet

Goats are reputed to be willing to eat almost anything, except tin cans and cardboard boxes. While goats will not actually eat inedible material, they are browsing animals, not grazers like cattle and sheep, and (coupled with their natural curiosity) will chew on and taste just about anything resembling plant matter in order to decide whether it is good to eat, including cardboard and paper labels from tin cans. Another possibility is that the goats are curious about the unusual smells of leftover food in discarded cans or boxes.

A domestic goat feeding in a field of capeweed, a weed which is toxic to most stock animals

Aside from sampling many things, goats are quite particular in what they actually consume, preferring to browse on the tips of woody shrubs and trees, as well as the occasional broad-leaved plant. However, it can fairly be said that their plant diet is extremely varied, and includes some species which are otherwise toxic. They will seldom

consume soiled food or contaminated water unless facing starvation. This is one reason goat rearing is most often free ranging, since stall-fed goat rearing involves extensive upkeep and is seldom commercially viable.

Goats prefer to browse on shrubbery and weeds, more like deer than sheep, preferring them to grasses. Nightshade is poisonous; wilted fruit tree leaves can also kill goats. Silage (corn stalks) is not good for goats, but haylage can be used if consumed immediately after opening. Alfalfa is their favorite hay; fescue is the least palatable and least nutritious. Mold in a goat's feed can make it sick and possibly kill it. Goats should not be fed grass showing any signs of mold.

The digestive physiology of a very young kid (like the young of other ruminants) is essentially the same as that of a monogastric animal. Milk digestion begins in the abomasum, the milk having bypassed the rumen via closure of the reticular/esophageal groove during suckling. At birth, the rumen is undeveloped, but as the kid begins to consume solid feed, the rumen soon increases in size and in its capacity to absorb nutrients.

Behavior

Goats establish a dominance hierarchy in flocks, sometimes through head butting

Goats are extremely curious and intelligent. They are easily trained to pull carts and walk on leads. Ches McCartney, nicknamed "the goat man", toured the United States for over three decades in a wagon pulled by a herd of pet goats. They are also known for escaping their pens. Goats will test fences, either intentionally or simply because they are handy to climb on. If any of the fencing can be spread, pushed over or down, or otherwise be overcome, the goats will escape. Being very intelligent, once a weakness in the fence has been discovered, it will be exploited repeatedly. Goats are very coordinated and can climb and hold their balance in the most precarious places. Goats are also widely known for their ability to climb trees, although the tree generally has to be on somewhat of an angle. The vocalization goats make is called bleating.

Goats have an intensely inquisitive and intelligent nature: they will explore anything new or unfamiliar in their surroundings. They do so primarily with their prehensile upper lip and tongue. This is why they investigate items such as buttons, camera cases or clothing (and many other things besides) by nibbling at them, occasionally even eating them.

When handled as a group, goats tend to display less clumping behavior than sheep, and when grazing undisturbed, tend to spread across the field or range, rather than feed side-by-side as do sheep. When nursing young, goats will leave their kids separated ('lying out') rather than clumped as do sheep. They will generally turn and face an intruder and bucks are more likely to charge or butt at humans than are rams.

Diseases

While goats are generally considered hardy animals and in many situations receive little medical care, they are subject to a number of diseases.

Among the conditions affecting goats are respiratory diseases, including pneumonia, foot rot, internal parasites, pregnancy toxosis and feed toxicity.

Goats can become infected with various viral and bacterial diseases such as foot-and-mouth disease, caprine arthritis encephalitis, caseous lymphadenitis, pinkeye, mastitis, and pseudorabies. They can transmit a number of zoonotic diseases to people, such as tuberculosis, brucellosis, Q-fever, and rabies.

Life expectancy

Life expectancy for goats is between 15 and 18 years. An instance of a goat reaching the age of 24 has been reported.

Several factors can reduce this average expectancy, however; problems during kidding can lower a doe's expected life span to 10 or 11, and stresses of going into rut can lower a buck's expected life span to 8 or 10.

Goats in agriculture

Goat husbandry is common through the Norte Chico region in Chile, but also produces severe erosion and desertification. Image from upper Limarí River

A goat is useful to humans either living or dead, first as a renewable provider of milk, manure, and fiber, and then as meat and hide. Some charities provide goats to impoverished people in poor countries, because goats are easier and cheaper to manage than cattle, and have multiple uses. In addition, goats are used for driving and packing purposes.

For instance, the intestine is used to make "catgut", which is still in use as a material for internal human surgical sutures and strings for musical instruments. The horn of the goat, which signifies wellbeing (Cornucopia), is also used to make spoons.

The Boer goat - in this case a buck - is a widely-kept meat breed.

Worldwide goat population statistics

According to the FAO, the top producers of goat milk in 2008 were India (4 million metric tons), Bangladesh (2.16 million metric tons) and the Sudan (1.47 metric tons.)

Country/Region	Total Animals (millions)	Goat Milk (MT)	Goat Meat (million MT)
World	-----	15.2	4.8
Africa	294.5	3.2	1.1
Nigeria	53.8	N/A	0.26
Sudan	43.1	1.47	0.19
Asia	511.3	8.89	3.4
Afghanistan	6.38	0.11	0.04
India	125.7	4.0	0.48
Bangladesh	56.4	2.16	0.21
China	149.37	0.26	1.83
Saudi Arabia	2.2	0.076	0.024
Americas	37.3	0.54	0.15

Mexico	8.8	0.16	0.04
USA	3.1	N/A	0.022
Europe	17.86	2.59	0.012
UK	0.09	N/A	N/A
France	1.2	0.58	0.007
Oceania	3.42	0.0004	0.018

Husbandry

Husbandry, or animal care and use, varies from region to region and from culture to culture. The particular housing used for goats depends not only on the intended use of the goat but also on the region of the world where they are raised. Historically, domestic goats were generally kept in herds that wandered on hills or other grazing areas, often tended by goatherds who were frequently children or adolescents, similar to the more widely known shepherd. These methods of herding are still used today.

In some parts of the world, especially Europe and North America, distinct breeds of goat are kept for dairy (milk) and for meat production. As with cattle, only the females give milk. Excess male kids of dairy breeds are typically slaughtered for meat. Both does and bucks of meat breeds may be slaughtered for meat, as well as older animals of any breed. The meat of older bucks (more than 1 year old) is generally considered not desirable for meat for human consumption. Castration at a young age prevents the development of typical buck odor.

Dairy goats are generally pastured in summer and may be stabled during the winter. As dairy does are milked daily, they are generally kept close to the milking shed. Their grazing is typically supplemented with hay and with concentrates. Stabled goats may be kept in stalls similar to horses, or in larger group pens. In the US system, does are generally re-bred annually. In some European commercial dairy systems, the does are bred only twice, and are milked continuously for several years after the second kidding.

Meat goats are more frequently pastured year-round, and may be kept many miles from barns. Angora and other fiber breeds are also kept on pasture or range. Range-kept and pastured goats may be supplemented with hay or concentrates, but this happens most frequently during the winter or dry seasons.

In India, Nepal, and much of Asia, goats are kept largely for milk production, both in commercial and household settings. The goats in this area may be kept closely housed or may be allowed to range for fodder. The Salem Black goat is herded to pasture in fields and along roads during the day but is kept penned at night for safe-keeping.

In Africa and the Mideast, goats are typically run in flocks with sheep. This maximizes the production per acre, as goats and sheep prefer different food plants. Multiple types of goat-raising are found in Ethiopia, where four main types of goat raising have been identified: goats kept pastured in annual crop systems, goats kept in perennial crop

systems, goats kept with cattle, and goats kept in arid areas under pastoral (nomadic) herding systems. In all four systems, however, goats were typically kept in extensive systems, with few purchased inputs. Household goats are traditionally kept in Nigeria. While many goats are allowed to wander the homestead or village, others are kept penned and fed in what is called a 'cut-and-carry' system. This type of husbandry is also used in parts of Latin America. Cut-and-carry, which refers to the practice of cutting down grasses, corn or cane for feed rather than allowing the animal access to the field, is particularly suited for types of feed, such as corn or cane, that are easily destroyed by trampling.

Pet goats may be found in many parts of the world when a family keeps one or more animals for emotional reasons rather than as production animals. It is becoming more common for goats to be kept exclusively as pets in North America and Europe.

Meat

The taste of goat kid meat is similar to that of spring lamb meat; in fact, in the English-speaking islands of the Caribbean, and in some parts of Asia, particularly Pakistan and India, the word “mutton” is used to describe both goat and lamb meat. However, some compare the taste of goat meat to veal or venison, depending on the age and condition of the goat. Its flavor is said to be primarily linked to the presence of 4-methyloctanoic and 4-methylnonanoic acid. It can be prepared in a variety of ways including stewed, baked, grilled, barbecued, minced, canned, fried, curried, or made into sausage. Due to its low fat content, the meat can toughen at high temperatures without additional moisture. One of the most popular goats grown for meat is the South African Boer, introduced into the United States in the early 1990s. The New Zealand Kiko is also considered a meat breed, as is the myotonic or "fainting goat", a breed originating in Tennessee.

Milk, butter and cheese

A goat being milked on an organic farm.

Goats produce approximately 2% of the world's total annual milk supply. Some goats are bred specifically for milk. If the strong-smelling buck is not separated from the does, his scent will affect the milk.

Doe milk naturally has small, well-emulsified fat globules, which means the cream remains suspended in the milk, instead of rising to the top, as in raw cow milk; therefore, it does not need to be homogenized. Indeed, if the milk is going to be used to make cheese it is recommended that it is not homogenized as this changes the structure of the milk impacting the culture's ability to coagulate the milk and the final quality and yield of cheese.

Dairy goats in their prime, which is generally around the third or fourth lactation cycle, average 6 to 8 pounds (2.7 to 3.6 kg) of milk production daily (roughly 3 to 4 US quarts (2.7 to 3.6 liters)) during a ten-month lactation, producing more just after freshening and gradually dropping in production toward the end of their lactation. The milk generally averages 3.5 percent butterfat. A doe may be expected to reach her heaviest production during her third or fourth lactation.

Doe milk is commonly processed into cheese, butter, ice cream, yoghurt, cajeta and other products. Goat cheese is known as *chèvre* in France, after the French word for "goat". Some varieties include Rocamadour and Montrachet. Goat butter is white because goats produce milk with the yellow beta-carotene converted to a colorless form of vitamin A.

Nutrition

The American Academy of Pediatrics discourages feeding infants milk derived from goats. An April 2010 case report summarizes their recommendation and presents "a comprehensive review of the consequences associated with this dangerous practice," also stating, "Many infants are exclusively fed unmodified goat's milk as a result of cultural beliefs as well as exposure to false online information. Anecdotal reports have described a host of morbidities associated with that practice, including severe electrolyte abnormalities, metabolic acidosis, megaloblastic anemia, allergic reactions including life-threatening anaphylactic shock, hemolytic uremic syndrome, and infections." Untreated caprine brucellosis results in a 2% case fatality rate. According to the United States Department of Agriculture (USDA), doe milk is not recommended for human infants because it contains "inadequate quantities of iron, folate, vitamins C and D, thiamin, niacin, vitamin B6, and pantothenic acid to meet an infant's nutritional needs" and may cause harm to an infant's kidneys and could cause metabolic damage.

The Department of Health in the United Kingdom has repeatedly released statements stating on various occasions that "Goats' milk is not suitable for babies, and infant formulas and follow-on formulas based on goats' milk protein have not been approved for use in Europe," and "infant milks based on goats' milk protein are not suitable as a source of nutrition for infants.".

On the other hand, some farming groups promote the practice. For example Small Farm Today in 2005 claimed beneficial use in invalid and convalescent diets, proposing that glycerol ethers, possibly important in nutrition for nursing infants, are much higher in doe milk than in cow milk. A 1970 book on animal breeding claimed that doe milk differs from cow or human milk by having higher digestibility, distinct alkalinity, higher buffering capacity, and certain therapeutic values in human medicine and nutrition. George Mateljan suggested that doe milk can replace ewe milk or cow milk in diets of those who are allergic to certain mammals' milk. However, like cow milk, doe milk has lactose (sugar), and may cause gastrointestinal problems for individuals with lactose intolerance. In fact, the level of lactose is similar to that of bovine milk.

Basic composition of various milks (mean values per 100g)

Constituent	Doe (Goat)	Cow	Human
Fat (g)	3.8	3.6	4.0
Protein (g)	3.5	3.3	1.2
Lactose (g)	4.1	4.6	6.9
Ash (g)	0.8	0.7	0.2

Total solids (g)	12.2	12.3	12.3
Calories	70	69	68

Milk composition analysis, per 100 grams

Constituents	unit	Cow	Doe (Goat)	Ewe (Sheep)	Water buffalo
Water	g	87.8	88.9	83.0	81.1
Protein	g	3.2	3.1	5.4	4.5
Fat	g	3.9	3.5	6.0	8.0
Carbohydrate	g	4.8	4.4	5.1	4.9
Energy	kcal	66	60	95	110
Energy	kJ	275	253	396	463
Sugars (lactose)	g	4.8	4.4	5.1	4.9
Cholesterol	mg	14	10	11	8
Calcium	IU	120	100	170	195
Saturated fatty acids	g	2.4	2.3	3.8	4.2
Monounsaturated fatty acids	g	1.1	0.8	1.5	1.7
Polyunsaturated fatty acids	g	0.1	0.1	0.3	0.2

These compositions vary by breed, animal, and point in the lactation period.

Fiber

An Angora goat

A Cashmere goat

The Angora breed of goats produces long, curling, lustrous locks of mohair. The entire body of the goat is covered with mohair and there are no guard hairs. The locks constantly grow and can be four inches or more in length. Angora crossbreeds, such as the pygora and the nigora, have been created to produce mohair and/or cashgora on a smaller, easier-to-manage animal. The wool is shorn (cut from the body) twice a year, with an average yield of about 10 pounds.

Most goats have softer insulating hairs nearer the skin, and longer guard hairs on the surface. The desirable fiber for the textile industry is the former, and it goes by several names (down, cashmere and pashmina). The coarse guard hairs are of little value as they are too coarse, difficult to spin and difficult to dye. The cashmere goat produces a commercial quantity of cashmere wool, which is one of the most expensive natural fibers commercially produced; cashmere is very fine and soft. The cashmere goat fiber is harvested once a year, yielding around 9 ounces (200 grammes) of down.

In South Asia, cashmere is called "pashmina" (from Persian *pashmina*, "fine wool"). In the 18th and early 19th century, Kashmir (then called Cashmere by the English), had a thriving industry producing shawls from goat down imported from Tibet and Tartary through Ladakh. The shawls were introduced into Western Europe when the General in Chief of the French campaign in Egypt (1799–1802) sent one to Paris. Since these shawls

were produced in the upper Kashmir and Ladakh region, the wool came to be known as "cashmere".

Goat breeds

Goat breeds fall into overlapping, general categories. They are generally distributed in to those used for dairy, fiber, meat, skins, and as companion animals. Some breeds are also particularly noted as pack goats.

Showing

A Nigerian Dwarf milker in show clip. This doe is angular and dairy with a capacious and well supported mammary system.

Goat breeders' clubs frequently hold shows, where goats are judged on traits relating to conformation, udder quality, evidence of high production, longevity, build and muscling (meat goats and pet goats) and fiber production and the fiber itself (fiber goats). People who show their goats usually keep registered stock and the offspring of award-winning

animals command a higher price. Registered goats, in general, are usually higher-priced if for no other reason than that records have been kept proving their ancestry and the production and other data of their sires, dams, and other ancestors. A registered doe is usually less of a gamble than buying a doe at random (as at an auction or sale barn) because of these records and the reputation of the breeder. Children's clubs such as 4-H also allow goats to be shown. Children's shows often include a showmanship class, where the cleanliness and presentation of both the animal and the exhibitor as well as the handler's ability and skill in handling the goat are scored. In a showmanship class, conformation is irrelevant since this is not what is being judged.

Various "Dairy Goat Scorecards" (milking does) are systems used for judging shows in the US. The American Dairy Goat Association (ADGA) scorecard for an adult doe includes a point system of a hundred total with major categories that include general appearance, the dairy character of a doe (physical traits that aid and increase milk production), body capacity, and specifically for the mammary system. Young stock and bucks are judged by different scorecards which place more emphasis on the other three categories; general appearance, body capacity, and dairy character.

The American Goat Society (**AGS**) has a similar, but not identical scorecard that is used in their shows. The miniature dairy goats may be judged by either of the two scorecards. The "Angora Goat scorecard" used by the **Colored Angora Goat Breeder's Association CAGBA** (which covers the white and the colored goats) includes evaluation of an animal's fleece color, density, uniformity, fineness, and general body confirmation. Disqualifications include: a deformed mouth, broken down pasterns, deformed feet, crooked legs, abnormalities of testicles, missing testicles, more than 3 inch split in scrotum, and close-set or distorted horns.

Religion, mythology, and folklore

The goat Heiðrún consumes the foliage of the tree Læraðr, while her udders produce mead, collected in a pot bellow (1895) by Lorenz Frølich.

The Scapegoat by William Holman Hunt (1854).

According to Norse mythology, the god of thunder, Thor, has a chariot that is pulled by the goats Tanngrisnir and Tanngnjóstr. At night when he sets up camp, Thor eats the meat of the goats, but take care that all bones remain whole. Then he wraps the remains up, and in the morning, the goats always come back to life to pull the chariot. When a farmer's son who is invited to share the meal breaks one of the goats' leg bones to suck the marrow, the animal's leg remains broken in the morning, and the boy is forced to serve Thor as a servant to compensate for the damage.

Possibly related, the Yule Goat is one of the oldest Scandinavian and Northern European Yule and Christmas symbols and traditions. Yule Goat originally denoted the goat that was slaughtered around Yule, but it may also indicate a goat figure made out of straw. It is also used about the custom of going door-to-door singing carols and getting food and drinks in return, often fruit, cakes and sweets. "Going Yule Goat" is similar to the British custom wassailing, both with heathen roots. The Gävle Goat is a giant version of the Yule Goat, erected every year in the Swedish city of Gävle.

The Greek god, Pan, is said to have the upper body of a man and the horns and lower body of a goat. Pan was a very lustful god, nearly all of the myths involving him had to do with him chasing nymphs. He is also credited with creating the pan flute.

The goat is one of the twelve-year cycle of animals which appear in the Chinese zodiac related to the Chinese calendar. Each animal is associated with certain personality traits; those born in a year of the goat are predicted to be shy, introverted, creative, and perfectionist.

Several mythological hybrid creatures are believed to consist of parts of the goat, including the Chimera. The Capricorn sign in the Western zodiac is usually depicted as a goat with a fish's tail. Fauns and satyrs are mythological creatures that are part goat and part human. The mineral bromine is named from the Greek word "brómos," which means "stench of he-goats."

Goats are mentioned many times in the Bible. A goat is considered a "clean" animal by Jewish dietary laws and was slaughtered for an honored guest. It was also acceptable for some kinds of sacrifices. Goat-hair curtains were used in the tent that contained the tabernacle (Exodus 25:4). Its horns can be used instead of sheep's horn to make a shofar. On Yom Kippur, the festival of the Day of Atonement, two goats were chosen and lots were drawn for them. One was sacrificed and the other allowed to escape into the wilderness, symbolically carrying with it the sins of the community. From this comes the word "scapegoat". A leader or king was sometimes compared to a male goat leading the flock. In the New Testament, Jesus told a parable of The Sheep and the Goats. (Gospel of Matthew 25)

Popular Christian folk tradition in Europe associated Satan with imagery of goats. A common superstition in the Middle Ages was that goats whispered lewd sentences in the ears of the saints. The origin of this belief was probably the behavior of the buck in rut, the very epitome of lust. The common medieval depiction of the Devil was that of a goat-like face with horns and small beard (a goatee). The Black Mass, a probably-mythological "Satanic mass," was said to involve a black goat, the form in which Satan supposedly manifested himself for worship.

The goat has had a lingering connection with Satanism and pagan religions, even into modern times. The inverted pentagram, a symbol used in Satanism, is said to be shaped like a goat's head. The "Baphomet of Mendes" refers to a satanic goat-like figure from 19th century occultism.

Feral goats

Feral goat in Aruba

Goats readily revert to the wild (become feral) if given the opportunity. The only domestic animal known to return to feral life as swiftly is the cat. Feral goats have established themselves in many areas: they occur in Australia, New Zealand, Great Britain, the Galapagos and in many other places. When feral goats reach large populations in habitats which are not adapted to them, they may have serious effects, such as removing native scrub, trees and other vegetation. Feral goats are common in Australia. However, in other circumstances they may become a natural component of the habitat.

Chapter 8

Gorilla

Gorillas

Western Gorilla
(*Gorilla gorilla*)

Conservation status

Endangered (IUCN 3.1)

Scientific classification

Kingdom:	Animalia
Phylum:	Chordata
Class:	Mammalia

Order:	Primates
Family:	Hominidae
Subfamily:	Homininae
Tribe:	**Gorillini**
Genus:	***Gorilla*** I. Geoffroy, 1852

Type species

Troglodytes gorilla Savage, 1847

Species

Gorilla gorilla
Gorilla beringei

distribution of *Gorilla*

Synonyms

- *Pseudogorilla* Elliot, 1913

Gorillas are the largest species of primates. Gorillas are ground-dwelling, predominantly herbivorous apes that inhabit the forests of central Africa. Gorillas are divided into two species and (still under debate as of 2008) either four or five subspecies. The DNA of gorillas is highly similar to that of a human, between 95 and 99% depending on what is counted, and they are the next closest living relatives to humans after the two chimpanzee species.

Gorillas' natural habitats cover tropical or subtropical forests in Africa. Although their range covers a small percentage of Africa, gorillas cover a wide range of elevations. The Mountain Gorilla inhabits the Albertine Rift montane cloud forests of the Virunga Volcanoes, ranging in altitude from 2,200–4,300 metres (7,200–14,100 ft). Lowland Gorillas live in dense forests and lowland swamps and marshes as low as sea level, with Western Lowland Gorillas living in Central West African countries and Eastern Lowland Gorillas living in the Democratic Republic of the Congo near its border with Rwanda.

Etymology

The American physician and missionary Thomas Staughton Savage and naturalist Jeffries Wyman first described the Western Gorilla (they called it *Troglodytes gorilla*) in 1847 from specimens obtained in Liberia. The name was derived from the Greek word "Γόριλλαι" (*Gorillai*), a "tribe of hairy women" described by Hanno the Navigator, a Carthaginian navigator and possible visitor (circa 480 BC) to the area that later became Sierra Leone.

Evolution and classification

The closest relatives of gorillas are chimpanzees and humans, all of the Hominidae having diverged from a common ancestor about 7 million years ago. Human genes differ only 1.6% on average from their corresponding gorilla genes in their sequence, but there is further difference in how many copies each gene has.

Until recently there was considered to be a single gorilla species, with three subspecies: the Western Lowland Gorilla, the Eastern Lowland Gorilla and the Mountain Gorilla. There is now agreement that there are two species with two subspecies each. More recently it has been claimed that a third subspecies exists in one of the species. The separate species and subspecies developed from a single type of gorilla during the Ice Age, when their forest habitats shrank and became isolated from each other.

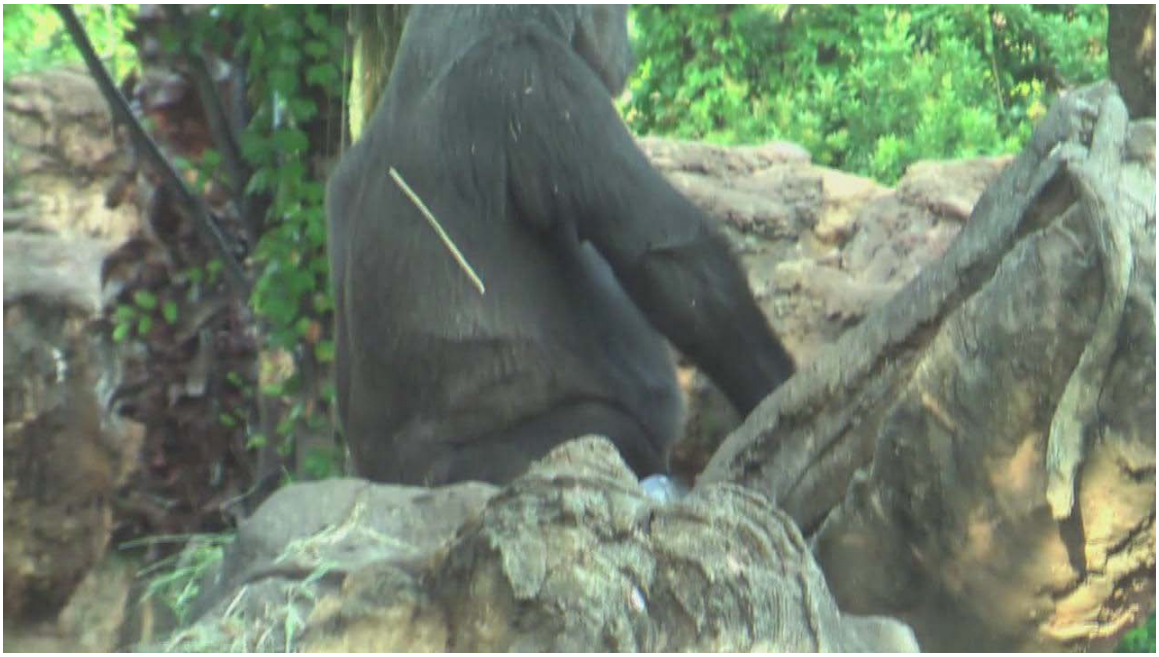
Primatologists continue to explore the relationships between various gorilla populations. The species and subspecies listed here are the ones upon which most scientists agree.

- **Genus *Gorilla***
  - Western Gorilla (*Gorilla gorilla*)
    - Western Lowland Gorilla (*Gorilla gorilla gorilla*)
    - Cross River Gorilla (*Gorilla gorilla diehli*)
  - Eastern Gorilla (*Gorilla beringei*)
    - Mountain Gorilla (*Gorilla beringei beringei*)
    - Eastern Lowland Gorilla (*Gorilla beringei graueri*)

The proposed third subspecies of *Gorilla beringei*, which has not yet received a trinomen, is the Bwindi population of the Mountain Gorilla, sometimes called the Bwindi Gorilla.

Some variations that distinguish the classifications of gorilla include varying density, size, hair color, length, culture, and facial widths. There are now thought to be over 100,000 Western Lowland Gorillas in the wild, with 4,000 in zoos; Eastern Lowland Gorillas have a population of 4,000 in the wild and 24 in zoos. Mountain Gorillas are the most severely endangered, with an estimated population of about 620 left in the wild and none in zoos.

Physical characteristics



Two Western Lowland Gorillas move around at Ueno Zoo.

Gorillas move around by knuckle-walking, although they sometimes walk bipedally for short distances while carrying food or in defensive situations. Adult males range in height 1.65–1.75 metres (5 ft 5 in–5 ft 9 in), and in weight 140–200 kg (310–440 lb). Adult females are often half the size of a silverback, averaging about 1.4 metres (4 ft 7 in) tall and 100 kg (220 lb). Occasionally, a silverback of over 1.8 metres (5 ft 11 in) and 230 kg (510 lb) has been recorded in the wild. Obese gorillas in captivity have reached a weight of 270 kg (600 lb). Gorillas have a facial structure which is described as mandibular prognathism, that is, their mandible protrudes farther out than the maxilla.

The Eastern Gorilla is more darkly colored than the Western Gorilla, with the Mountain Gorilla being the darkest of all. The Mountain Gorilla also has the thickest hair. The Western Lowland Gorilla can be brown or grayish with a reddish forehead. In addition, gorillas that live in lowland forests are more slender and agile than the more bulky Mountain Gorilla.

Almost all gorillas share the same blood type (B) and, like humans, have individual finger prints.

Behavior

Group life

A silverback gorilla portrait.

A **silverback** is an adult male gorilla, typically more than 12 years of age and named for the distinctive patch of silver hair on his back. A silverback gorilla has large canine teeth that come with maturity. **Blackbacks** are sexually mature males of up to 11 years of age. Silverbacks are the strong, dominant troop leaders. Each typically leads a troop (group size ranges from 5 to 30) and is in the center of the troop's attention, making all the decisions, mediating conflicts, determining the movements of the group, leading the others to feeding sites and taking responsibility for the safety and well-being of the troop. Blackbacks may serve as backup protection. Adult females tend to be unrelated.

Males will slowly begin to leave their paternal troop at 11 years old, which is when they reach their young adult or sub-adult years. Sometimes a male may stay in his father's troop and inherit control when he ages. Female gorillas will also leave their parental troop when they reach sexual maturity. When they leave, they immediately search for a silverback who is usually nearby. However, females usually transfer more than once, to

find a male that has the best fighting prowess and access to quality of habitat. Once a female reproduces, she will become a permanent member of a troop.

While infant gorillas normally stay with their mother for 3–4 years, silverbacks will care for weaned young orphans, though never to the extent of carrying the little gorillas. If challenged by a younger or even by an outsider male, a silverback will scream, beat his chest, break branches, bare his teeth, then charge forward. If the leader is killed by disease, accident, fighting or poachers, the group will split up, as the animals disperse to look for a new protective male. There is a strong risk that the new male will kill the infants of the dead silverback.

Food and foraging

Gorillas are herbivores, eating fruits, leaves, and shoots. Further, they are classified as folivores. Much like other animals that feed on plants and shoots, they sometimes ingest small insects as well (however, there has been video proof that gorillas do eat ants and termites much in the same way as chimpanzees.) Gorillas spend most of the day eating. Their large sagittal crest and long canines allow them to crush hard plants like bamboo. Lowland gorillas feed mainly on fruit while Mountain gorillas feed mostly on herbs, stems and roots.

Reproduction and lifespan

Female and baby gorilla.

Gestation is 8½ months. There are typically 3 to 4 years between births. Infants stay with their mothers for 3–4 years. Females mature at 10–12 years (earlier in captivity); males at 11–13 years. Lifespan is between 30–50 years, although there have been exceptions. For example the Dallas Zoo's Jenny lived to the age of 55. Recently, gorillas have been observed engaging in face-to-face sex, a trait that was once considered unique to humans and the Bonobo.

Intelligence

Gorillas are closely related to humans and are considered highly intelligent. A few individuals in captivity, such as Koko, have been taught a subset of sign language. Like the other great apes, gorillas can laugh, grieve, have "rich emotional lives," develop strong family bonds, can make and use tools, and can think about the past and future. Some researchers believe that gorillas have spiritual feelings or religious sentiments. Gorillas have been shown to have cultures in different areas revolving around different methods of food preparation, and gorillas will show individual color preferences.

Tool use

A female gorilla exhibiting tool use by using a tree trunk as a support whilst fishing.

The following observations were made by a team led by Thomas Breuer of the Wildlife Conservation Society in September 2005. Gorillas are now known to use tools in the wild. A female gorilla in the Nouabalé-Ndoki National Park in the Republic of Congo was recorded using a stick as if to gauge the depth of water whilst crossing a swamp. A second female was seen using a tree stump as a bridge and also as a support whilst fishing in the swamp. This means that all of the great apes are now known to use tools.

In September 2005, a two and a half year old gorilla in the Republic of Congo was discovered using rocks to smash open palm nuts inside a game sanctuary. While this was the first such observation for a gorilla, over 40 years previously chimpanzees had been

seen using tools in the wild, famously 'fishing' for termites. Great apes are endowed with a semi-precision grip, and certainly have been able to use both simple tools and even weapons, by improvising a club from a convenient fallen branch.

Endangerment

Both species of gorilla are endangered, and have been subject to intense poaching for a long time. Threats to gorilla survival include habitat destruction and the bushmeat trade. In 2004, a population of several hundred gorillas in the Odzala National Park, Republic of Congo was essentially wiped out by the Ebola virus. A 2006 study published in *Science* concluded that more than 5,000 gorillas may have died in recent outbreaks of the Ebola virus in central Africa. The researchers indicated that in conjunction with commercial hunting of these apes, the virus creates "a recipe for rapid ecological extinction." Conservation efforts include the Great Ape Survival Project, a partnership between the United Nations Environment Programme and the UNESCO, and also an international treaty, the Agreement on the Conservation of Gorillas and Their Habitats, concluded under UNEP-administered Convention on Migratory Species. The Gorilla Agreement is the first legally binding instrument exclusively targeting Gorilla conservation and came into effect on 1 June 2008.

Chapter 9

Horse

Domestic horse

Conservation status
Domesticated
Scientific classification
Kingdom: Animalia
Phylum: Chordata
Class: Mammalia
Subclass: Theria
Infraclass: Eutheria
Order: Perissodactyla
Family: Equidae
Genus: *Equus*
Species: *E. ferus*
Subspecies: ***E. f. caballus***
Trinomial name
Equus ferus caballus Linnaeus, 1758
Synonyms

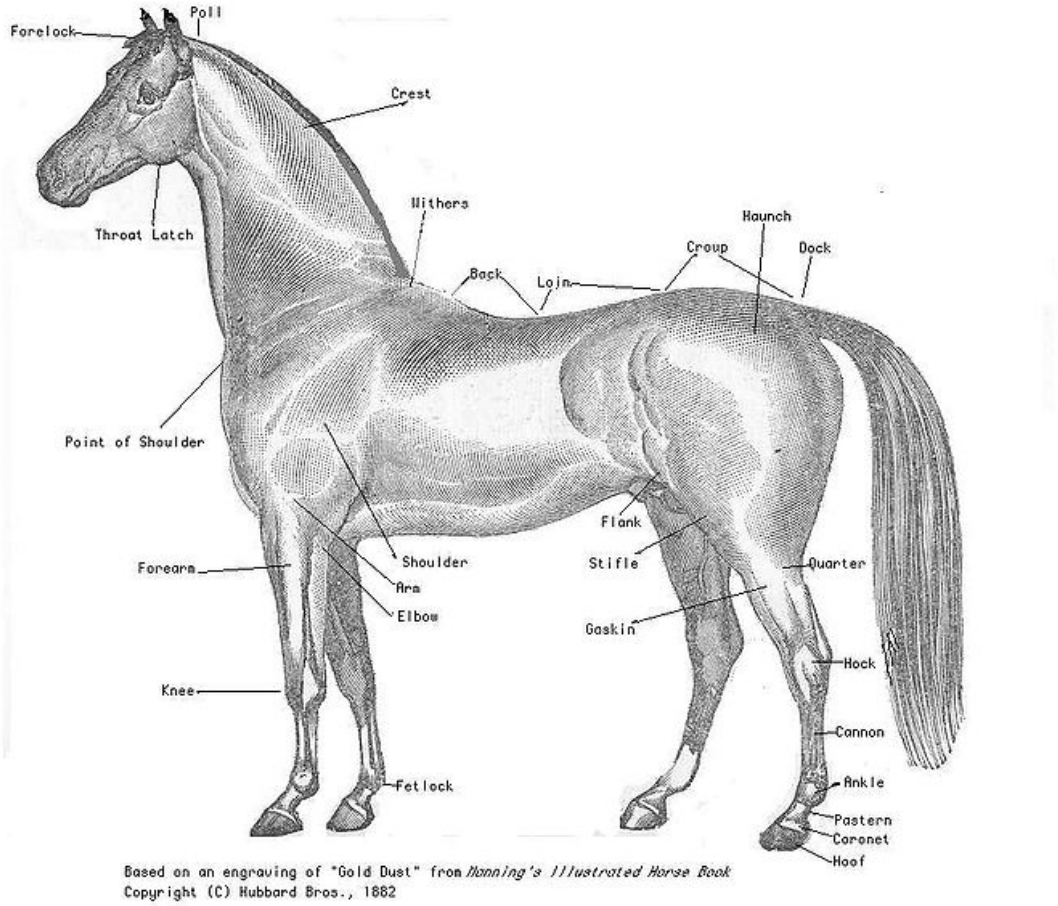
The **horse** (*Equus ferus caballus*) is a hooved (ungulate) mammal, a subspecies of the family Equidae. The horse has evolved over the past 45 to 55 million years from a small multi-toed creature into the large, single-toed animal of today. Humans began to domesticate horses around 4000 BC, and their domestication is believed to have been widespread by 3000 BC. Although most horses today are domesticated, there are still endangered populations of the Przewalski's Horse, the only remaining true wild horse, as well as more common populations of feral horses which live in the wild but are descended from domesticated ancestors. There is an extensive, specialized vocabulary used to describe equine-related concepts, covering everything from anatomy to life stages, size, colors, markings, breeds, locomotion, and behaviour.

Horses' anatomy enables them to make use of speed to escape predators and they have a well-developed sense of balance and a strong fight-or-flight instinct. Related to this need to flee from predators in the wild is an unusual trait: horses are able to sleep both standing up and lying down. Female horses, called mares, carry their young for approximately 11 months, and a young horse, called a foal, can stand and run shortly following birth. Most domesticated horses begin training under saddle or in harness between the ages of two and four. They reach full adult development by age five, and have an average lifespan of between 25 and 30 years.

Horse breeds are loosely divided into three categories based on general temperament: spirited "hot bloods" with speed and endurance; "cold bloods", such as draft horses and some ponies, suitable for slow, heavy work; and "warmbloods", developed from crosses between hot bloods and cold bloods, often focusing on creating breeds for specific riding purposes, particularly in Europe. There are over 300 breeds of horses in the world today, developed for many different uses.

Horses and humans interact in a wide variety of sport competitions and non-competitive recreational pursuits, as well as in working activities such as police work, agriculture, entertainment, and therapy. Horses were historically used in warfare, from which a wide variety of riding and driving techniques developed, using many different styles of equipment and methods of control. Many products are derived from horses, including meat, milk, hide, hair, bone, and pharmaceuticals extracted from the urine of pregnant mares. Humans provide domesticated horses with food, water and shelter, as well as attention from specialists such as veterinarians and farriers.

Biology



Parts of a horse

Horse anatomy is described by a large number of specific terms, as illustrated by the chart to the right. Specific terms also describe various ages, colors and breeds.

Lifespan and life stages

Depending on breed, management and environment, the domestic horse today has a life expectancy of 25 to 30 years. It is uncommon, but a few animals live into their 40s and, occasionally, beyond. The oldest verifiable record was "Old Billy", a 19th-century horse that lived to the age of 62. In modern times, Sugar Puff, who had been listed in the Guinness Book of World Records as the world's oldest living pony, died in 2007, aged 56.

Regardless of a horse's actual birth date, for most competition purposes an animal is considered a year older on January 1 of each year in the northern hemisphere and August 1 in the southern hemisphere. The exception is in endurance riding, where the

minimum age to compete is based on the animal's calendar age. A very rough estimate of a horse's age can be made from looking at its teeth.

The following terminology is used to describe horses of various ages:

- Foal: a horse of either sex less than one year old. A nursing foal is sometimes called a *suckling* and a foal that has been weaned is called a *weanling.* Most domesticated foals are weaned at 5 to 7 months of age, although foals can be weaned at 4 months with no adverse effects.
- Yearling: a horse of either sex that is between one and two years old.
- Colt: a male horse under the age of four. A common terminology error is to call any young horse a "colt", when the term actually only refers to young male horses.
- Filly: a female horse under the age of four.
- Mare: a female horse four years old and older.
- Stallion: a non-castrated male horse four years old and older. Some people, particularly in the UK, refer to a stallion as a "horse".
- Gelding: a castrated male horse of any age.

In horse racing, these definitions may differ: For example, in the British Isles, Thoroughbred horse racing defines colts and fillies as less than five years old. However, for Australian Thoroughbred racing, colts and fillies are less than four years old.

Size and measurement

The height of horses is measured at the highest point of the withers, where the neck meets the back. This point was chosen as it is a stable point of the anatomy, unlike the head or neck, which move up and down.

The English-speaking world measures the height of horses in hands (abbreviated "h" or "hh", for "hands high") and inches. One hand is equal to 101.6 millimetres (4 in). The height is expressed as the number of full hands, followed by a decimal point, then the number of additional inches. Thus, a horse described as "15.2 h" is 15 hands (60 inches (152.4 cm)) plus 2 inches (5.1 cm), for a total of 62 inches (157.5 cm) in height.

Size varies greatly among horse breeds, as with this full-sized horse and a miniature horse.

The size of horses varies by breed, but also is influenced by nutrition. Light riding horses usually range in height from 14 to 16 hands (56 to 64 inches, 142 to 163 cm) and can weigh from 380 to 550 kilograms (840 to 1,200 lb). Larger riding horses usually start at about 15.2 hands (62 inches, 157 cm) and often are as tall as 17 hands (68 inches, 173 cm), weighing from 500 to 600 kilograms (1,100 to 1,300 lb). Heavy or draft horses are usually at least 16 to 18 hands (64 to 72 inches, 163 to 183 cm) high and can weigh from about 700 to 1,000 kilograms (1,500 to 2,200 lb).

The largest horse in recorded history was probably a Shire horse named Mammoth, who was born in 1848. He stood 21.2½ hands high (86.5 in/220 cm), and his peak weight was estimated at 1,500 kilograms (3,300 lb). The current record holder for the world's smallest horse is Thumbelina, a fully mature miniature horse affected by dwarfism. She is 17 inches (43 cm) tall and weighs 57 pounds (26 kg).

Ponies

The general rule for height between a horse and a pony at maturity is 14.2 hands (58 inches, 147 cm). An animal 14.2 h or over is usually considered to be a horse and one less than 14.2 h a pony. However, there are many exceptions to the general rule. In Australia, ponies measure under 14 hands (56 inches, 142 cm). The International Federation for Equestrian Sports, which uses metric measurements, defines the cutoff between horses and ponies at 148 centimetres (58.27 in) (just over 14.2 h) without shoes

and 149 centimetres (58.66 in) (just over 14.2½ h) with shoes. Some breeds which typically produce individuals both under and over 14.2 h consider all animals of that breed to be horses regardless of their height. Conversely, some pony breeds may have features in common with horses, and individual animals may occasionally mature at over 14.2 h, but are still considered to be ponies.

The distinction between a horse and pony is not simply a difference in height, but other aspects of *phenotype* or appearance, such as conformation and temperament. Ponies often exhibit thicker manes, tails, and overall coat. They also have proportionally shorter legs, wider barrels, heavier bone, shorter and thicker necks, and short heads with broad foreheads. They may have calmer temperaments than horses and also a high level of equine intelligence that may or may not be used to cooperate with human handlers. In fact, small size, by itself, is sometimes not a factor at all. While the Shetland pony stands on average 10 hands (40 inches, 102 cm), the Falabella and other miniature horses, which can be no taller than 30 inches (76 cm), the size of a medium-sized dog, are classified by their respective registries as very small horses rather than as ponies.

Colors and markings

Bay (left) and chestnut (sometimes called "sorrel") are two of the most common coat colors, seen in almost all breeds.

Horses exhibit a diverse array of coat colors and distinctive markings, described with a specialized vocabulary. Often, a horse is classified first by its coat color, before breed or

sex. Horses of the same color may be distinguished from one another by white markings, which, along with various spotting patterns, are inherited separately from coat color.

Many genes that create horse coat colors have been identified, although research continues to further identify factors that result in specific traits. One of the first genetic relationships to be understood was that between recessive "red" (chestnut) and dominant "black", which is controlled by the "red factor" or extension gene. Additional alleles control spotting, graying, suppression or dilution of color, and other effects that create the dozens of possible coat colors found in horses.

Chestnut, bay, and black are the basic equine coat colors. These colors are modified by at least ten other genes to create all other colors, including dilutions such as palomino and spotting patterns such as pinto. Horses which are white in coat color are often mislabeled as "white" horses. However, a horse that looks white is usually a middle-aged or older gray. Grays are born a darker shade, get lighter as they age, and usually have black skin underneath their white hair coat (with the exception of pink skin under white markings). The only horses properly called white are born with a white hair coat and have predominantly pink skin, a fairly rare occurrence. There are no truly "albino" horses having both pink skin and red eyes.

Reproduction and development

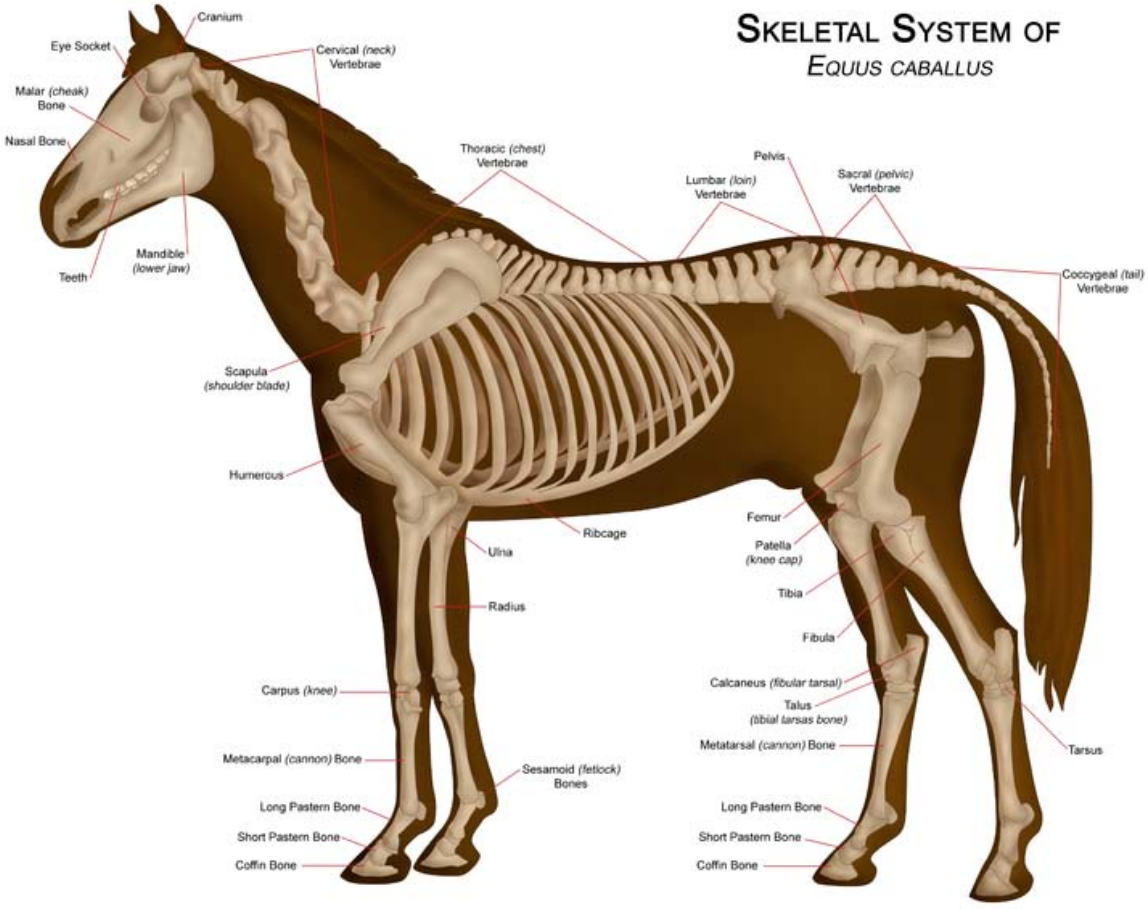
Gestation lasts for approximately 335–340 days and usually results in one foal. Twins are rare. Horses are a precocial species, and foals are capable of standing and running within a short time following birth.

Horses, particularly colts, sometimes are physically capable of reproduction at about 18 months, but domesticated horses are rarely allowed to breed before the age of three, especially females. Horses four years old are considered mature, although the skeleton normally continues to develop until the age of six; maturation also depends on the horse's size, breed, sex, and quality of care. Also, if the horse is larger, its bones are larger; therefore, not only do the bones take longer to actually form bone tissue, but the epiphyseal plates are also larger and take longer to convert from cartilage to bone. These plates convert after the other parts of the bones, and are crucial to development.

Depending on maturity, breed, and work expected, horses are usually put under saddle and trained to be ridden between the ages of two and four. Although Thoroughbred race horses are put on the track at as young as two years old in some countries, horses specifically bred for sports such as dressage are generally not put under saddle until they are three or four years old, because their bones and muscles are not solidly developed. For endurance riding competition, horses are not deemed mature enough to compete until they are a full 60 calendar months (5 years) old.

Anatomy

Skeletal system



The skeletal system of a modern horse

Horses have a skeleton that averages 205 bones. A significant difference between the horse skeleton and that of a human, is the lack of a collarbone—the horse's forelimbs are attached to the spinal column by a powerful set of muscles, tendons, and ligaments that attach the shoulder blade to the torso. The horse's legs and hooves are also unique structures. Their leg bones are proportioned differently from those of a human. For example, the body part that is called a horse's "knee" is actually made up of the carpal bones that correspond to the human wrist. Similarly, the hock contains bones equivalent to those in the human ankle and heel. The lower leg bones of a horse correspond to the bones of the human hand or foot, and the fetlock (incorrectly called the "ankle") is actually the proximal sesamoid bones between the cannon bones (a single equivalent to the human metacarpal or metatarsal bones) and the proximal phalanges, located where one finds the "knuckles" of a human. A horse also has no muscles in its legs below the

knees and hocks, only skin, hair, bone, tendons, ligaments, cartilage, and the assorted specialized tissues that make up the hoof.

Hooves

The critical importance of the feet and legs is summed up by the traditional adage, "no foot, no horse". The horse hoof begins with the distal phalanges, the equivalent of the human fingertip or tip of the toe, surrounded by cartilage and other specialized, blood-rich soft tissues such as the laminae. The exterior hoof wall and horn of the sole is made of essentially the same material as a human fingernail. The end result is that a horse, weighing on average 500 kilograms (1,100 lb), travels on the same bones as would a human on tiptoe. For the protection of the hoof under certain conditions, some horses have horseshoes placed on their feet by a professional farrier. The hoof continually grows, and needs to be trimmed (and horseshoes reset, if used) every five to eight weeks.

Teeth

Horses are adapted to grazing. In an adult horse, there are 12 incisors, adapted to biting off the grass or other vegetation, at the front of the mouth. There are 24 teeth adapted for chewing, the premolars and molars, at the back of the mouth. Stallions and geldings have four additional teeth just behind the incisors, a type of canine teeth that are called "tushes". Some horses, both male and female, will also develop one to four very small vestigial teeth in front of the molars, known as "wolf" teeth, which are generally removed because they can interfere with the bit. There is an empty interdental space between the incisors and the molars where the bit rests directly on the bars (gums) of the horse's mouth when the horse is bridled.

The incisors show a distinct wear and growth pattern as the horse ages, as well as change in the angle at which the chewing surfaces meet. The teeth continue to erupt throughout life as they are worn down by grazing, so a very rough estimate of a horse's age can be made by an examination of its teeth, although diet and veterinary care can affect the rate of tooth wear.

Digestion

Horses are herbivores with a digestive system adapted to a forage diet of grasses and other plant material, consumed steadily throughout the day. Therefore, compared to humans, they have a relatively small stomach but very long intestines to facilitate a steady flow of nutrients. A 450-kilogram (990 lb) horse will eat 7 to 11 kilograms (15 to 24 lb) of food per day and, under normal use, drink 38 litres (8.4 imp gal; 10 US gal) to 45 litres (9.9 imp gal; 12 US gal) of water. Horses are not ruminants, so they have only one stomach, like humans, but unlike humans, they can digest cellulose, a major component of grass. Cellulose digestion occurs in the cecum, or "water gut", which food goes through before reaching the large intestine. Unlike humans, horses cannot vomit, so digestion problems can quickly cause colic, a leading cause of death.

Senses

A horse's eye

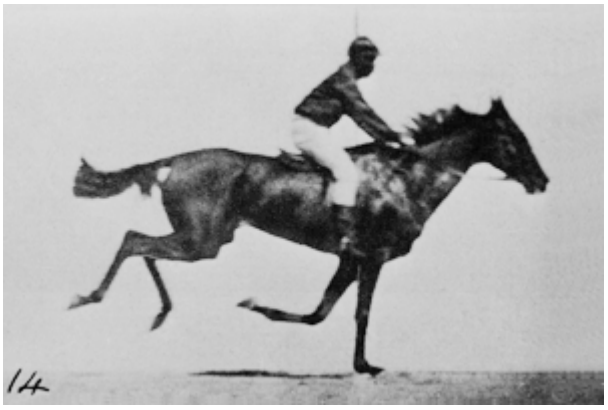
The horse's senses are generally superior to those of a human. As prey animals, they must be aware of their surroundings at all times. They have the largest eyes of any land mammal, and are lateral-eyed, meaning that their eyes are positioned on the sides of their heads. This means that horses have a range of vision of more than 350°, with approximately 65° of this being binocular vision and the remaining 285° monocular vision. Horses have excellent day and night vision, but they have two-color, or dichromatic vision; their color vision is somewhat like red-green color blindness in humans, where certain colors, especially red and related colors, appear more green.

Their hearing is good, and the pinna of each ear can rotate up to 180°, giving the potential for 360° hearing without having to move the head. Their sense of smell, while much better than that of humans, is not their strongest asset; they rely to a greater extent on vision.

Horses have a great sense of balance, due partly to their ability to feel their footing and partly to highly developed proprioceptive abilities (the unconscious sense of where the body and limbs are at all times). A horse's sense of touch is well developed. The most sensitive areas are around the eyes, ears, and nose. Horses sense contact as subtle as an insect landing anywhere on the body.

Horses have an advanced sense of taste that allows them to sort through fodder to choose what they would most like to eat, and their prehensile lips can easily sort even the smallest grains. Horses generally will not eat poisonous plants. However, there are exceptions and horses will occasionally eat toxic amounts of poisonous plants even when there is adequate healthy food.

Movement



The gallop

All horses move naturally with four basic gaits: the four-beat walk, which averages 6.4 kilometres per hour (4.0 mph); the two-beat trot or jog at 13 to 19 kilometres per hour (8.1 to 12 mph) (faster for harness racing horses); the canter or lope, a three-beat gait that is 19 to 24 kilometres per hour (12 to 15 mph); and the gallop. The gallop averages 40 to 48 kilometres per hour (25 to 30 mph), but the world record for a horse galloping over a short, sprint distance is 88 kilometres per hour (55 mph). Besides these basic gaits, some horses perform a two-beat pace, instead of the trot. There also are several four-beat "ambling" gaits that are approximately the speed of a trot or pace, though smoother to ride. These include the lateral rack, running walk, and tölt as well as the diagonal fox trot. Ambling gaits are often genetic in some breeds, known collectively as gaited horses. Often, gaited horses replace the trot with one of the ambling gaits.

Behavior

Horses are prey animals with a strong fight-or-flight instinct. Their first response to threat is to startle and usually flee, although they will stand their ground and defend themselves when flight is not possible, or if their young are threatened. They also tend to be curious; when startled, they will often hesitate an instant to ascertain the cause of their fright, and may not always flee from something that they perceive as non-threatening. Most light horse riding breeds were developed for speed, agility, alertness and endurance; natural qualities that extend from their wild ancestors. However, through selective breeding, some breeds of horses are quite docile, particularly certain draft horses. Horses are herd animals, with a clear hierarchy of rank, led by a dominant animal (usually a mare). They are also social creatures who are able to form companionship attachments to their own species and to other animals, including humans. They communicate in various ways,

including vocalizations such as nickering or whinnying, mutual grooming, and body language. Many horses will become difficult to manage if they are isolated, but with training, horses can learn to accept a human as a companion, and thus be comfortable away from other horses. However, when confined with insufficient companionship, exercise, or stimulation, individuals may develop stable vices, an assortment of bad habits, mostly psychological in origin, that include wood chewing, wall kicking, "weaving" (rocking back and forth), and other problems.

Intelligence and learning

In the past, horses were considered unintelligent, with no abstract thinking ability, unable to generalize, and driven primarily by a herd mentality. However, modern studies show that they perform a number of cognitive tasks on a daily basis, with mental challenges that include food procurement and social system identification. They also have good spatial discrimination abilities. Studies have assessed equine intelligence in the realms of problem solving, learning speed, and knowledge retention. Results show that horses excel at simple learning, but also are able to solve advanced cognitive challenges that involve categorization and concept learning. They learn from habituation, desensitization, Pavlovian conditioning, and operant conditioning. They respond to and learn from both positive and negative reinforcement. Recent studies even suggest horses are able to count if the quantity involved is less than four.

Domesticated horses tend to face greater mental challenges than wild horses, because they live in artificial environments that stifle instinctual behaviour while learning tasks that are not natural. Horses are creatures of habit that respond and adapt well to regimentation, and respond best when the same routines and techniques are used consistently. Some trainers believe that "intelligent" horses are reflections of intelligent trainers who effectively use response conditioning techniques and positive reinforcement to train in the style that fits best with an individual animal's natural inclinations. Others who handle horses regularly note that personality also may play a role separate from intelligence in determining how a given animal responds to various experiences.

Temperament

Horses are mammals, and as such are "warm-blooded" creatures, as opposed to cold-blooded reptiles. However, these words have developed a separate meaning in the context of equine terminology, used to describe temperament, not body temperature. For example, the "hot-bloods", such as many race horses, exhibit more sensitivity and energy, while the "cold-bloods", such as most draft breeds, are quieter and calmer. Sometimes "hot-bloods" are classified as "light horses" or "riding horses", with the "cold-bloods" classified as "draft horses" or "work horses".

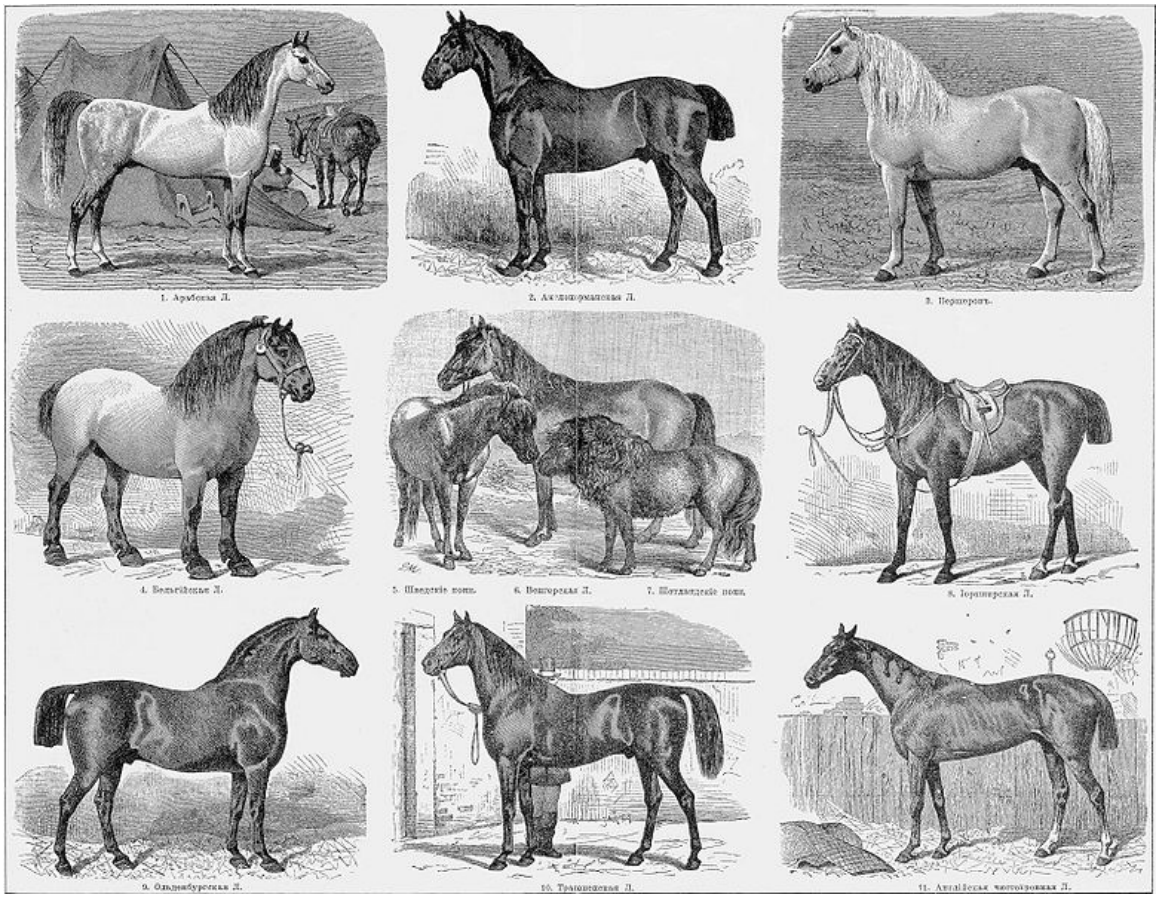


Illustration of hotbloods, warmbloods and coldblood breeds

"Hot blooded" breeds include "oriental horses" such as the Akhal-Teke, Barb, Arabian horse and now-extinct Turkoman horse, as well as the Thoroughbred, a breed developed in England from the older oriental breeds. Hot bloods tend to be spirited, bold, and learn quickly. They are bred for agility and speed. They tend to be physically refined—thin-skinned, slim, and long-legged. The original oriental breeds were brought to Europe from the Middle East and North Africa when European breeders wished to infuse these traits into racing and light cavalry horses.

Muscular, heavy draft horses are known as "cold bloods", as they are bred not only for strength, but also to have the calm, patient temperament needed to pull a plow or a heavy carriage full of people. They are sometimes nicknamed "gentle giants". Well-known draft breeds include the Belgian and the Clydesdale. Some, like the Percheron are lighter and livelier, developed to pull carriages or to plow large fields in drier climates. Others, such as the Shire, are slower and more powerful, bred to plow fields with heavy, clay-based soils. The cold-blooded group also includes some pony breeds.

"Warmblood" breeds, such as the Trakehner or Hanoverian, developed when European carriage and war horses were crossed with Arabians or Thoroughbreds, producing a riding horse with more refinement than a draft horse, but greater size and milder

temperament than a lighter breed. Certain pony breeds with warmblood characteristics have been developed for smaller riders. Warmbloods are considered a "light horse" or "riding horse".

Today, the term "Warmblood" refers to a specific subset of sport horse breeds that are used for competition in dressage and show jumping. Strictly speaking, the term "warm blood" refers to any cross between cold-blooded and hot-blooded breeds. Examples include breeds such as the Irish Draught or the Cleveland Bay. The term was once used to refer to breeds of light riding horse other than Thoroughbreds or Arabians, such as the Morgan horse.

Sleep patterns

When horses lie down to sleep, others in the herd remain standing, awake or in a light doze, keeping watch.

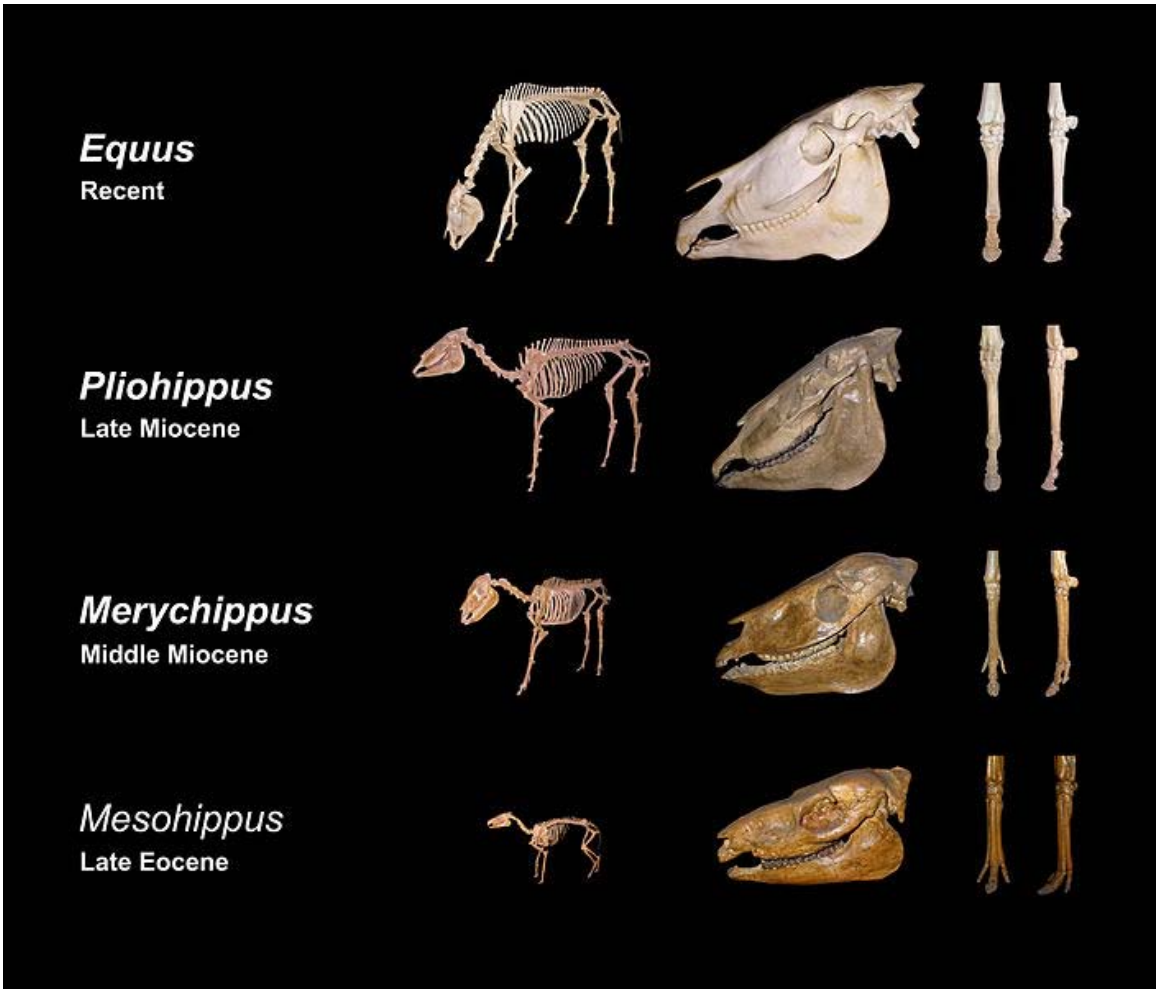
Horses are able to sleep both standing up and lying down. In an adaptation from life in the wild, horses are able to enter light sleep by using a "stay apparatus" in their legs, allowing them to doze without collapsing. Horses sleep better when in groups because some animals will sleep while others stand guard to watch for predators. A horse kept alone will not sleep well because its instincts are to keep a constant eye out for danger.

Unlike humans, horses do not sleep in a solid, unbroken period of time, but take many short periods of rest. Horses spend four to fifteen hours a day in standing rest, and from a

few minutes to several hours lying down. Total sleep time in a 24-hour period may range from several minutes to a couple of hours, mostly in short intervals of about 15 minutes each.

Horses must lie down to reach REM sleep. They only have to lie down for an hour or two every few days to meet their minimum REM sleep requirements. However, if a horse is never allowed to lie down, after several days it will become sleep-deprived, and in rare cases may suddenly collapse as it involuntarily slips into REM sleep while still standing. This condition differs from narcolepsy, although horses may also suffer from that disorder.

Taxonomy and evolution



From left to right: Size development, biometrical changes in the cranium, reduction of toes (left forefoot)

The horse adapted to survive in areas of wide-open terrain with sparse vegetation, surviving in an ecosystem where other large grazing animals, especially ruminants, could not. Horses and other equids are odd-toed ungulates of the order Perissodactyla, a group

of mammals that was dominant during the Tertiary period. In the past, this order contained 14 families, but only three—Equidae (the horse and related species), the tapir, and the rhinoceros—have survived to the present day. The earliest known member of the Equidae family was the *Hyracotherium*, which lived between 45 and 55 million years ago, during the Eocene period. It had 4 toes on each front foot, and 3 toes on each back foot. The extra toe on the front feet soon disappeared with the *Mesohippus*, which lived 32 to 37 million years ago. Over time, the extra side toes shrank in size until they vanished. All that remains of them in modern horses is a set of small vestigial bones on the leg below the knee, known informally as splint bones. Their legs also lengthened as their toes disappeared until they were a hooved animal capable of running at great speed. By about 5 million years ago, the modern *Equus* had evolved. Equid teeth also evolved from browsing on soft, tropical plants to adapt to browsing of drier plant material, then to grazing of tougher plains grasses. Thus proto-horses changed from leaf-eating forest-dwellers to grass-eating inhabitants of semi-arid regions worldwide, including the steppes of Eurasia and the Great Plains of North America.

By about 15,000 years ago, *Equus ferus* was a widespread holarctic species. Horse bones from this time period, the late Pleistocene, are found in Europe, Eurasia, Beringia, and North America. Yet between 10,000 and 7,600 years ago, the horse became extinct in North America and rare elsewhere. The reasons for this extinction are not fully known, but one theory notes that extinction in North America paralleled human arrival. Another theory points to climate change, noting that approximately 12,500 years ago, the grasses characteristic of a steppe ecosystem gave way to shrub tundra, which was covered with unpalatable plants.

Wild species surviving into modern times

A small herd of Przewalski's Horses

A truly wild horse is a species or subspecies with no ancestors that were ever domesticated. Therefore, most "wild" horses today are actually feral horses, animals that escaped or were turned loose from domestic herds and the descendants of those animals. Only one truly wild horse species (*Equus ferus*) with two subspecies, the Tarpan and the Przewalski's Horse, survived into recorded history.

The only true wild horse alive today is the Przewalski's Horse (*Equus ferus przewalskii*), named after the Russian explorer Nikolai Przhevalsky. It is a rare Asian animal, also known as the Mongolian Wild Horse; Mongolian people know it as the *taki*, and the Kyrgyz people call it a *kirtag*. The species was presumed extinct in the wild between 1969 and 1992, while a small breeding population survived in zoos around the world. In 1992, it was reestablished in the wild due to the conservation efforts of numerous zoos. Today, a small wild breeding population exists in Mongolia. There are additional animals still maintained at zoos throughout the world.

The Tarpan or European Wild Horse (*Equus ferus ferus*) was found in Europe and much of Asia. It survived into the historical era, but became extinct in 1909, when the last captive died in a Russian zoo. Thus, the genetic line was lost. Attempts have been made

to recreate the Tarpan, which resulted in horses with outward physical similarities, but nonetheless descended from domesticated ancestors and not true wild horses.

Periodically, populations of horses in isolated areas are speculated to be relic populations of wild horses, but generally have been proven to be feral or domestic. For example, the Riwoche horse of Tibet was proposed as such, but testing did not reveal genetic differences with domesticated horses, Similarly, the Sorraia of Spain was proposed as a direct descendant of the Tarpan based on shared characteristics, but genetic studies have shown that the Sorraia is more closely related to other horse breeds and that the outward similarity is an unreliable measure of relatedness.

Other modern equids

Besides the horse, there are seven other species of genus *Equus* in the Equidae family. These are the ass or donkey, *Equus asinus*; the mountain zebra, *Equus zebra*; plains zebra, *Equus burchelli*; Grévy's zebra, *Equus grevyi*; the kiang, *Equus kiang*; and the onager, *Equus hemionus*.

Horses can crossbreed with other members of their genus. The most common hybrid is the mule, a cross between a "jack" (male donkey) and a mare. A related hybrid, a hinny, is a cross between a stallion and a jenny (female donkey). Other hybrids include the zorse, a cross between a zebra and a horse. With rare exceptions, most hybrids are sterile and cannot reproduce.

Domestication

Domestication of the horse most likely took place in central Asia prior to 3500 BC. Two major sources of information are used to determine where and when the horse was first domesticated and how the domesticated horse spread around the world. The first source is based on palaeological and archaeological discoveries, the second source is a comparison of DNA obtained from modern horses to that from bones and teeth of ancient horse remains.

The earliest archaeological evidence for the domestication of the horse comes from sites in Ukraine and Kazakhstan, dating to approximately 3500–4000 BC. By 3000 BC, the horse was completely domesticated and by 2000 BC there was a sharp increase in the number of horse bones found in human settlements in northwestern Europe, indicating the spread of domesticated horses throughout the continent. The most recent, but most irrefutable evidence of domestication comes from sites where horse remains were interred with chariots in graves of the Sintashta and Petrovka cultures c. 2100 BC.

Domestication is also studied by using the genetic material of present day horses and comparing it with the genetic material present in the bones and teeth of horse remains found in archaeological and palaeological excavations. The variation in the genetic material shows that very few wild stallions contributed to the domestic horse, while many mares were part of early domesticated herds. This is reflected in the difference in genetic

variation between the DNA that is passed on along the paternal, or sire line (Y-chromosome) versus that passed on along the maternal, or dam line (mitochondrial DNA). There are very low levels of Y-chromosome variability, but a great deal of genetic variation in mitochondrial DNA. There is also regional variation in mitochondrial DNA due to the inclusion of wild mares in domestic herds. Another characteristic of domestication is an increase in coat color variation. In horses, this increased dramatically between 5000 and 3000 BC.

Before the availability of DNA techniques to resolve the questions related to the domestication of the horse, various hypothesis were proposed. One classification was based on body types and conformation, suggesting the presence of four basic prototypes that had adapted to their environment prior to domestication. Another hypothesis held that the four prototypes originated from a single wild species and that all different body types were entirely a result of selective breeding after domestication. However, the lack of a detectable substructure in the horse has resulted in a rejection of both hypotheses.

Feral populations

Feral horses are born and live in the wild, but are descended from domesticated animals. Many populations of feral horses exist throughout the world. Studies of feral herds have provided useful insights into the behavior of prehistoric horses, as well as greater understanding of the instincts and behaviors that drive horses that live in domesticated conditions.

Breeds

Horse breeds are groups of horses with distinctive characteristics that are transmitted consistently to their offspring, such as conformation, color, performance ability, or disposition. These inherited traits result from a combination of natural crosses and artificial selection methods. Horses have been selectively bred since their domestication. Breeds developed due to a need for "form to function", the necessity to develop certain characteristics in order to perform a particular type of work. Thus, powerful but refined breeds such as the Andalusian developed as riding horses that also had a great aptitude for dressage, while heavy draft horses such as the Clydesdale developed out of a need to perform demanding farm work and pull heavy wagons. Other horse breeds developed specifically for light agricultural work, carriage and road work, various sport disciplines, or simply as pets. Some breeds developed through centuries of crossings with other breeds, while others, such as Tennessee Walking Horses and Morgans, descended from a single foundation sire. There are more than 300 horse breeds in the world today.

However, the concept of purebred bloodstock and a controlled, written breed registry only became of significant importance in modern times. Sometimes purebred horses are called Thoroughbreds, which is incorrect; "Thoroughbred" is a specific breed of horse, while a "purebred" is a horse (or any other animal) with a defined pedigree recognized by a breed registry. An early example of people who practiced selective horse breeding were the Bedouin, who had a reputation for careful practices, keeping extensive pedigrees of

their Arabian horses and placing great value upon pure bloodlines. These pedigrees were originally transmitted via an oral tradition. In the 14th century, Carthusian monks of southern Spain kept meticulous pedigrees of bloodstock lineages still found today in the Andalusian horse. One of the earliest formal registries was General Stud Book for Thoroughbreds, which began in 1791 and traced back to the foundation bloodstock for the breed.

Therapeutic use

People of all ages with physical and mental disabilities obtain beneficial results from association with horses. Therapeutic riding is used to mentally and physically stimulate disabled persons and help them improve their lives through improved balance and coordination, increased self-confidence, and a greater feeling of freedom and independence. The benefits of equestrian activity for people with disabilities has also been recognized with the addition of equestrian events to the Paralympic Games and recognition of para-equestrian events by the International Federation for Equestrian Sports (FEI). Hippotherapy and therapeutic horseback riding are names for different physical, occupational, and speech therapy treatment strategies that utilize equine movement. In hippotherapy, a therapist uses the horse's movement to improve their patient's cognitive, coordination, balance, and fine motor skills, whereas therapeutic horseback riding uses specific riding skills.

Horses also provide psychological benefits to people whether they actually ride or not. "Equine-assisted" or "equine-facilitated" therapy is a form of experiential psychotherapy that uses horses as companion animals to assist people with mental illness, including anxiety disorders, psychotic disorders, mood disorders, behavioral difficulties, and those who are going through major life changes. There are also experimental programs using horses in prison settings. Exposure to horses appears to improve the behavior of inmates and help reduce recidivism when they leave.

Chapter 10

Rabbit

Rabbit

Scientific classification
Kingdom: Animalia
Superphylum: Chordata
Phylum: Vertebrata
Class: Mammalia
Order: Lagomorpha
Family: Leporidae in part
Genera
Pentalagus *Brachylagus*
Bunolagus *Sylvilagus*
Nesolagus *Oryctolagus*
Romerolagus *Poelagus*

Rabbits are small mammals in the family Leporidae of the order Lagomorpha, found in several parts of the world. There are eight different genera in the family classified as

rabbits, including the European rabbit (*Oryctolagus cuniculus*), cottontail rabbits (genus *Sylvilagus*; 13 species), and the Amami rabbit (*Pentalagus furnessi*, an endangered species on Amami Ōshima, Japan). There are many other species of rabbit, and these, along with pikas and hares, make up the order Lagomorpha. The male is called a *buck* and the female is a *doe*; a young rabbit is a *kitten* or *kit*.

Habitat and range

Outdoor entrance to a rabbit burrow

Rabbit habitats include meadows, woods, forests, grasslands, deserts and wetlands. Rabbits live in groups, and the best known species, the European rabbit, lives in underground burrows, or rabbit holes. A group of burrows is called a warren.

More than half the world's rabbit population resides in North America. They are also native to southwestern Europe, Southeast Asia, Sumatra, some islands of Japan, and in parts of Africa and South America. They are not naturally found in most of Eurasia, where a number of species of hares are present. Rabbits first entered South America relatively recently, as part of the Great American Interchange. Much of the continent has just one species of rabbit, the tapeti, while most of South America's southern cone is without rabbits.

The European rabbit has been introduced to many places around the world.

Morphology and Ecology

The rabbit's long ears, which can be more than 10 cm (4 in) long, are probably an adaptation for detecting predators. They have large, powerful hind legs. The two front paws have 5 toes, the extra called the dewclaw. The hind feet have 4 toes. They are digitigrade animals; they move around on the tips of their toes. Wild rabbits do not differ much in their body proportions or stance, with full, egg-shaped bodies. Their size can range anywhere from 20 cm (8 in) in length and 0.4 kg in weight to 50 cm (20 in) and more than 2 kg. The fur is most commonly long and soft, with colors such as shades of brown, gray, and buff. The tail is a little plume of brownish fur (white on top for cottontails).

Because the rabbit's epiglottis is engaged over the soft palate except when swallowing, the rabbit is an obligate nasal breather. Rabbits have two sets of incisor teeth, one behind the other. This way they can be distinguished from rodents, with which they are often confused. Carl Linnaeus originally grouped rabbits and rodents under the class Glires; later, they were separated as the predominant opinion was that many of their similarities were a result of convergent evolution. However, recent DNA analysis and the discovery of a common ancestor has supported the view that they share a common lineage, and thus rabbits and rodents are now often referred to together as members of the superclass Glires.

Rabbits are hindgut digesters. This means that most of their digestion takes place in their large intestine and cecum. In rabbits the cecum is about 10 times bigger than the stomach and it along with the large intestine makes up roughly 40% of the rabbit's digestive tract. The unique musculature of the cecum allows the intestinal tract of the rabbit to separate fibrous material from more digestible material; the fibrous material is passed as feces, while the more nutritious material is encased in a mucous lining as a cecotrope. Cecotropes, sometimes called "night feces", are high in minerals, vitamins and proteins that are necessary to the rabbit's health. Rabbits eat these to meet their nutritional requirements; the mucous coating allows the nutrients to pass through the acidic stomach for digestion in the intestines. This process allows rabbits to extract the necessary nutrients from their food.

Rabbits are prey animals and are therefore constantly aware of their surroundings. For instances, in Mediterranean Europe, rabbits are the main prey of red foxes, badgers, and Iberian lynxes. If confronted by a potential threat, a rabbit may freeze and observe then warn others in the warren with powerful thumps on the ground. Rabbits have a remarkably wide field of vision, and a good deal of it is devoted to overhead scanning. They survive predation by burrowing, hopping away in a zig- zag motion, and, if captured, delivering powerful kicks with their hind legs. Their strong teeth allow them to eat and to bite in order to escape a struggle.

Reproduction

A litter of rabbit kits (baby rabbits)

A nest containing baby rabbits

Rabbits have a very rapid reproductive rate. The breeding season for most rabbits lasts 9 months, from February to October. In Australia & New Zealand breeding season is late July to late January. Normal gestation is about 30 days. The average size of the litter varies but is usually between 4 and 12 babies, with larger breeds having larger litters. A kit (baby rabbit) can be weaned at about 4 to 5 weeks of age. This means in one season a single female rabbit can produce as many as 800 children, grandchildren, and great-grandchildren. A doe is ready to breed at about 6 months of age, and a buck at about 7 months. Courtship and mating are very brief, lasting only 30 to 40 seconds. Courtship behavior involves licking, sniffing, and following the doe. Spraying urine is also a common sexual behavior. Female rabbits are reflex ovulators. The female rabbit also may or may not lose clumps of hair during the gestation period.

Ovulation begins 10 hours after mating. After mating, the female will make a nest or borough, and line the nest with fur from the dewlap, flanks, and belly. This behavior also exposes the nipples enabling her to better nurse the kits. Kits are altricial, which means they're born blind, naked, and helpless. Passive immunity (immunity acquired by transfer of antibodies or sensitized lymphocytes from another animal) is acquired by kits prior to birth via placental transfer. At 10 to 11 days after birth the baby rabbits' eyes will open and they will start eating on their own at around 14 days old.

Although born naked, they form a soft baby coat of hair within a few days. At the age of 5 to 6 weeks the soft baby coat is replaced with a pre-adult coat. At about 6 to 8 months of age this intermediate coat is replaced by the final adult coat, which is shed twice a year thereafter. Due to the nutritious nature of rabbit milk kits only need to be nursed for a few minutes once or twice a day.

The expected rabbit lifespan is about 9–12 years; the world's longest-lived was 18 years.

Diet and eating habits

Rabbits are herbivores that feed by grazing on grass, forbs, and leafy weeds. In consequence, their diet contains large amounts of cellulose, which is hard to digest. Rabbits solve this problem by passing two distinct types of feces: hard droppings and soft black viscous pellets, the latter of which are immediately eaten. Rabbits reingest their own droppings (rather than chewing the cud as do cows and many other herbivores) to digest their food further and extract sufficient nutrients.

Rabbits graze heavily and rapidly for roughly the first half hour of a grazing period (usually in the late afternoon), followed by about half an hour of more selective feeding. In this time, the rabbit will also excrete many hard fecal pellets, being waste pellets that will not be reingested. If the environment is relatively non-threatening, the rabbit will remain outdoors for many hours, grazing at intervals. While out of the burrow, the rabbit will occasionally reingest its soft, partially digested pellets; this is rarely observed, since the pellets are reingested as they are produced. Reingestion is most common within the burrow between 8 o'clock in the morning and 5 o'clock in the evening, being carried out intermittently within that period.

Hard pellets are made up of hay-like fragments of plant cuticle and stalk, being the final waste product after redigestion of soft pellets. These are only released outside the burrow and are not reingested. Soft pellets are usually produced several hours after grazing, after the hard pellets have all been excreted. They are made up of micro-organisms and undigested plant cell walls.

The chewed plant material collects in the large cecum, a secondary chamber between the large and small intestine containing large quantities of symbiotic bacteria that help with the digestion of cellulose and also produce certain B vitamins. The pellets are about 56% bacteria by dry weight, largely accounting for the pellets being 24.4% protein on average. These pellets remain intact for up to six hours in the stomach; the bacteria within continue to digest the plant carbohydrates. The soft feces form here and contain up to five times the vitamins of hard feces. After being excreted, they are eaten whole by the rabbit and redigested in a special part of the stomach. This double-digestion process enables rabbits to use nutrients that they may have missed during the first passage through the gut, as well as the nutrients formed by the microbial activity and thus ensures that maximum nutrition is derived from the food they eat. This process serves the same purpose within the rabbit as rumination does in cattle and sheep.

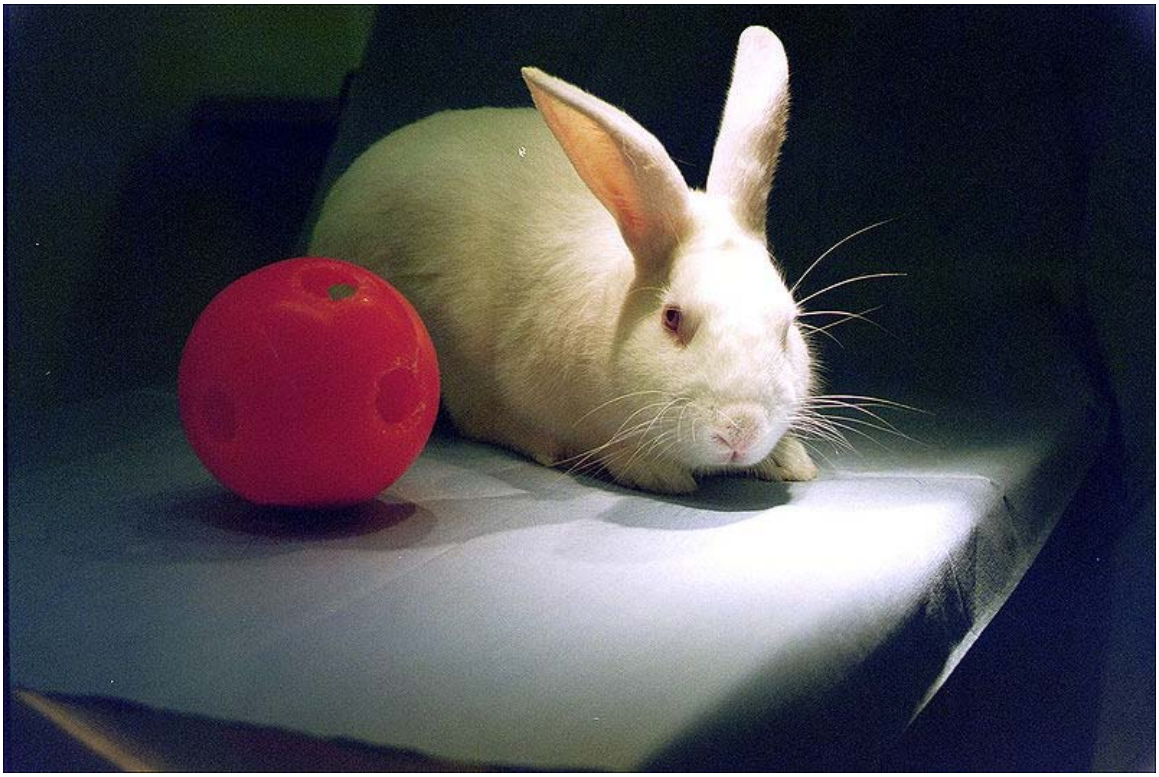
Rabbits are incapable of vomiting.

Rabbit diseases

Differences from hares

Rabbits are clearly distinguished from hares in that rabbits are altricial, having young that are born blind and hairless. In contrast, hares are generally born with hair and are able to see (precocial). All rabbits except cottontail rabbits live underground in burrows or warrens, while hares live in simple nests above the ground (as do cottontail rabbits), and usually do not live in groups. Hares are generally larger than rabbits, with longer ears, and have black markings on their fur. Hares have not been domesticated, while European rabbits are often kept as house pets. In gardens, they are typically kept in hutches — small, wooden, house-like boxes — that protect the rabbits from the environment and predators.

As pets



European Rabbit (*Oryctolagus cuniculus*)

Pet rabbits kept indoors are referred to as house rabbits. House rabbits typically have an indoor pen or cage and a rabbit-safe place to run and exercise, such as an exercise pen, living room or family room. Rabbits can be trained to use a litter box and some can learn to come when called. Domestic rabbits that do not live indoors can also often serve as companions for their owners, typically living in an easily accessible hutch outside the home. Some pet rabbits live in outside hutches during the day for the benefit of fresh air and natural daylight and are brought inside at night.

Whether indoor or outdoor, pet rabbits' pens are often equipped with enrichment activities such as shelves, tunnels, balls, and other toys. Pet rabbits are often provided additional space in which to get exercise, simulating the open space a rabbit would traverse in the wild. Exercise pens or lawn pens are often used to provide a safe place for rabbits to run.

A pet rabbit's diet typically consists of unlimited timothy-grass, a small amount of pellets, and a small portion of fresh vegetables and need unrestricted access to fresh clean water. Rabbits are social animals. Rabbits as pets can find their companionship with a variety of creatures, including humans, other rabbits, guinea pigs, and sometimes even cats and dogs. Animal welfare organisations such as the House Rabbit Society advise that rabbits do not make good pets for small children because children generally do not know how to stay quiet, calm, and gentle around rabbits. As prey animals, rabbits are alert, timid

creatures that startle easily. They have fragile bones, especially in their backs, that require support on the belly and bottom when picked up. Children 7 years old and older usually have the maturity required to care for a rabbit.

Environmental problems

Rabbits have been a source of environmental problems when introduced into the wild by humans. As a result of their appetites, and the rate at which they breed, feral rabbit depredation can be problematic for agriculture. Gassing, barriers (fences), shooting, snaring, and ferreting have been used to control rabbit populations, but the most effective measures are diseases such as myxomatosis (myxo or mixi, colloquially) and calicivirus. In Europe, where rabbits are farmed on a large scale, they are protected against myxomatosis and calicivirus with a genetically modified virus. The virus was developed in Spain, and is beneficial to rabbit farmers. If it were to make its way into wild populations in areas such as Australia, it could create a population boom, as those diseases are the most serious threats to rabbit survival. Rabbits in Australia and New Zealand are considered to be such a pest that land owners are legally obliged to control them.

Classifications

Eastern Cottontail (*Sylvilagus floridanus*)

Rabbits and hares were formerly classified in the order Rodentia (rodent) until 1912, when they were moved into a new order Lagomorpha. This order also includes pikas.

Order **Lagomorpha**

- Family **Leporidae**
  - Genus *Pentalagus*
    - Amami Rabbit/Ryūkyū Rabbit, *Pentalagus furnessi*
  - Genus *Bunolagus*

        - Bushman Rabbit, *Bunolagus monticularis*
    - Genus *Nesolagus*
        - Sumatran Striped Rabbit, *Nesolagus netscheri*
        - Annamite Striped Rabbit, *Nesolagus timminsi*
    - Genus *Romerolagus*
        - Volcano Rabbit, *Romerolagus diazi*
    - Genus *Brachylagus*
        - Pygmy Rabbit, *Brachylagus idahoensis*
    - Genus *Sylvilagus*
        - Forest Rabbit, *Sylvilagus brasiliensis*
        - Dice's Cottontail, *Sylvilagus dicei*
        - Brush Rabbit, *Sylvilagus bachmani*
        - San Jose Brush Rabbit, *Sylvilagus mansuetus*
        - Swamp Rabbit, *Sylvilagus aquaticus*
        - Marsh Rabbit, *Sylvilagus palustris*
        - Eastern Cottontail, *Sylvilagus floridanus*
        - New England Cottontail, *Sylvilagus transitionalis*
        - Mountain Cottontail, *Sylvilagus nuttallii*
        - Desert Cottontail, *Sylvilagus audubonii*
        - Omilteme Cottontail, *Sylvilagus insonus*
        - Mexican Cottontail, *Sylvilagus cunicularis*
        - Tres Marias Rabbit, *Sylvilagus graysoni*
    - Genus *Oryctolagus*
        - European Rabbit, *Oryctolagus cuniculus*
    - Genus *Poelagus*
        - Central African Rabbit, *Poelagus marjorita*
    - Three other genera in family, regarded as hares, not rabbits

Chapter 11

Sheep

Domestic sheep

A research flock at U.S. Sheep Experiment Station near Dubois, Idaho
Conservation status
Domesticated
Scientific classification
Kingdom: Animalia
Phylum: Chordata
Class: Mammalia

Order:	Artiodactyla
Family:	Bovidae
Subfamily:	Caprinae
Genus:	*Ovis*
Species:	***O. aries***

Binomial name

Ovis aries
Linnaeus, 1758

Sheep (***Ovis aries***) are quadrupedal, ruminant mammals typically kept as livestock. Like all ruminants, sheep are members of the order Artiodactyla, the even-toed ungulates. Although the name "sheep" applies to many species in the genus *Ovis*, in everyday usage it almost always refers to *Ovis aries*. Numbering a little over one billion, domestic sheep are also the most numerous species of sheep.

Sheep are most likely descended from the wild mouflon of Europe and Asia. One of the earliest animals to be domesticated for agricultural purposes, sheep are raised for fleece, meat (lamb, hogget or mutton) and milk. A sheep's wool is the most widely used animal fiber, and is usually harvested by shearing. Ovine meat is called lamb when from younger animals and mutton when from older ones. Sheep continue to be important for wool and meat today, and are also occasionally raised for pelts, as dairy animals, or as model organisms for science.

Sheep husbandry is practised throughout the majority of the inhabited world, and has been fundamental to many civilizations. In the modern era, Australia, New Zealand, the southern and central South American nations, and the British Isles are most closely associated with sheep production.

Sheep-raising has a large lexicon of unique terms which vary considerably by region and dialect. Use of the word *sheep* began in Middle English as a derivation of the Old English word *scēap*; it is both the singular and plural name for the animal. A group of sheep is called a flock, herd or mob. Adult female sheep are referred to as ewes, intact males as rams or occasionally tups, castrated males as wethers, and younger sheep as lambs. Many other specific terms for the various life stages of sheep exist, generally related to lambing, shearing, and age.

Being a key animal in the history of farming, sheep have a deeply entrenched place in human culture, and find representation in much modern language and symbology. As livestock, sheep are most-often associated with pastoral, Arcadian imagery. Sheep figure in many mythologies—such as the Golden Fleece—and major religions, especially the Abrahamic traditions. In both ancient and modern religious ritual, sheep are used as sacrificial animals.

Description

A sheep's skull

Domestic sheep are relatively small ruminants, usually with a crimped hair called wool and often with horns forming a lateral spiral. Domestic sheep differ from their wild relatives and ancestors in several respects, having become uniquely neotenic as a result of selective breeding by humans. A few primitive breeds of sheep retain some of the characteristics of their wild cousins, such as short tails. Depending on breed, domestic sheep may have no horns at all (polled), or horns in both sexes (as in wild sheep), or in males only. Most horned breeds have a single pair, but a few breeds may have several.

Another trait unique to domestic sheep (as compared to wild ovines, not other livestock) is their wide variation in color. Wild sheep are largely variations of brown hues, and variation with species is extremely limited. Colors of domestic sheep range from pure white to dark chocolate brown and even spotted or piebald. Selection for easily dyeable white fleeces began early in sheep domestication, and as white wool is a dominant trait it spread quickly. However, colored sheep do appear in many modern breeds, and may even appear as a recessive trait in white flocks. While white wool is desirable for large commercial markets, there is a niche market for colored fleeces, mostly for handspinning. The nature of the fleece varies widely among the breeds, from dense and highly crimped, to long and hair-like. There is variation of wool type and quality even among members of the same flock, so wool classing is a step in the commercial processing of the fibre.

Suffolks are a medium wool, black-faced breed of meat sheep that make up 60% of the sheep population in the U.S.

Depending on breed, sheep show a range of heights and weights. Their rate of growth and mature weight is a heritable trait that is often selected for in breeding. Ewes typically weigh between 45 and 100 kilograms (99 and 220 lb), and rams between 45 and 160 kilograms (99 and 350 lb). Mature sheep have 32 teeth. As with other ruminants, the front teeth in the lower jaw bite against a hard, toothless pad in the upper jaw. These are used to pick off vegetation, then the rear teeth grind it before it is swallowed. There are eight lower front teeth in ruminants, but there is some disagreement as to whether these are eight incisors, or six incisors and two incisor-shaped canines. This means that the dental formula for sheep is either I:0/4 C:0/0 P:3/3 M:3/3, or I:0/3 C:0/1 P:3/3 M:3/3. There is a large toothless gap between the front "biting" teeth and the rear "grinding" teeth.

For the first few years of life it is possible to calculate the age of sheep from their front teeth, as a pair of milk teeth is replaced by larger adult teeth each year, the full set of eight adult front teeth being complete at about four years of age. The front teeth are then gradually lost as sheep age, making it harder for them to feed and hindering the health and productivity of the animal. For this reason, domestic sheep on normal pasture begin to slowly decline from four years on, and the average life expectancy of a sheep is 10 to 12 years, though some sheep may live as long as 20 years.

Sheep have good hearing, and are sensitive to noise when being handled. Sheep have horizontal slit-shaped pupils, possessing excellent peripheral vision; with visual fields of approximately 270° to 320°, sheep can see behind themselves without turning their heads. However, sheep have poor depth perception; shadows and dips in the ground may cause sheep to baulk. In general, sheep have a tendency to move out of the dark and into well-lit areas, and prefer to move uphill when disturbed. Sheep also have an excellent sense of smell, and, like all species of their genus, have scent glands just in front of the eyes, and interdigitally on the feet. The purpose of these glands is uncertain, but those on the face may be used in breeding behaviors. The foot glands might also be related to reproduction, but alternative reasons, such as secretion of a waste product or a scent marker to help lost sheep find their flock, have also been proposed.

Sheep and goats are closely related as both are in the subfamily Caprinae. However, they are separate species, so hybrids rarely occur, and are always infertile. A hybrid of a ewe and a buck (a male goat) is called a sheep-goat hybrid (only a single such animal has been confirmed), and is not to be confused with the genetic chimera called a geep. Visual differences between sheep and goats include the beard and divided upper lip unique to goats. Sheep tails also hang down, even when short or docked, while the short tails of goats are held upwards. Sheep breeds are also often naturally polled (either in both sexes or just in the female), while naturally polled goats are rare (though many are polled artificially). Males of the two species differ in that buck goats acquire a unique and strong odor during the rut, whereas rams do not.

Breeds

Sheep being judged for adherence to their breed standard, and being held by the most common method of restraint

The domestic sheep is a multi-purpose animal, and the more than 200 breeds now in existence were created to serve these diverse purposes. Some sources give a count of a thousand or more breeds, but these numbers cannot be verified. Almost all sheep are classified as being best suited to furnishing a certain product: wool, meat, milk, hides, or a combination in a dual-purpose breed. Other features used when classifying sheep include face color (generally white or black), tail length, presence or lack of horns, and the topography for which the breed has been developed. This last point is especially stressed in the UK, where breeds are described as either upland (hill or mountain) or lowland breeds. A sheep may also be of a fat-tailed type, which is a dual-purpose sheep common in Africa and Asia with larger deposits of fat within and around its tail.

Breeds are also grouped based on how well they are suited to producing a certain type of breeding stock. Generally, sheep are thought to be either "ewe breeds" or "ram breeds". Ewe breeds are those that are hardy, and have good reproductive and mothering capabilities – they are for replacing breeding ewes in standing flocks. Ram breeds are selected for rapid growth and carcase quality, and are mated with ewe breeds to produce meat lambs. Lowland and upland breeds are also crossed in this fashion, with the hardy hill ewes crossed with larger, fast-growing lowland rams to produce ewes called mules, which can then be crossed with meat-type rams to produce prime market lambs. Many breeds, especially rare or primitive ones, fall into no clear category.

The Barbados Blackbelly is a hair sheep breed of Caribbean origin.

Breeds are categorized by the type of their wool. Fine wool breeds are those that have wool of great crimp and density, which are preferred for textiles. Most of these were derived from Merino sheep, and the breed continues to dominate the world sheep

industry. Downs breeds have wool between the extremes, and are typically fast-growing meat and ram breeds with dark faces. Some major medium wool breeds, such as the Corriedale, are dual-purpose crosses of long and fine-wooled breeds and were created for high-production commercial flocks. Long wool breeds are the largest of sheep, with long wool and a slow rate of growth. Long wool sheep are most valued for crossbreeding to improve the attributes of other sheep types. For example: the American Columbia breed was developed by crossing Lincoln rams (a long wool breed) with fine-wooled Rambouillet ewes.

Coarse or carpet wool sheep are those with a medium to long length wool of characteristic coarseness. Breeds traditionally used for carpet wool show great variability, but the chief requirement is a wool that will not break down under heavy use (as would that of the finer breeds). As the demand for carpet-quality wool declines, some breeders of this type of sheep are attempting to use a few of these traditional breeds for alternative purposes. Others have always been primarily meat-class sheep.

A minor class of sheep are the dairy breeds. Dual-purpose breeds that may primarily be meat or wool sheep are often used secondarily as milking animals, but there are a few breeds that are predominantly used for milking. These sheep do produce a higher quantity of milk and have slightly longer lactation curves. In the quality of their milk, fat and protein content percentages of dairy sheep vary from non-dairy breeds but lactose content does not.

A last group of sheep breeds is that of fur or hair sheep, which do not grow wool at all. Hair sheep are similar to the early domesticated sheep kept before woolly breeds were developed, and are raised for meat and pelts. Some modern breeds of hair sheep, such as the Dorper, result from crosses between wool and hair breeds. For meat and hide producers, hair sheep are cheaper to keep, as they do not need shearing. Hair sheep are also more resistant to parasites and hot weather.

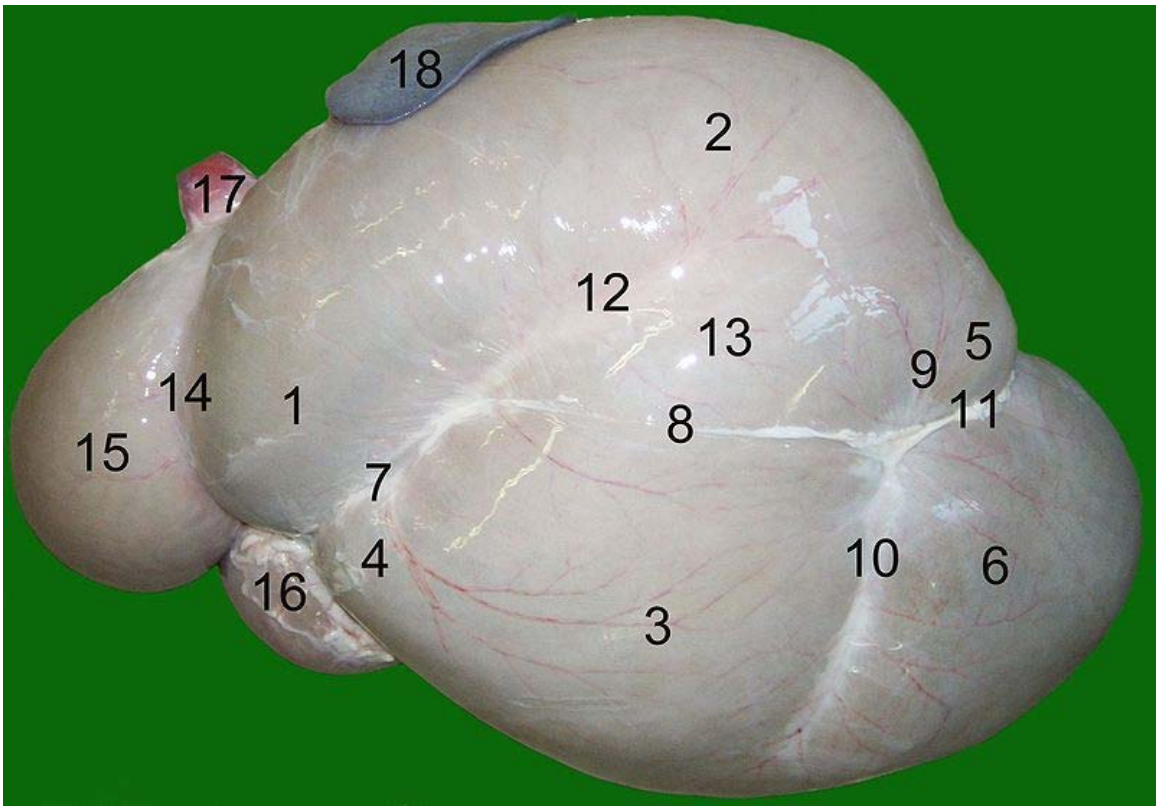
With the modern rise of corporate agribusiness and the decline of localized family farms, many breeds of sheep are in danger of extinction. The Rare Breeds Survival Trust of the UK lists 22 native breeds as having only 3,000 registered animals (each), and the American Livestock Breeds Conservancy lists 14 as having fewer than 10,000. Preferences for breeds with uniform characteristics and fast growth have pushed heritage (or heirloom) breeds to the margins of the sheep industry. Those that remain are maintained through the efforts of conservation organizations, breed registries, and individual farmers dedicated to their preservation.

Diet

A ewe grazing

Sheep are exclusively herbivorous mammals. Most breeds prefer to graze on grass and other short roughage, avoiding the taller woody parts of plants that goats readily consume. Both sheep and goats use their lips and tongues to select parts of the plant that are easier to digest or higher in nutrition. Sheep, however, graze well in monoculture pastures where most goats fare poorly. Like all ruminants, sheep have a complex digestive system composed of four chambers, allowing them to break down cellulose from stems, leaves, and seed hulls into simpler carbohydrates. When sheep graze, vegetation is chewed into a mass called a bolus, which is then passed into the first chamber: the rumen. The rumen is a 19 to 38-liter (5 to 10 gal) organ in which feed is

fermented via a symbiotic relationship with the bacteria, protozoa, and yeasts of the gut flora. The bolus is periodically regurgitated back to the mouth as cud for additional chewing and salivation. Cud chewing is an adaptation allowing ruminants to graze more quickly in the morning, and then fully chew and digest feed later in the day. This is beneficial as grazing, which requires lowering the head, leaves sheep vulnerable to predators, while cud chewing does not.



A sheep's ruminant system

During fermentation, the rumen produces gas that must be expelled; disturbances of the organ, such as sudden changes in a sheep's diet, can cause the potentially fatal condition of bloat, when gas becomes trapped in the rumen. After fermentation in the rumen, feed passes in to the reticulum and the omasum; special feeds such as grains may bypass the rumen altogether. After the first three chambers, food moves in to the abomasum for final digestion before processing by the intestines. The abomasum is the only one of the four chambers analogous to the human stomach (being the only one that absorbs nutrients for use as energy), and is sometimes called the "true stomach".

Sheep follow a diurnal pattern of activity, feeding from dawn to dusk, stopping sporadically to rest and chew their cud. Ideal pasture for sheep is not lawn-like grass, but an array of grasses, legumes and forbs. Types of land where sheep are raised vary widely, from pastures that are seeded and improved intentionally to rough, native lands. Common plants toxic to sheep are present in most of the world, and include (but are not limited to) oak and acorns, tomato, yew, rhubarb, potato, and rhododendron.

Sheep graze on public land in Snake Valley, Utah.

Sheep are largely grazing herbivores, unlike browsing animals such as goats and deer that prefer taller foliage. With a much narrower face, sheep crop plants very close to the ground and can overgraze a pasture much faster than cattle. For this reason, many shepherds use managed intensive rotational grazing, where a flock is rotated through multiple pastures, giving plants time to recover. Paradoxically, sheep can both cause and solve the spread of invasive plant species. By disturbing the natural state of pasture, sheep and other livestock can pave the way for invasive plants. However, sheep also prefer to eat invasives such as cheatgrass, leafy spurge, kudzu and spotted knapweed over native species such as sagebrush, making grazing sheep effective for conservation grazing. Research conducted in Imperial County, California compared lamb grazing with herbicides for weed control in seedling alfalfa fields. Three trials demonstrated that grazing lambs were just as effective as herbicides in controlling winter weeds. Entomologists also compared grazing lambs to insecticides for insect control in winter alfalfa. In this trial, lambs provided insect control as effectively as insecticides.

Other than forage, the other staple feed for sheep is hay, often during the winter months. The ability to thrive solely on pasture (even without hay) varies with breed, but all sheep can survive on this diet. Also included in some sheep's diets are minerals, either in a trace mix or in licks.

Naturally, a constant source of potable water is also a fundamental requirement for sheep. The amount of water needed by sheep fluctuates with the season and the type and quality of the food they consume. When sheep feed on large amounts of new growth and there is precipitation (including dew, as sheep are dawn feeders), sheep need less water. When sheep are confined or are eating large amounts of cured hay, more water is typically needed. Sheep also require clean water, and may refuse to drink water that is covered in scum or algae.

Sheep are one of the few livestock animals raised for meat today that have never been widely raised in an intensive, confined animal feeding operation (CAFO). Although there is a growing movement advocating alternative farming styles, a large percentage of beef cattle, pigs, and poultry are still produced under such conditions. In contrast, only some sheep are regularly given high-concentration grain feed, much less kept in confinement. Especially in industrialized countries, sheep producers may fatten market lambs before slaughter (called "finishing") in feedlots. Many sheep breeders flush ewes and rams with a daily ration of grain during breeding to increase fertility. Ewes are also flushed during pregnancy to increase birth weights, as 70% of a lamb's growth occurs in the last five to six weeks of gestation. Otherwise, only lactating ewes and especially old or infirm sheep are commonly provided with grain. Feed provided to sheep must be specially formulated, as most cattle, poultry, pig, and even some goat feeds contain levels of copper that are lethal to sheep. The same danger applies to mineral supplements such as salt licks.

Behavior and intelligence

Sheep showing flocking behavior during a sheepdog trial

Sheep are prey animals with a strong gregarious instinct, and a majority of sheep behaviors can be understood in these terms. The dominance hierarchy of *Ovis aries* and its natural inclination to follow a leader to new pastures were the pivotal factors in it being one of the first domesticated livestock species. All sheep have a tendency to congregate close to other members of a flock, although this behavior varies with breed. Farmers exploit this behavior to keep sheep together on unfenced pastures and to move

them more easily. Shepherds may also use herding dogs in this effort, whose highly bred herding ability can assist in moving flocks. Sheep are also extremely food-oriented, and association of humans with regular feeding often results in sheep soliciting people for food. Those who are moving sheep may exploit this behavior by leading sheep with buckets of feed, rather than forcing their movements with herding.

In regions where sheep have no natural predators, none of the native breeds of sheep exhibit a strong flocking behavior. Sheep can also become hefted to one particular local pasture (heft) so they do not roam freely in unfenced landscapes. Ewes teach the heft to their lambs, and if whole flocks are culled it must be retaught to the replacement animals.

Escaped sheep being led back to pasture with the enticement of food. This method of moving sheep works best with smaller flocks.

Flock dynamics in sheep are, as a rule, only exhibited in a group of four or more sheep. Fewer sheep may not react as normally expected when alone or with few other sheep. For sheep, the primary defense mechanism is simply to flee from danger when their flight zone is crossed. Secondly, cornered sheep may charge or threaten to do so through hoof stamping and aggressive posture. This is particularly true for ewes with newborn lambs.

In displaying flocking, sheep have a strong lead-follow tendency, and a leader often as not is simply the first sheep to move. However, sheep do establish a pecking order through physical displays of dominance. Dominant animals are inclined to be more aggressive with other sheep, and usually feed first at troughs. Primarily among rams, horn

size is a factor in the flock hierarchy. Rams with different size horns may be less inclined to fight to establish pecking order, while rams with similarly sized horns are more so.

Sheep can become stressed when separated from their flock members. Sheep can recognize individual human and ovine faces, and remember them for years. Relationships in flocks tend to be closest among related sheep: in mixed-breed flocks same-breed subgroups tend to form, and a ewe and her direct descendants often move as a unit within large flocks.

Sheep are frequently thought of as extremely unintelligent animals. A sheep's herd mentality and quickness to flee and panic in the face of stress often make shepherding a difficult endeavor for the uninitiated. Despite these perceptions, a University of Illinois monograph on sheep found them to be just below pigs and on par with cattle in IQ, and some sheep have shown problem-solving abilities; a flock in West Yorkshire, England allegedly found a way to get over cattle grids by rolling on their backs, although documentation of this has relied on anecdotal accounts. In addition to long-term facial recognition of individuals, sheep can also differentiate emotional states through facial characteristics. If worked with patiently, sheep may learn their names, and many sheep are trained to be led by halter for showing and other purposes. Sheep have also responded well to clicker training. Very rarely, sheep are used as pack animals. Tibetan nomads distribute baggage equally throughout a flock as it is herded between living sites.

Reproduction

The second of twins being born on a New Zealand pasture

Sheep follow a similar reproductive strategy to other herd animals. A group of ewes is generally mated by a single ram, who has either been chosen by a breeder or has established dominance through physical contest with other rams (in feral populations). Most sheep are seasonal breeders, although some are able to breed year-round. Ewes generally reach sexual maturity at six to eight months of age, and rams generally at four

to six months. Ewes have estrus cycles about every 17 days, during which they emit a scent and indicate readiness through physical displays towards rams. A minority of sheep display a preference for homosexuality (8% on average) or are freemartins (female animals that are behaviorally masculine and lack functioning ovaries).

In feral sheep, rams may fight during the rut to determine which individuals may mate with ewes. Rams, especially unfamiliar ones, will also fight outside the breeding period to establish dominance; rams can kill one another if allowed to mix freely. During the rut, even normally friendly rams may become aggressive towards humans due to increases in their hormone levels.

After mating, sheep have a gestation period of about five months, and normal labor take one to three hours. Although some breeds regularly throw larger litters of lambs, most produce single or twin lambs. During or soon after labor, ewes and lambs may be confined to small lambing jugs, small pens designed to aid both careful observation of ewes and to cement the bond between them and their lambs.

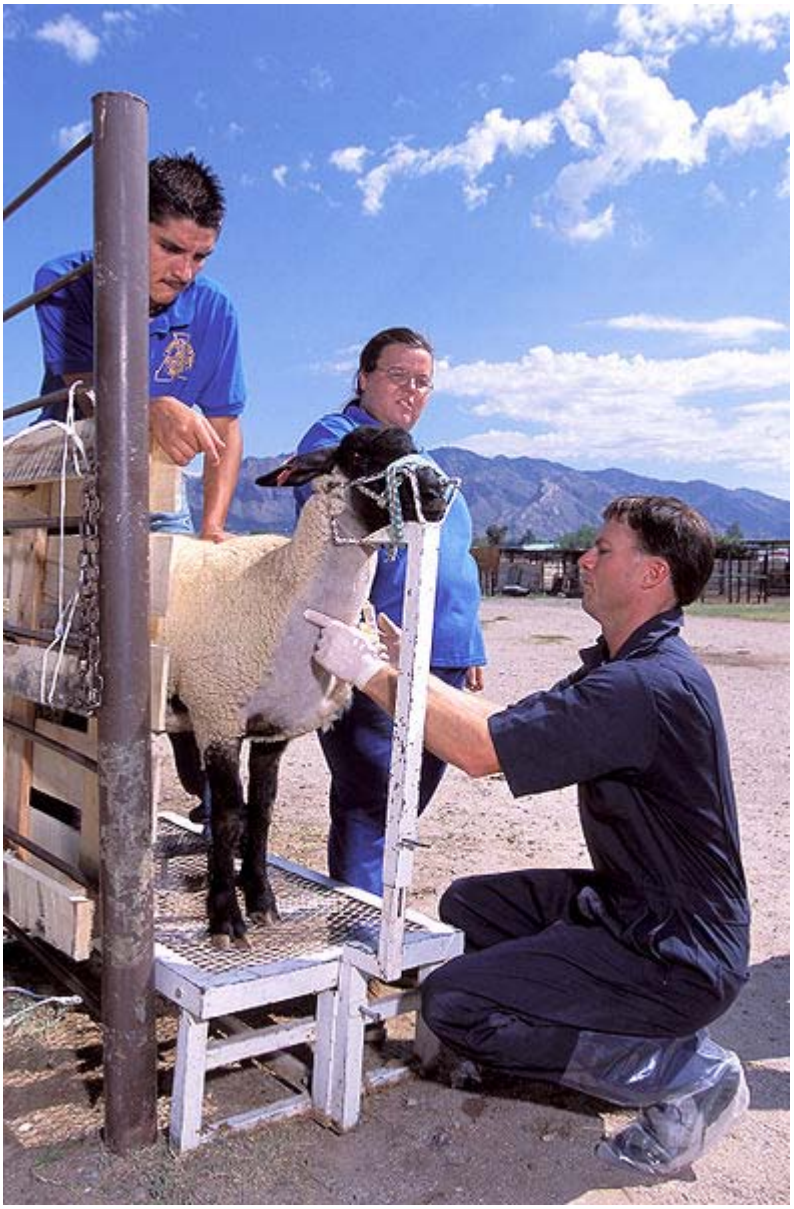
A lamb's first steps

Ovine obstetrics can be problematic. By selectively breeding ewes that produce multiple offspring with higher birth weights for generations, sheep producers have inadvertently caused some domestic sheep to have difficulty lambing; balancing ease of lambing with high productivity is one of the dilemmas of sheep breeding. In the case of any such

problems, those present at lambing may assist the ewe by extracting or repositioning lambs. After the birth, ewes ideally break the amniotic sac (if it is not broken during labor), and begin licking clean the lamb. Most lambs will begin standing within an hour of birth. In normal situations, lambs nurse after standing, receiving vital colostrum milk. Lambs that either fail to nurse or that are rejected by the ewe require aid to live, such as bottle-feeding or fostering by another ewe.

After lambs are several weeks old, lamb marking (the process of ear tagging, docking, and castrating) is carried out. Vaccinations are usually carried out at this point as well. Ear tags with numbers are attached, or ear marks are applied for ease of later identification of sheep. Castration is performed on ram lambs not intended for breeding, although some shepherds choose to avoid the procedure for ethical, economic or practical reasons. Ram lambs that will either be slaughtered or separated from ewes before sexual maturity are not usually castrated. Docking, which is the shortening of a lamb's tail, is practised for health reasons. Objections to all these procedures have been raised by animal rights groups, but farmers defend them by saying they solve many practical and veterinary problems, and inflict only temporary pain.

Health



A veterinarian draws blood to test for resistance to scrapie

Sheep may fall victim to poisons, infectious diseases, and physical injuries. As a prey species, a sheep's system is adapted to hide the obvious signs of illness, to prevent being targeted by predators. However, there are some obvious signs of ill health, with sick sheep eating little, vocalizing excessively, and being generally listless. Throughout history, much of the money and labor of sheep husbandry has aimed to prevent sheep ailments. Historically, shepherds often created remedies by experimentation on the farm. In some developed countries, including the United States, sheep lack the economic importance for drugs companies to perform expensive clinical trials required to approve drugs for ovine use. In such instances, shepherds resort to illegal, extra-label usage of

drugs approved for other animals. In the 20th and 21st centuries, a minority of sheep owners have turned to alternative treatments such as homeopathy, herbalism and even traditional Chinese medicine to treat sheep veterinary problems. Despite some favorable anecdotal evidence, the effectiveness of alternative veterinary medicine has been met with skepticism in scientific journals. The need for traditional anti-parasite drugs and antibiotics is widespread, and is the main impediment to certified organic farming with sheep.

Many breeders take a variety of preventive measures to ward off problems. The first is to ensure that all sheep are healthy when purchased. Many buyers avoid outlets known to be clearing houses for animals culled from healthy flocks as either sick or simply inferior. This can also mean maintaining a closed flock, and quarantining new sheep for a month. Two fundamental preventive programs are maintaining good nutrition and reducing stress in the sheep. Handling sheep in loud, erratic ways causes them to produce cortisol, a stress hormone. This can lead to a weakened immune system, thus making sheep far more vulnerable to disease. Signs of stress in sheep include: excessive panting, teeth grinding, restless movement, wool eating, and wood chewing. Avoiding poisoning is also important; common poisons are pesticide sprays, inorganic fertilizer, motor oil, as well as radiator coolant (the ethylene glycol antifreeze is sweet-tasting).

A sheep infected with Orf, a disease transmittable to humans through skin contact

Common forms of preventive medication for sheep are vaccinations and treatments for parasites. Both external and internal parasites are the most prevalent malady in sheep, and are either fatal, or reduce the productivity of flocks. Worms are the most common internal parasites. They are ingested during grazing, incubate within the sheep, and are expelled through the digestive system (beginning the cycle again). Oral anti-parasitic medicines, known as drenches, are given to a flock to treat worms, sometimes after worm eggs in the feces has been counted to assess infestation levels. Afterwards, sheep may be moved to a new pasture to avoid ingesting the same parasites. External sheep parasites include: lice (for different parts of the body), sheep keds, nose bots, sheep itch mites, and maggots. Keds are blood-sucking parasites that cause general malnutrition and decreased productivity, but are not fatal. Maggots are those of the bot fly and the blow-fly. Fly maggots cause the extremely destructive condition of flystrike. Flies lay their eggs in wounds or wet, manure-soiled wool; when the maggots hatch they burrow into a sheep's

flesh, eventually causing death if untreated. In addition to other treatments, crutching (shearing wool from a sheep's rump) is a common preventive method. Nose bots are flies that inhabit a sheep's sinuses, causing breathing difficulties and discomfort. Common signs are a discharge from the nasal passage, sneezing, and frantic movement such as head shaking. External parasites may be controlled through the use of backliners, sprays or immersive sheep dips.

A wide array of bacterial diseases affect sheep. Diseases of the hoof, such as foot rot and foot scald may occur, and are treated with footbaths and other remedies. These painful conditions cause lameness and hinder feeding. Ovine Johne's disease is a wasting disease that affects young sheep. Bluetongue disease is an insect-borne illness causing fever and inflammation of the mucous membranes. Ovine rinderpest (or *peste des petits ruminants*) is a highly contagious and often fatal viral disease affecting sheep and goats.

A few sheep conditions are transmissible to humans. Orf (also known as scabby mouth, contagious ecthyma or soremouth) is a skin disease leaving lesions that is transmitted through skin-to-skin contact. Cutaneous anthrax is also called woolsorter's disease, as the spores can be transmitted in unwashed wool. More seriously, the organisms that can cause spontaneous enzootic abortion in sheep are easily transmitted to pregnant women. Also of concern are the prion disease scrapie and the virus that causes foot-and-mouth disease (FMD), as both can devastate flocks. The latter poses a slight risk to humans. During the 2001 FMD pandemic in the UK, hundreds of sheep were culled and some rare British breeds were at risk of extinction due to this.

Predation

A lamb being attacked by coyotes with the most typical method, a bite to the throat

Other than parasites and disease, predation is a threat to sheep and the profitability of sheep raising. Sheep have little ability to defend themselves, compared with other species kept as livestock. Even if sheep survive an attack, they may die from their injuries, or simply from panic. However, the impact of predation varies dramatically with region. In Africa, Australia, the Americas, and parts of Europe and Asia predators are a serious problem. In the United States, for instance, over one third of sheep deaths in 2004 were caused by predation. In contrast, other nations are virtually devoid of sheep predators, particularly islands known for extensive sheep husbandry. Worldwide, canids—including the domestic dog—are responsible for most sheep deaths. Other animals that occasionally prey on sheep include: felines, bears, birds of prey, ravens and feral hogs.

Sheep producers have used a wide variety of measures to combat predation. Pre-modern shepherds used their own presence, livestock guardian dogs, and protective structures such as barns and fencing. Fencing (both regular and electric), penning sheep at night and lambing indoors all continue to be widely used. More modern shepherds used guns, traps, and poisons to kill predators, causing significant decreases in predator populations. In the wake of the environmental and conservation movements, the use of these methods now usually falls under the purview of specially designated government agencies in most developed countries .

The 1970s saw a resurgence in the use of livestock guardian dogs and the development of new methods of predator control by sheep producers, many of them non-lethal. Donkeys and guard llamas have been used since the 1980s in sheep operations, using the same basic principle as livestock guardian dogs. Interspecific pasturing, usually with larger livestock such as cattle or horses, may help to deter predators, even if such species do not actively guard sheep. In addition to animal guardians, contemporary sheep operations may use non-lethal predator deterrents such as motion-activated lights and noisy alarms.

Chapter 12

Zebra

Zebras

Scientific classification
Kingdom: Animalia
Phylum: Chordata
Class: Mammalia

Order:	Perissodactyla
Family:	Equidae
Genus:	*Equus*
Subgenus:	***Hippotigris*** and ***Dolichohippus***

Species
Equus zebra
Equus quagga
Equus grevyi

Zebras are African equids best known for their distinctive black and white stripes. Their stripes come in different patterns unique to each individual. They are generally social animals that live in small harems to large herds. Unlike their closest relatives, horses and asses, zebras have never been truly domesticated.

There are three species of zebras: the plains zebra, the Grévy's zebra and the mountain zebra. The plains zebra and the mountain zebra belong to the subgenus *Hippotigris*, but Grevy's zebra is the sole species of subgenus *Dolichohippus*. The latter resembles an ass, to which it is closely related, while the former two are more horse-like. All three belong to the genus *Equus*, along with other living equids.

The unique stripes of zebras make these among the animals most familiar to people. They occur in a variety of habitats, such as grasslands, savannas, woodlands, thorny scrublands, mountains, and coastal hills. However, various anthropogenic factors have had a severe impact on zebra populations, in particular hunting for skins and habitat destruction. Grevy's zebra and the mountain zebra are endangered. While plains zebras are much more plentiful, one subspecies, the quagga, went extinct in the late 19th century.

Etymology

Zebra in English dates back to c.1600, from Italian **Zebra**, perhaps from Portuguese, which in turn is said to be Congolese (as stated in the Oxford English Dictionary). The *Encarta Dictionary* says its ultimate origin is uncertain, but perhaps it may come from Latin **Equiferus** meaning "Wild horse," from equus "horse" and ferus "wild, untamed".

Taxonomy and evolution

Zebras arose within the Old World horses within the last 4 million years. Grevy's zebras (and perhaps also Mountain Zebras) are with asses and donkeys in a separate lineage from the other zebra lineages. This means either that striped equids zebras evolved more than once, or that common ancestors of zebras and asses were striped and only zebras retained the stripes. Extensive stripes are posited to have been be of little use to equids that live in low densities in deserts (like asses and some horses) or ones that live in colder

climates with shaggy coats and annual shading (like some horses). Fossils of an ancient equid were discovered in the Hagerman Fossil Beds National Monument in Hagerman, Idaho. It was named the Hagerman horse with a scientific name of *Equus simplicidens*. It is believed to have been similar to the Grevy's zebra. The animals had stocky zebra-like bodies and short, narrow, donkey-like skulls. Grevy's zebra also has a donkey-like skull. The Hagerman horse is also called the American zebra or Hagerman zebra.

Classification

Zebras in Botswana

There are three extant species. Collectively, two of the species have 8 subspecies (7 extant). Zebra populations are diverse, and the relationships between and the taxonomic status of several of the subspecies are not well known.

- **Genus: *Equus***
  - **Subgenus: *Hippotigris***

- Plains Zebra, *Equus quagga*
  - Quagga, *Equus quagga quagga* (extinct)
  - Burchell's Zebra, *Equus quagga burchellii* (includes Damara Zebra)
  - Grant's Zebra, *Equus quagga boehmi*
  - Selous' Zebra, *Equus quagga borensis*
  - Chapman's Zebra, *Equus quagga chapmani*
  - Crawshay's Zebra, *Equus quagga crawshayi*
- Mountain Zebra, *Equus zebra*
  - Cape Mountain Zebra, *Equus zebra zebra*
  - Hartmann's Mountain Zebra, *Equus zebra hartmannae*

- **Subgenus: *Dolichohippus***
  - Grévy's Zebra, *Equus grevyi*

An albino zebra in captivity

The plains zebra (*Equus quagga*, formerly *Equus burchelli*) is the most common, and has or had about twelve subspecies distributed across much of southern and eastern Africa. It, or particular subspecies of it, have also been known as the common zebra, the dauw, Burchell's Zebra (actually the subspecies *Equus quagga burchellii*), Chapman's zebra, Wahlberg's zebra, Selous' zebra, Grant's zebra, Boehm's zebra and the quagga (another extinct subspecies, *Equus quagga quagga*).

The mountain zebra (*Equus zebra*) of southwest Africa tends to have a sleek coat with a white belly and narrower stripes than the plains Zebra. It has two subspecies and is classified as vulnerable.

Grévy's Zebra (*Equus grevyi*) is the largest type, with a long, narrow head, making it appear rather mule-like. It is an inhabitant of the semiarid grasslands of Ethiopia and northern Kenya. Grévy's zebra is the rarest species, and is classified as endangered.

Although zebra species may have overlapping ranges, they do not interbreed. This held true even when the quagga and Burchell's race of plains zebra shared the same area. In captivity, plains zebras have been crossed with mountain zebras. The hybrid foals lacked a dewlap and resembled the plains zebra apart from their larger ears and their hindquarters pattern. Attempts to breed a Grévy's zebra stallion to mountain zebra mares resulted in a high rate of miscarriage. In captivity, crosses between zebras and other (non-zebra) equines have produced several distinct hybrids, including the zebroid, zeedonk, zony, and zorse. In certain regions of Kenya, plains zebras and Grévy's Zebra coexist, and fertile hybrids occur.

Physical attributes

Stripes

It was previously believed that zebras were white animals with black stripes, since some zebras have white underbellies. Embryological evidence, however, shows that the animal's background color is black and the white stripes and bellies are additions.

A mother nursing her young blends into a stand of deadwood.

The stripes are typically vertical on the head, neck, forequarters, and main body, with horizontal stripes at the rear and on the legs of the animal. The "zebra crossing" is named after the zebra's black and white stripes.

It has been suggested that the stripes serve as visual cues and identification. With each striping pattern unique to each individual, zebras can recognize one another by their stripes.

Others believe that the stripes act as a camouflage mechanism. This is accomplished in several ways. First, the vertical striping helps the zebra hide in grass. While seeming absurd at first glance, considering that grass is neither white nor black, it is supposed to be effective against the zebra's main predator, the lion, which is color blind. Theoretically, a zebra standing still in tall grass may not be noticed at all by a lion. Additionally, since zebras are herd animals, the stripes may help to confuse predators - a number of zebras standing or moving close together may appear as one large animal, making it more difficult for the lion to pick out any single zebra to attack.

A more recent theory, supported by experiment, posits that the disruptive colouration is also an effective means of confusing the visual system of the blood-sucking tsetse fly. Alternative theories include that the stripes coincide with fat patterning beneath the skin,

serving as a thermoregulatory mechanism for the zebra, and that wounds sustained disrupt the striping pattern to clearly indicate the fitness of the animal to potential mates.

A zebra walking

Gaits

Like horses, zebras walk, trot, canter and gallop. They are generally slower than horses, but their great stamina helps them outpace predators. When chased, a zebra will zig-zag from side to side, making it more difficult for the predator. When cornered, the zebra will rear up and kick or bite its attacker.

Closeup of a zebra

Senses

Zebras have excellent eyesight. It is believed that they can see in color. Like most ungulates, the zebra has its eyes on the sides of its head, giving it a wide field of view. Zebras also have night vision, although not as advanced as that of most of their predators.

Zebras have excellent hearing, and tend to have larger, rounder ears than horses. Like horses and other ungulates, zebra can turn their ears in almost any direction. In addition to eyesight and hearing, zebras have an acute sense of smell and taste.

Ecology and behavior

Harems

Zebras in Tanzania

Like most members of the horse family, zebras are highly social. Their social structure, however, depends on the species. Mountain zebras and plains zebras live in groups, known as 'harems', consisting of one stallion with up to six mares and their foals. Bachelor males either live alone or with groups of other bachelors until they are old enough to challenge a breeding stallion. When attacked by packs of hyenas or wild dogs a zebra group will huddle together with the foals in the middle while the stallion tries to ward them off.

Unlike the other zebra species, Grevy's zebras do not have permanent social bonds. A group of these zebras rarely stays together for more than a few months. The foals stay with their mothers, while adult males live alone. Like the other two zebra species, bachelor male zebras will organize in groups.

Like horses, zebras sleep standing up, and only sleep when neighbors are around to warn them of predators.

Communication

A zebra feeding on grass

Zebras communicate with each other with high pitched barks and whinnying. Grevy's zebras make mule-like brays. A zebra's ears signify its mood. When a zebra is in a calm, tense or friendly mood, its ears stand erect. When it is frightened, its ears are pushed forward. When angry, the ears are pulled backward. When surveying an area for predators, zebras will stand in an alert posture; with ears erect, head held high, and staring. When tense they will also snort. When a predator is spotted or sensed, a zebra will bark (or bray) loudly.

Hartmann's Mountain Zebra with a Barbary sheep behind it, in captivity at Ueno Zoo, in Japan.

Food and foraging

Zebras are very adaptable grazers. They feed mainly on grasses but will also eat shrubs, herbs, twigs, leaves and bark. Their well-adapted digestive systems allow them to subsist on diets of lower nutritional quality than that necessary for other herbivores.

Reproduction

Female zebras mature earlier than the males, and a mare may have her first foal by the age of three. Males are not able to breed until the age of five or six. Mares may give birth to one foal every twelve months. She nurses the foal for up to a year. Like horses, zebras are able to stand, walk and suckle shortly after they are born. A zebra foal is brown and white instead of black and white at birth.

Plains and mountain zebra foals are protected by their mothers, as well as the head stallion and the other mares in their group. Grevy’s zebra foals have only their mother as a regular protector, since, as noted above, Grevy's zebra groups often disband after a few months.